# Design Reductionism:

# Exploring the potential use of reduced and incomplete information acting as a prompt for designers' imagination

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# Design Reductionism: Exploring the Potential Use Of Reduced And Incomplete Information Acting As A Prompt For Designers' Imagination

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# ABSTRACT

This thesis explores the potential impact in the use of incomplete information (i.e. the state of information that the viewer recognises is not yet 'complete') generated from reduced information (i.e. the state of information in which the constituents that dictate the fidelity of the information are decreased qualitatively and quantitatively), and how it affects an industrial designer's imagination. Human cognition has the ability to interpret or infer meaning when they are confronted with incomplete information and can use this as a means of ideas generation within their cognitive reasoning. The cognitive evidence suggests that human cognition per se is able to read rich knowledge in incomplete information during a process of reasoning.

Within the design context, studies report that incompleteness of information plays a significant role in the designer's imagination, particularly at the preliminary phase of the design process where they conceptualise ideas. Incomplete states of information, such as lack of clarity, uncertainty or ambiguity, act as a driving force for the designer's idea development. This research explores the intersection between the cognitive ability and the designer's tendency of utilising uncertainty as a creative resource, aiming at developing a set of visualised tools to support this.

This thesis reports on a collection of studies observing how incomplete information dictates the design practitioners' reasoning, providing a series of tailored 2D and 3D "reductionist prompts." The results showed that reduced and incomplete information stimulated the design practitioners' diverse imagination, and the act of *autonomous reduction* encouraged them to interact, elicit insights and consider, the subject from multiple perspectives.

This thesis highlights the potential and value of purposefully engaging with incomplete information derived from using a reductive approach. It proposes a set of reductionist tools that assist the designer's reasoning, as well as developing a method of visualisation that represents these complex processes.

# DECLARATION

I declare that the work contained in this thesis has not been submitted for any other award and that is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others. Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the University Ethics Committee on 03/11/2014. I declare that the Word Count of this thesis is 96,218 words.

Name: Shiro Inoue

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Date:

# List of Publications

Inoue, S. and Smith, N. (2018). Reductive Is Augmentative: How Reduced Information Enhances a Designer's Imagination (In Press). In: Columbus, A. M. (Ed). *Advances in Psychology Research*. Vol. 133. Hauppauge, NY: Nova Science Publisher.

Smith, N., Inoue, S., Tennant, A. and Spencer, N. (2017). Creative Puzzlement: How Deconstructing Elements of an Object Facilitates Industrial Design Student's Imagination. In: *12th European Academy of Design Conference (EAD 12).* Sapienza University, Rome, Italy.

Inoue, S., Rodgers, P. A., Tennant, A. and Spencer, N. (2017). Reducing Information to Stimulate Design Imagination In: Gero, J. S. (Ed.). *Design Computing and Cognition 16*. Switzerland: Springer (pp. 3–21).

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Inoue, S. Rodgers, P. A., Tennant, A and Spencer, N. (2015). Reductionism as a Tool for Creative Exploration. In: *11th European Academy of Design Conference (EAD 11)*. Paris Descartes University, Paris, France.

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# ACKNOWLEDGEMENTS

The long journey of my doctoral study was almost like climbing a high mountain without having a map. The route to the summit was unclear to begin with, and I as a climber had to develop a map by myself, exploring the unfamiliar and various terrains. The journey of undertaking my doctoral study was also incredibly exciting, challenging, joyful, nerve wrecking, and fulfilling. What made this impossible challenge possible was the tremendous support I received from many people I met along the way.

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Above all, my thanks and love go to my family, particularly my mother, who has patiently and unconditionally supported me thoroughly this long journey.

Chapter 1

# *Introduction*

# 1.1 — Research Intent

The journey of this research originated in a graphic that was created by the researcher in 2010 (Figure 1). This poster illustrates how our visual perception can instantly capture and interpret the content of the graphic where the image is reduced to less than thirty per cent, as long as the viewer knows this famous painting. This incomplete graphic communicates not only what is depicted, but also relevant notions about the painter and the subject, referenced through our prior knowledge. This example suggests that visual perception is capable of eliciting rich information even when the image presented does not fully represented. This example reminds the researcher of Schelling's words:

> *"'The perfect is the imperfect,' the meaning is this: the imperfect is not due to that through which it is imperfect, but rather through the perfect that is in it" (Schelling, 2006, p.13).*

This can be interpreted in that a complete state of being (i.e. perfection) does not lie by itself but rather exists within the relationship between "completeness" and "incompleteness." These concepts are two sides of the same coin and "incompleteness" represents possibilities for its future "completeness." The researcher wondered whether this "incompleteness" could be purposefully utilised as a method to enhance the designer's imagination. The researcher considered that information incompleteness could potentially compel the designer's memory, association, and design reasoning as a creative trigger. This question became the base of this enquiry.

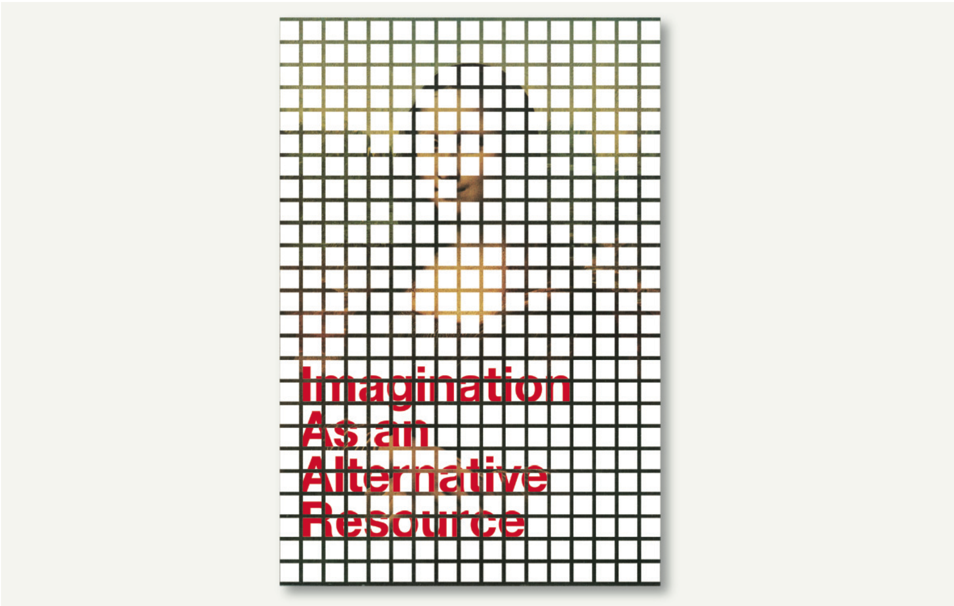



***Figure 1. A graphic designed by the researcher in 2010.***

This research explores the relationship between "incomplete information" and the industrial designer's imagination, focusing on the key concept of "information reduction." For clarification of the terminology, "reduced information" is defined in this thesis as:

> *"the state of information in which the constituents that dictate the fidelity of the information are decreased qualitatively and quantitatively."*

In other words, if we reduce an image from a photo real representation of a product to a sketch, or we have elements missing or ill-defined (e.g. where part of an image is in sharp focus and the remainder is faded out) we can still assess and define the incomplete within those images.

On the other hand, the other critical term "incomplete information" is defined as:

> *"the state of information that the viewer recognises is not yet 'complete.'"*

In other words, although the viewer recognises the information as incomplete, the information offers possible options for them to be "completed." An example of this would be the photograph of a lady standing in a location, the focus may well be on the portrait of the person, yet it may offer some options about the place where the photograph was taken as the background image does not clearly describe. In this way, incomplete information potentially provides the viewer with multiple scenarios, stimulating their imagination beyond that incomplete information is not complete.

## 1.2 — Research Question and Aims

The goals of this PhD thesis are the following:

1. To provide an understanding of the impact of reduced incomplete information as a stimulus on the industrial designer's creative imagination, and
2. To suggest a reductive technique that can be a useful tool for the industrial designer's ideation process at the early phase of the design process.

Accordingly, the primary research question of this thesis can be articulated as follows:

*"How does reduced and incomplete information have a beneficial impact on the industrial designers' design imagination?"*

In order to answer the primary research question, this research examined the following areas:

1. Understanding how the industrial designer builds on their imagination when confronted with reduced and incomplete information.

2. Identifying what type of information the industrial designers primarily consider when they address reduced incomplete information and how those elements are used for their reasoning.

3. Identifying values and limitations of a reductive approach within the context of professional design practices.

This research pursues the potential utilities of a reductive approach for the industrial designers' design imagination. Additionally, it aims to find techniques where the reduced information prompts their design reasoning. Accordingly, this research explores the potential applicability of the reductive approach to design practices by identifying both values and limitations of proposed techniques.

## 1.3 — Research Audience

This research investigates the industrial designers' behaviour when presented with reduced and incomplete visual information, focusing particularly on their reasoning and design ideation as the outcome of their thought process. This research challenges how the incompleteness derived from reduced information influences the industrial designers' imagination, with the aim of developing a reductionist tool that potentially enhances their design reasoning. Therefore, this research illustrates how information incompleteness dictates the industrial designer's reasoning and impacts on their creative performances. It also illustrates how the industrial designer can utilise the information incompleteness within their design practices. Moreover, it demonstrates how creative problem solvers develop their reasoning when faced with reduced and incomplete information. Accordingly, this research speaks to the following audiences:

- Design research community
- Design practitioners
- Psychology research community

Although initially the primary audience of this research was directed at the design research community, the researcher believes that the reductionist tool developed through this research is beneficial to practicing industrial designers. Also, the results and insights derived from this research have made a contribution within the psychology research community, suggesting how an incomplete state of information can impact on the creative reasoning with a particular group of people engaged within the case studies.

# 1.4 — BACKGROUND OF THE RESEARCHER

The researcher has a strong interest in understanding the design practitioner's cognitive activities within the processes of idea generation. This was rooted in the researcher's design background. The researcher considers himself as both a design practitioner and design researcher. The researcher has engaged in a number of design research activities and professional design practices in several countries namely, Japan, the Netherlands, Denmark and the United Kingdom. Although industrial design is always at the centre of the researcher's interest within his design practice, the researcher has also worked across other design fields, including visual communication and spatial design. This cross-cultural and cross-sectorial design background encouraged the researcher to focus on designers' cognition within their ideation process that can be considered as the origin of the design outcomes. Although there are a number of effective design methods that encourage the designers to conceive ideas here and there, the researcher wanted to look into and challenge to uncover the complexity of the designer's cognitive activities within the process of ideation or conceptualisation of their thoughts. The researcher himself has also struggled with conceiving bold and satisfactory design ideas in his past design practices and so these experiences allowed him to investigate the design practitioners' cognitive activities both objectively and subjectively. Also, this research used many visual/tangible prompts as the external stimuli within the studies and these were designed and prepared by the researcher. The researcher's capability of visualising and actualising these prompts, derived from his experience, allowed him to effectively conduct the research studies. Thus, the researcher's design background critically contributed to the accomplishment of the research activities.

# 1.5 — Structure of the Thesis

This thesis consists of five chapters, the first of which is the introduction including the intent, the audience, the background of the researcher and the aims and objectives of the research.

Chapter 2 presents a literature review considering two key areas: "human's cognitive strategy towards incomplete information" and "designer's behaviours within the design process." This chapter explores how human cognition addresses incomplete information and also how designers cope with information incompleteness at the early phase of the design process, referring to the key theories from the subject areas of both cognitive psychology and design cognition studies. Additionally, the literature review also explored how designers utilise the information incompleteness within their design practices. The research areas this research contributes to are articulated at the end of this chapter.

Chapter 3 outlines the methodological approach used within the three preliminary investigations and two main studies. This chapter thoroughly describes how all the methodologies were employed within the studies and how the research process has been developed, addressing the methods for data collection and analysis.

Chapter 4 presents all the studies carried out including both the preliminary and main studies. This chapter exhaustively presents the details of all the studies conducted, including the different methodologies applied for each of the studies, the results, the findings and the conclusions. The findings discovered and the questions raised within each of the studies are respectively illustrated at the end of the sections.

Chapter 5 summarises the primary findings of all the main studies. This chapter concludes in discussing the impact of "reduced and incomplete information" upon the design practitioners' reasoning based on the results and findings from each of the studies. This chapter also articulates the potential key values and possible limitations of the reductionist technique developed through the studies. It addresses the value for the design community as well as its contribution to new knowledge.

Chapter 2

# *Literature Review*

## 2.1 — Introduction

Investigating the relationship between a “designer’s imagination” and “incomplete information” requires understanding of the characteristics of both human cognitive strategy towards incomplete information and designers’ behaviours within the design process. This literature review, therefore, delves into the two scopes:

1. *the nature of human cognitive strategy for addressing unknown information in order to identify or interpret it.*
2. *the relationship between designer’s imagination and incomplete information within their design processes in which ideas are generated.*

Reviewing the literature regarding the characteristics of our visual recognition illustrates how our perception is capable of processing incomplete information and the tendency of finding out a meaning within it, from a cognitive psychological perspective. Additionally, this literature review also unveils how the incomplete nature of information as a stimulus dictates a designer’s imagination or design reasoning. Accordingly, this review seeks and articulates the potential connection where the relationship between incomplete information and designer’s imagination and their design reasoning resonates.

## 2.2 — Cognitive Strategies to Process Incomplete Information

This section highlights the cognitive abilities of human beings, focusing specifically on how they strategically address incomplete information within their reasoning process. The characteristics of human cognition mentioned here illustrate the tendency of finding out meanings within insufficient or meaningless information. These examples underpin the possibility of utilising incomplete information for developing imagination on a cognitive level.

### 2.2.1 Bottom-up Strategy Towards Incomplete Information

Human visual perception, *that is a process by which we make sense of sensory information we receive (Galotti, 2013, p.60)*, is capable of finding out meanings from incomplete information, making use of multiple perceptual models. Our perception has the ability to identify meaningful objects from meaningless low-level features of information by forming patterns in both *bottom-up* and *top-down* strategies of our cognition (Neisser, 1976: Ware, 2008). Galotti (2013) explains that the *bottom-up* model helps us to form a meaning of what is seen by combining the fragments of information obtained from the environment. Galotti explained that this model was achieved by the following three processes:

- *template matching*
- *featural analysis*
- *prototype matching*

*"Template matching"* is the process in which our visual perception recognises patterns when perceivers match them to stored mental representations i.e. long-term memory. Galotti further described: *"Templates work like stencils in reverse. An unknown incoming pattern is compared to all of the templates (stencils) on hand identified by the template that best matches it" (Galotti, 2013, p.46).*

*"Featural analysis"* is the process in which our visual perception recognises features or components of patterns and objects and then combines those fragments of information together to form an integrated interpretation.

*"Prototype matching"* is the perceptual processing theory that addresses some of the weaknesses of "template matching" and "featural analysis" (Eames, 2016). As well as *"template matching,"* prototyping matching considers that our visual perception recognises the distal images, referencing mental representations in long-term memory. However, *the mental representations are not specific templates, but "ideal" representations of a class of stimuli called "prototypes"* (Eames, 2016, p.38).

These processes explain how our visual perception organises sensory data into recognisable patterns and describes how we can cope when faced with unknown information.

#### 2.2.1.1 Patterns of Visual Recognition on Gestalt Psychological View

The classical theory of "Gestalt" described the tendency of our visual cognition to elicit information from the environment, deciphering optical patterns. Gestalt psychology is the theory that studied *thinking, learning and perception in whole units, not by analysing experiences into parts (Coon, 2005, p.21)* proposed by a group of German scholars—notably, Max Wertheimer, Kurt Koffka, and Wolfgang Kohler (Solso, 1994). Gestalt psychologists argued that humans group objects according to certain organisational principles such as:

- **"proximity"** the principle that elements near each other will be perceived as belonging to a common set.
- **"similarity"** the principle that objects that are similar will be perceived as belonging to the same group.
- **"continuity"** the principle that a series of stimuli will be perceived as representing a unified form.
- **"closure"** the perceptual principle that people tend to piece together disconnected bits of information to perceive whole forms.
- **"connectedness"** the principle that objects positioned together or moving together will be perceived as belonging to the same group (Nevid, 2016, p.119).

As well as these principles, Gestalt psychologists asserted that human visual perception has a tendency to see things in the simplest form possible e.g. simple geometric forms such as a circle, square, triangle or hexagon (Roeckelein, 1998; Solso, 1994). Human visual perception is not built up of sensations but rather making sense of the perceptual organisations, following such cognitive patterns (Goldstein, 2009). For example, we can perceive a Dalmatian (Figure 2) grouping some of the black areas and others are seen as shadows in the background (Goldstein, 2014). This suggests that our visual perception finds out a meaning of the forms even in the less resolved visual stimulus.

*Figure 2. Effects of grouping derived from past experience (Photography by R. C. James).*

### 2.2.1.2 Imagining Incomplete Visual of Artefact

Another example of *"bottom-up processing"* in terms of object recognition is Biederman's (1987) theory of *"recognition-by-components."* Recognition By Components (RBC) theory suggests that our perception can construct mental imagery of an object from incomplete depiction by identifying the combination of simple geometric features (e.g. blocks, cylinders, wedges and cones) named GEON (namely, geometric icon) in the image. For example, our perception can readily recognise a watering pot without effort even if considerable amount of the visual elements are removed (Figure 3). Our perception successfully deciphers what the object can possibly be within incomplete visual information by seeing it as a collection of geometric components. Thus, our optical perception can build the image of objects even if their images are imperfect as long as appropriate visual clues are given.

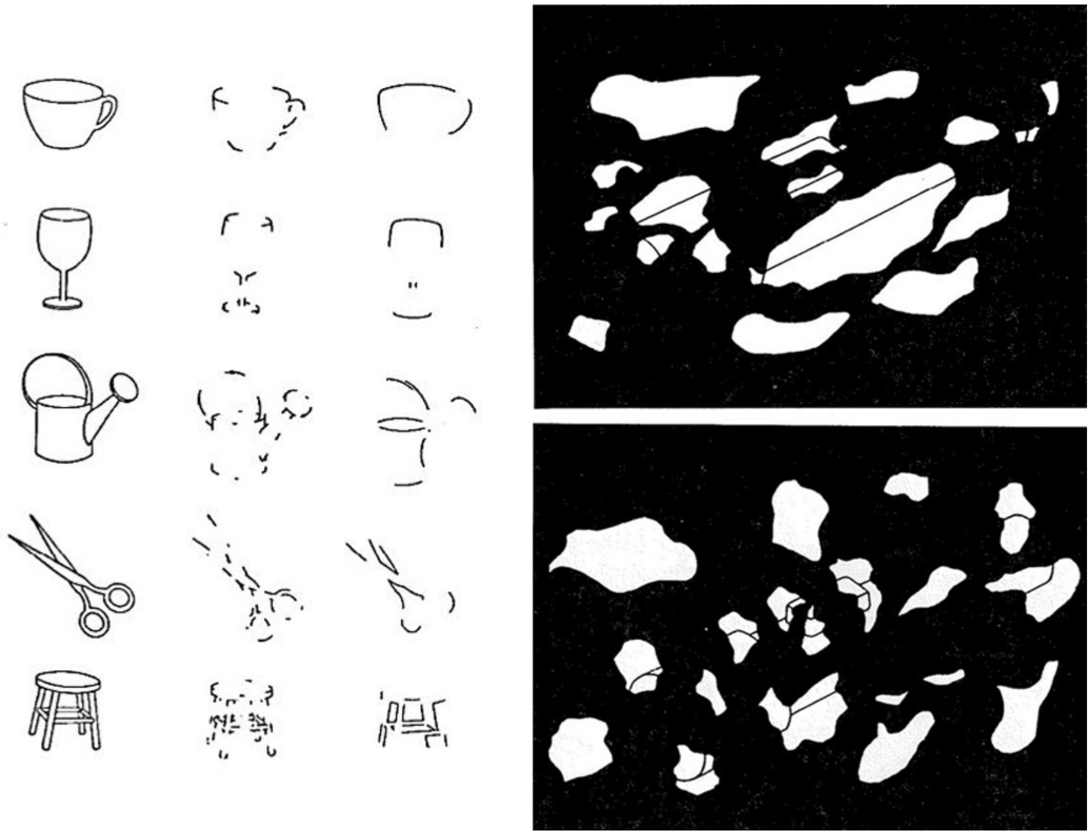


*Figure 3. Biederman's Recognition By Components theory (1987).*

### 2.2.2 Top-down Strategy Towards Incomplete Information

On the other hand, in top-down (also called theory-driven or conceptually driven) processing, *the perceiver's expectations, theories or concepts guide the selection and combination of the information in the pattern-recognition processes (Galotti, 2013)*. In top-down processing, we make use of stored knowledge, past experiences, motivations and cultural background to interpret an incoming stimulus (Groome, 2013; Levitin, 2002). Also, "context" plays an important role in interpreting objects (Biederman et al., 1973; Palmer, 1975). In other words, within top-down process, our recognition is capable of interpreting unknown information confronted using our prior knowledge in context. For example, Krippendorff (2006) illustrated how our recognition is variable under the influence of context (Figure 4). In this image, we perceive the letter/number located at the centre as "B" when the top and the bottom are hidden. However, we also perceive the letter/number as "13" when the right and the left are hidden. The way we perceive the letter/number is changed depending on the context of where it is placed. Another example also illustrates the influence of the context on our recognition (Figure

5). Even though we may read the words as “THE CAT,” both letters “H” and “A” share the same figure. This example also explains how the way our recognition is affected by the context.


*Figure 4. An example illustrated by Krippendorff (2006).*


*Figure 5. An example illustrated by Galotti (2013) reproduced by the researcher.*

Many objects we perceive involve multiple contexts. A knife is used as a cooking tool in the kitchen whereas it is considered as a weapon when it is found at a crime scene. Or, a banknote is used as a piece of paper when a person makes a note on its surface. The meaning of an object and the context are often inseparable in human perception. In other words, context restricts the numbers of possible meanings regarding the way we interpret an object (Krippendorff, 2006). The balance between a “probability of meanings” that the information represents and the “number of contexts” that the information suggests, appears to affect the process of reasoning in which we identify unknown information.

### 2.2.2.1 Schema and Expertise as a Clue for Recognition

Our cognition refers to stored knowledge within the process of identifying an object. The knowledge structure that represents objects or events and provides default assumptions about their characteristics, relationships, and entailments under conditions of incomplete information is called “schema” (DiMaggio, 1997). Schema is also defined as *“a data structure for representing the generic concepts stored in memory” (Rumelhart, 1980, p.34)*. Rumelhart

(1980) further asserted that schema exists for all kinds of knowledge and concepts such as objects, situations, events, and actions. Rumelhart and Ortony (1977) outlined that schema has four essential characteristics:

1. *Schemas have variables*
2. *Schemas can embed one within the other*
3. *Schemas represent generic concepts which vary in their levels of abstraction*
4. *Schemas represent knowledge rather than definition.*

Our cognition finds out meanings in the world using this knowledge structure. Also, when a schema is incompletely instantiated, the schema fills in missing information with "default values" (Crocker, 1984). This means that, even if the detail of the information is not given, our cognition has a tendency to interpret its schema using a typical assumption (default value of the schema) within the context.

Hanson (1969) illustrated how schema activates our knowledge structure in order to interpret the meaning when we confront abstract visual information (Figure 6). Even if we are given an abstract image composed of a set of meaningless figures, once appropriate keywords (namely *"a bear climbing up the other side of a tree"*) are given, we interpret the meanings of each element depicted.

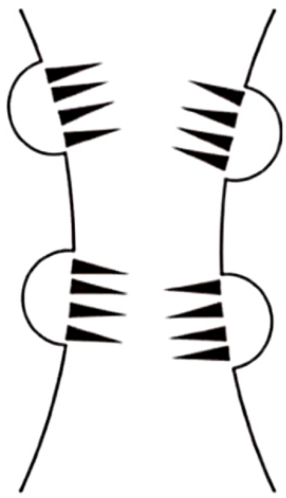


***Figure 6. Observation by Hanson (1969) reproduced by the researcher.***

Expertise is a form of schema that involves both *"knowing–that"* (conceptual understanding) and *"knowing–how"* (the capacity to do things) (Stevenson, 2003). The expertise as cognitive behaviour and as collective and social constructs has been recognised in the design realm, and it is widely used in design practices for both professional designers and design students (Cross et al., 1994; Cross, 2004; Lawson & Dorst, 2009). Although each design discipline (e.g. product design, graphic design, or architecture design) has specific areas of expertise, some common aspects across the fields are identified in the design processes (Lawson & Dorst, 2009). A general feature is that all designers have specialist knowledge regarding the creation and use of artefacts. *Their knowledge, skills and values lie in the technique of the artificial* and, therefore, *design knowledge focuses mainly on how to contribute to the creation and maintenance of the artificial world* (Cross, 2001a, p.54). Cross (2001a) further asserted that the design knowledge is inherent in: *the activity of designing*, *the artefacts of the artificial world (e.g. in their forms and configurations – knowledge that is used in copying form, re-using or varying aspects of existing artefacts) or the process of manufacturing the artefact.* This knowledge is acquired through the reflection on their design practices, the use and the making of artefacts. This schematic knowledge regarding the artefacts in the artificial world, learned and gained through practices, affects the process of their design reasoning.

Although "design knowledge" is acquired through action (Lawson, 2004a), designers also use a schematic knowledge structure stored in their design experiences. This knowledge schema is called *"design prototype." Design prototype*, coined by Gero (1987), is a conceptual schema for comprehensively representing generalised classes of design elements derived from design experiences. This conceptual schema is used as a base for the start and continuation of a design (Gero, 1990). Gero and Rosenman (1990) described that *design prototype* schema consists of the necessary "function" and "structure" descriptions as well as behaviours in a generic sense, regarding the selected object (Figure 7).

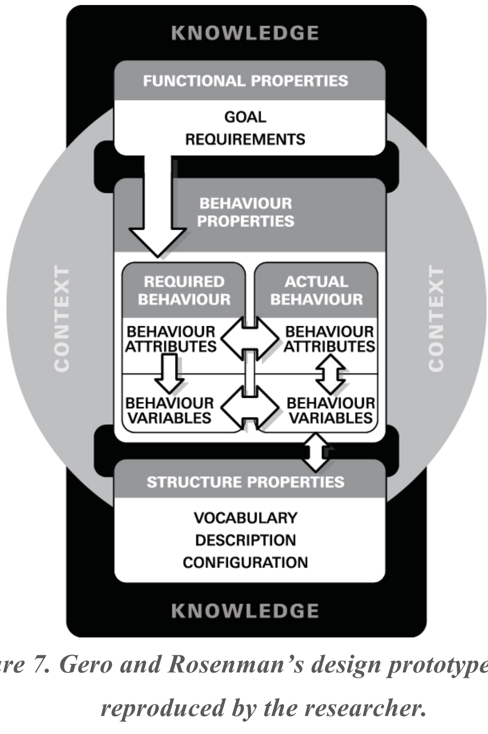



***Figure 7. Gero and Rosenman's design prototypes (1990) reproduced by the researcher.***

Design prototypes represent mainly *"function properties,"* and *"structure properties." "Function properties"* include intended function, and the expected behaviour as attributes and variables. *"Structure properties"* include vocabulary (representing elements that are essential to the existence of the prototype), the prototype description (typological properties e.g. dimensions, material etc.), configurational knowledge as well as the actual behaviours as attributes and variables of the prototype. (Gero and Rosenman, 1990, p.69). This model allows designers to store design schematic knowledge regarding their experiences. This schematic system of knowledge built up by a set of past *design experiences can be directly used in new design projects and becomes a repertoire of earlier design solutions* (Lawson and Dorst, 2009, p.100).

As well as the design expertise as schema that can commonly be used among different designers, they also develop their "designerly schema." For example, Lawson (2004b) identified how architects manipulate schema that represented complex and sophisticated sets of ideas within their communication:

> *"For experienced architects, the concept or schema of 'round shapes in square containers' includes not just the simple idea of that geometry but the whole game of contrasting the curved and straight lines, and all the examples and variations have been developed by other architects" (Lawson, 2004, p. 446).*

Or, Hillier and Leaman (1976) described that designers utilise kind of a *"code"* that enables them to translate from individual, organisational and social needs to physical artefacts. Hillier and Leaman further described that designers create a connection between human needs and artificial environment by leaning this "code" like a language:

> *"This code (...) is supposed to express and contain actual connections which exist between human needs and their artificial environment. In effect, the designer learns to 'speak' a language - to make a useful transaction between domains which are unlike each other (sounds and meanings in language, artefacts and needs in design) by means of a code or system of codes which structure that connection" (Hillier and Leaman, 1976, p.29).*

Even though designers do not fully understand the way in which they use their design knowledge themselves (Lawson and Dorst, 2009), they still acquire "design expertise as schema" within the process of their education and practice and even develop new schema by themselves. This particular schema that includes both explicit and implicit knowledge structure affects and helps the designers' to develop their design reasoning.

### 2.2.2.2 Categorisation as a Cognitive Strategy to Approach Incomplete Information

Our cognition efficiently processes information through categorising what we perceive. There are infinite variations of different information in the environment. However, our cognition needs to *conserve finite resources as much as possible* (Rosch, 1978). Instead of discriminating every single entity in the world, *our mind automatically selects the cognitively economical option of neglecting the infinite differences among objects to behaviourally and cognitively usable proportions* (Athavankar, 1989, p.102). Our cognition, therefore, gains *maximum information with the least cognitive effort*. Rosch (1978) called this function as *"cognitive economy."* We naturally sort out information and identify what the object perceived possibly is.

Barsalou (1992) described that the process of categorisation is generally carried out through the following stages (Figure 8). First, our cognition recognises a pattern, and form a structural description of the information perceived. Second, our recognition seeks whether or not there is a similar knowledge representation to the information perceived. Third, the most similar and plausible category is selected. Fourth, our cognition considers the relevance between the information faced and the category selected by inference. Then, finally the information about the particular categorisation is stored in their memory.

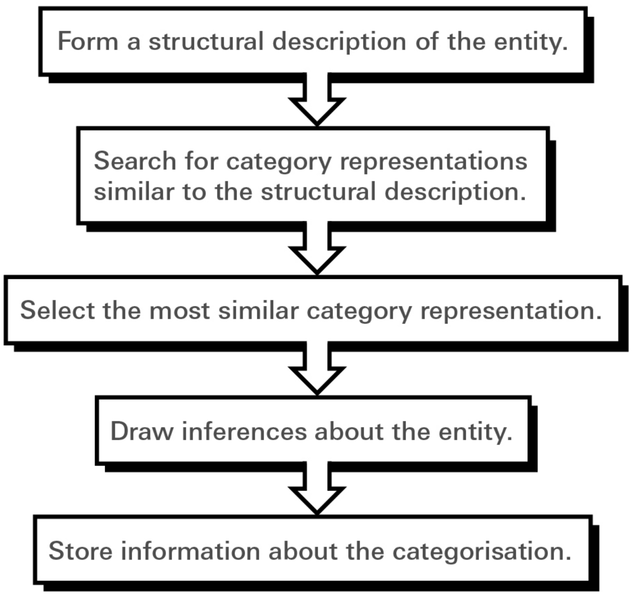



***Figure 8. The generic process of categorisation described by Barsalou (1992).***

Thus, the process of categorisation is not merely classifying the information perceived in the world and putting it into an existing taxonomy but also includes the behaviour of inference between the information perceived and the category representation selected.

Athavankar (1989) argued how vague the boundary between two different object categories was, referring to a linguist William Labov's study (1973). Labov illustrated the relationship between forms of object in transformation and its conceptual meaning (Figure 9). Although all objects shown share some characteristics in functionality, the lexical term of an object varies in accordance with the transformation of form. The object recognised as a "cup" changes to a "bowl" when the width of its form becomes wider. Meanwhile, a "cup" also changes to a "vase" when the depth of its form becomes deeper.

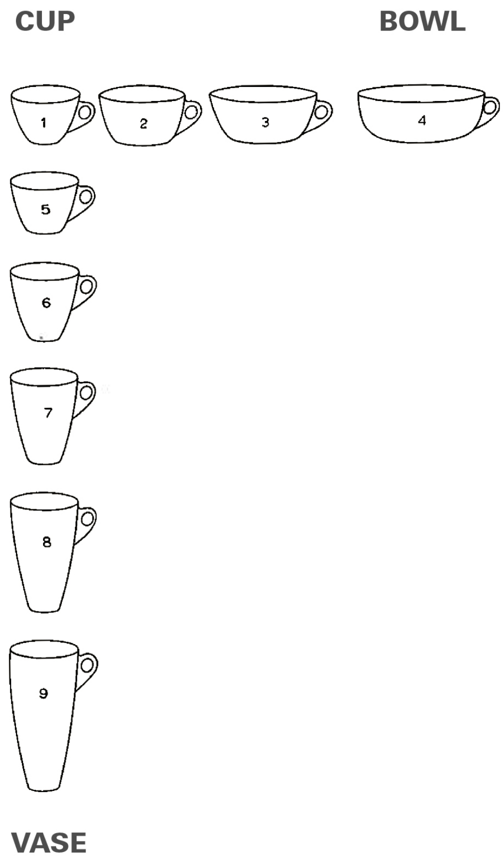



*Figure 9. Image of objects used in Labov's study (1973).*

Athavankar stressed that the boundaries amongst the object concepts are vague and even movable when context or subjects change (Athavankar, 1989, p.102). A category of object is not defined by its boundaries but by its centre, and this characteristic allows flexibility in dealing with a wide range of manifestations of the concept. Object categories are represented by a summary representation of a category called "prototype" that shows *the most common features, the average values or even the ideal characteristics of a category* (Pothos and Wills, 2011, p.40). A novel instance is then *classified into a category when the similarity between the instance and the category prototype is high* (Pothos and Wills, 2011, p.8). Human cognition carries out the process of categorisation relying on this "prototype" as the centre for identifying the definition an object. These prototypes help us to develop discontinuities between objects. This means that as the object perceived is closer to a prototype, our recognition readily identifies what it is (Krippendorff, 2006, p.103). Accordingly, when the object is distant from its relevant prototype, the belongingness of the object becomes more ambiguous where offers the viewer to consider multiple options.

Rosch et al. (1976) asserted that the category system composed of the three hierarchical levels of abstraction: "superordinate level," "basic level" and "subordinate level." *"Superordinate level"* where situates at the top of the hierarchy, represents the higher abstract classification of object categories such as "animal," "vegetable," "furniture" and so on. *"Basic level,"* that situates at the middle of the hierarchy, represents the categories that are the intermediate level of abstraction of object categories such as "horse," "tomato," "chair" and so on. *"Subordinate level"* that situates below "basic level" represents more concrete typologies of objects such as "pony," "baby plum tomato," "bar stool" and so on. Athavankar illustrated that, in the context of artefact, the actual products situate below "subordinate level" as concrete instance (Figure 10).

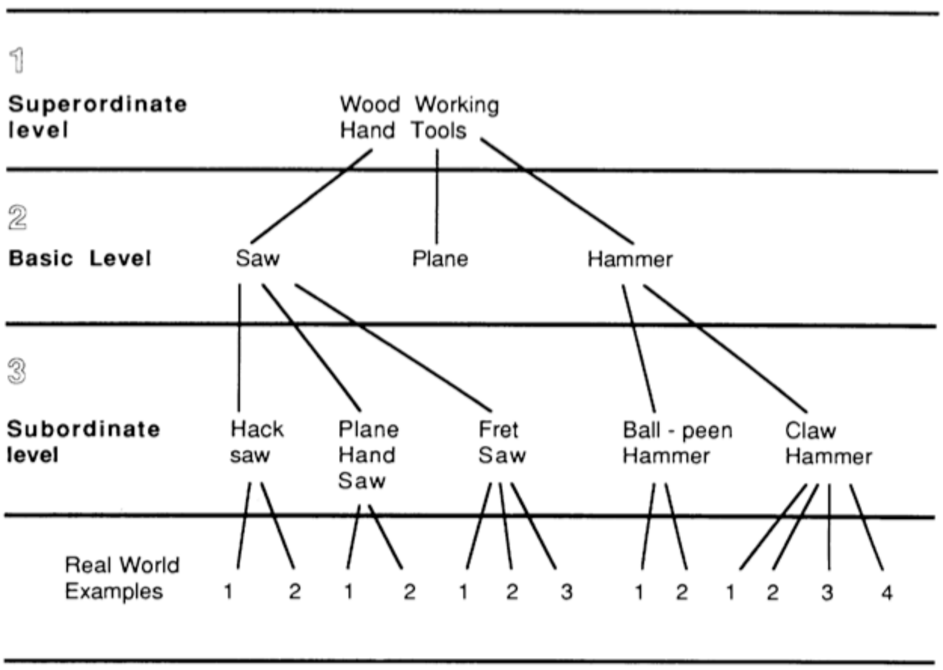



***Figure 10. An example demonstrated by Athavankar (1989).***

Rosch et al. (1976) and Rosch (1978) stressed the importance of *"basic level."* The *categories on basic level objects are the most inclusive level at which objects have numbers of attributes in common*. Although *"superordinate level"* situates at the higher level of abstraction than *"basic level,"* it only shares a few attributes with the other. In contrast, *"subordinate level"* categories that are the bundles of predictable attributes and function but contain many attributes that overlap with other categories (for example, dining lamp shares most of its attributes with other kinds of lighting objects). Accordingly, the categories that situate at "basic level" are the most inclusive and, therefore, play an important role within the structural relationship of the categorisation hierarchy.

Human cognition carries out its categorisation process within this hierarchical system where concepts of objects are mapped out depending on the abstract levels. This structural relationship of concepts is not isolated or fixed. The cognition continuously develops a working model of the real world, recreating the relationship amongst multiple concepts (Athavankar, 1989).

Recognition of objects is conducted within such a hierarchical knowledge network, categorising the attributes of objects. Unknown information is also processed within this intricate knowledge structure and then stored in human memory, finding similarity and discontinuity among each element.

### 2.2.3 Conclusion of Cognitive Strategies to Process Incomplete Information

As discussed, our cognition approaches to unknown information through a number of multiple cognitive strategies. This section of the literature review did not encompass all the cognitive strategies. However, it argues the cognitive strategies for finding meanings when faced with unknown information, focusing particularly on the two interpretative approaches: "bottom up" which addresses information by synthesising the fragments and "top-down" which processes information through existing knowledge framework. These approaches are not taken in isolation but rather complement each other within the interpretative process of incomplete information (Figure 11).

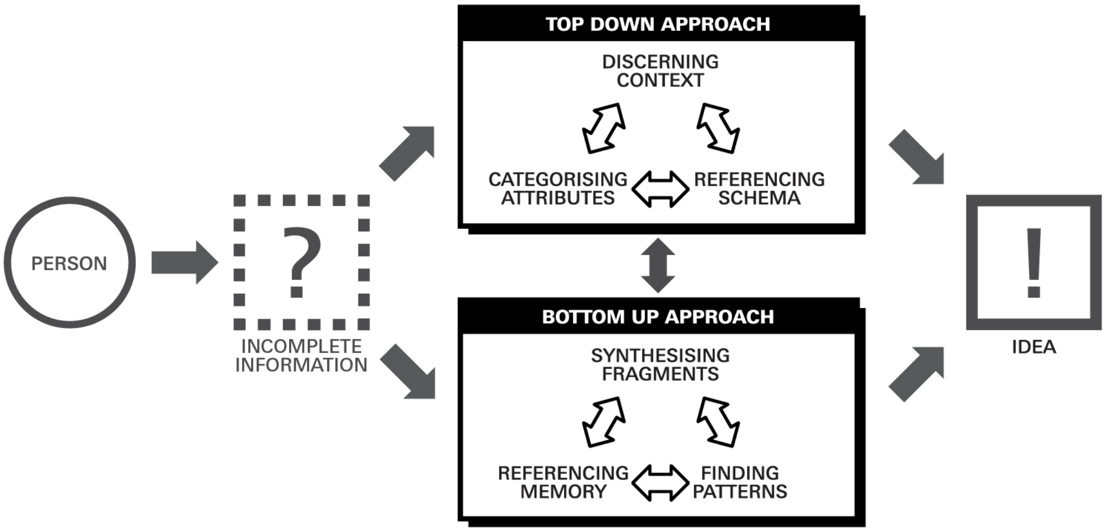



***Figure 11. Bottom up and top down approaches towards incomplete information.***

In the *"bottom up"* view, human cognition finds out or interprets a meaning within incomplete information by finding patterns through synthesising fragments. Through the pattern-seeking behaviours such as "featural analysis," "recognition by components" or "gestalt," the cognition detects patterns within the fragments of information. These patterns are also referenced to the viewer's long-term memory for interpretation through exploratory behaviours i.e. "template matching" or "prototype matching." The prominent characteristic of this approach is that the meaning is identified by synthesis of information of distal images particularly at the very beginning of the pattern detecting process. This appears to suggest that the first pattern detection is conducted dismissing preconceived ideas. This potentially allows the cognition to explore multiple directions within the process of reasoning as the first approach towards incomplete information confronted.

In the *"top down"* view, on the other hand, human cognition understands and interprets incomplete information by referencing existing knowledge structures. The incomplete information perceived is scrutinised in order to identify how the attributes of the information can be related to the systematic knowledge structure such as "object categories" or "schemas." The characteristic of *"top down"* approach assists the cognition to figure out where the incomplete information perceived potentially fits within the knowledge structure and suggests the way to approach to the information when interpreted. This appears to suggest that *"top down"* approach allows the cognition to systematically understand the meaning of incomplete information in the bigger picture and at multiple levels of knowledge types.

As discussed, a *"bottom up"* approach can be regarded as a *"description of parts"* whereas *"top down"* can be considered as a *"prescription of the whole."* Both approaches play an important role in object imagination. In the pursuit of understanding the impact of reduced and incomplete information on a designer's imagination, the researcher considers that the "incompleteness" of information derived from reduction should effectively restrict their access of these cognitive approaches. The incomplete information needs to partially suggest its schematic knowledge structure behind, yet it should also encourage the designer to actively scrutinise the relationship amongst multiple constituents of the information. If the incomplete information involves a high-level of both suggestiveness and ambiguity, it then potentially triggers the designer's dynamic imagination.

## 2.3 — INCOMPLETE INFORMATION AND DESIGNERS

The preceding section has discussed the cognitive strategy towards incomplete information in object imagination. The elaborate cognitive system is capable of finding meanings in incomplete information through the approaches where our cognition scrutinises the relation of the parts to the whole, i.e. top down and bottom up processes. Then, how do designers address incomplete information in their profession? How does incomplete information dictate the designer's imagination? Following these questions, this section explores the relationship between *"incomplete state of information"* and "designers." Many design studies highlighted the role of *"information incompleteness"* such as uncertainty, ambiguity and indeterminacy as a key impetus for the designers' imagination. Designers purposefully keep detailed information less resolved as a means of manipulating it, particularly in the process of idea generation or even in their design development. This section explores the ways in which designers interact with incomplete information, aiming at finding how "reduction" as a factor can facilitate a designer's reasoning.

### 2.3.1 Early Phase of Product Design Process

It is commonly known that designers are required to formulate design concepts at the preliminary phase of the design process. As this investigation focuses on the way in which designers develop their imagination, it is necessary to understand how designers engage with idea generation activities at this particular stage of the design process. Accordingly, this section describes how industrial designers commonly behave and how they articulate the prescribed tasks required from them, at this early conceptual stage. The aim of this section is to articulate what is required for the designers in order to conceive creative ideas at this early phase.

In the product design context, the design process involves two major phases: *the "product design phase," followed by the "product realisation phase*," *including manufacture, distribution and sales* (Open University, 1992, p.115). The product development phase can be subdivided into two sub-phases: the *"product planning"* and *"product designing."* Following this, the *"product planning phase"* comprises two sub-sections: *"strategic planning"* and *"idea finding"* (Figure 12). The *"idea finding phase"* in which this research is specifically concerned, is located in between two steps: "product policy" and "new product proposal." In this step, the designer engages with idea generation and selection based on the direction of the project (i.e. objectives and strategies) formulated from the previous step. The idea generated and selected will then become a new product proposal and continued to be processed towards the further product design phase where the details of the design are determined. Although the previous and next steps (namely product policy and new product proposal) are deterministic, the action of *"generating and selecting ideas"* is rather explorative. This means that the designer is essentially required to produce many ideas that will eventually be selected as the potential design concept for the further development.

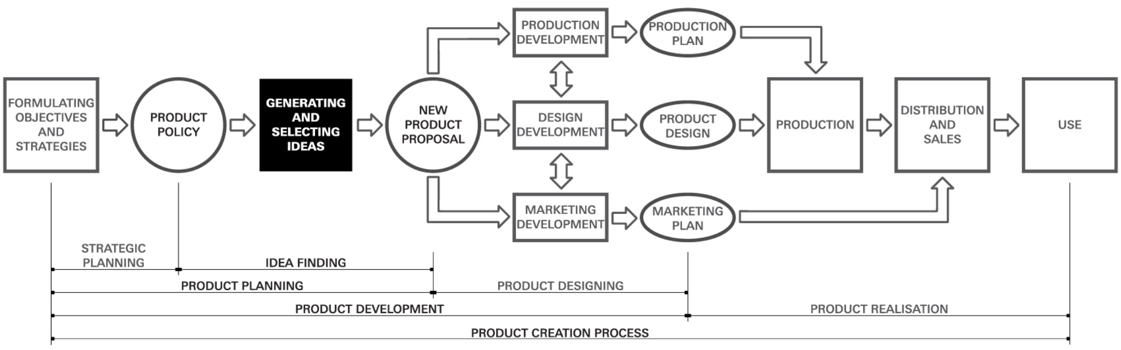



***Figure 12. The product design process described by Open University (1992) reproduced by the researcher.***

Rodgers (2011) describes that the industrial design process generally involves the following six stages:

1. **"Research"** *(background stage/exploratory stage)*
2. **"The brief"** *(identifying customer needs/completing Product Design Specification)*

3. **“Concept design”** *(generation of ideas/sketches, drawings and renderings/evaluation of concept)*
4. **“Design development”** *(technical drawings/prototypes)*
5. **“Detail design”** *(exploring materials/exploring manufacturing techniques/testing and refinement)*
6. **“Production”** *(marketing/supply/disposal)*

In particular, the stage of *“concept design,”* generally means the act of representing the ideas in the designer’s mind, is by means of hand-drawn or digital sketches (Reeves, 2015). Within the process of idea generation, the designers develop many ideas through a number of steps (Morris, 2016) such as:

- **“preparation”** *where they explore workable ideas, being open minded, playing and reflecting,*
- **“incubation”** *where they develop ideas by adaptation to existing designs, drawing an analogy and/or focusing on new materials and technologies.*
- **“illumination”** *where they discover breakthrough ideas by Subversion, Scenario analysis, learning from nature and/or making links between areas that have no normal associations.*
- **“validation”** *where they critically validate the ideas conceived through taking a different view or challenging new perspectives on the subject.*

Within the stage of *“concept design,”* where the designers seek to create a concise description of how a product will satisfy a customer’s needs using sketches, models and descriptions, the quality of a concept generated largely dictates the execution of the products (Rodgers, 2011) or the entire design process (Jansson and Smith, 1991). Rodgers stressed the importance of this stage within the designing process: *“While a good concept may be implemented poorly in the finished product, a poor concept can rarely be turned into a successful product” (Rodgers, 2011, p.78).* Cross (2006) also stated that designers need to clarify the client’s requirements by suggesting possible solutions since the problem as set by their brief is often vague. Accordingly, *the designer’s very first conceptualisations and representations of problem and solution are critical (Cross, 2006, p.16)* during the design process. At the early phase of the design process, it is often not at all clear what “the problem” is and many constraints and criteria may be un-defined (Cross, 2011; Rittel, 1973; Buchanan, 1992; Goldschmidt, 1994; Cross, 2004; Lawson and Dorst, 2009). It is, therefore, important for the designers to explore meaningful concepts as the preliminary approach within the design process. Thus, the quality of the ideas explored within this *“concept design”* stage substantially affects the entire design process. This thesis primarily focuses on this phase of the design process and investigates how reduced and incomplete nature of information as stimuli can play a role in designer’s creative imagination where ideas are generated and conceptualised.

### 2.3.2 Incompleteness for Designer’s Imagination

Designers, who are generally recognised to deliver creative ideas, are well skilled at understanding what the artefact communicates by reading information that resides in objects (Cross, 2006). They infer information from images of objects by attaching meaning to their attributes, including shape and form, colour, texture, relationship among components and so on (Goldschmidt, 2014). Closely observing physical properties, such as reconciliations between structure and cost, the designer’s intentions of the object or characteristics of the material used, enables designers to read technical and historical knowledge embodied in the objects (Tsutsumi, 2013). As such, designers are equipped with the ability of reading information regarding artefacts through observation. Designers, who seek not-yet-existing and never-before-seen solutions (Folkman, 2014), often confront ill-defined and wicked problems that are highly complex and indeterminate (Rittel, 1973; Buchanan, 1992; Goldschmidt, 1994; Cross, 2004; Lawson and Dorst, 2009). In such a situation, the problem with which the designer is challenged, is often not at all clear and even the goal is unknown or ambiguous (Goldschmidt, 1997) or maybe re-defined (Cross, 2001) during the project. In pursuit of seeking ideas within the indeterminate design process, dealing with incompleteness of information inevitably plays important role for designer’s imagination during their ideation process. During the early phase, in particular, the design process where designers conceptualise ideas, they explore and develop multiple ideas as solutions in parallel (Lawson, 2006; Dorst, 2003). Goel (1995) asserted that the ambiguous nature of visual information produced during the early stages of design is not inferior but rather plays a very important role for a designer’s cognitive process. Within such process, it is important to keep a certain level of ambiguity in their visual representations (e.g., design sketches) in order to increase the possibilities for their design imagination. The ambiguous nature of these indeterminate sketches facilitates a designer’s multiple interpretations and helps to develop their design alternatives (Do and Gross, 1996). Additionally, those tentative depictions that are often produced quickly and cheaply (Rodgers et al., 2000) are reinterpreted in order to transform, develop, and generate new ideas (Menezes and Lawson, 2006). Further, this ambiguity significantly supports the exploration of a wide variety of innovations and increases the number of ideas available for designers (Tseng and Ball, 2011). Accordingly, good designers inevitably learn how to deal with this ambiguity and discover solution concepts but in an imprecise and incomplete way (Cross, 1999).

In the process of initial idea sketching where the designers engage in reflective conversation with externalised ideas on paper (Schön, 1983; Goldschmidt, 2003), the indeterminate and ambiguous nature of visual representation is significant as crystallising ideas at the early phase of design process hinders design development (Goel, 1995). Additionally, in such a reflective conversation, designers discover unexpected meanings within the relationship between depicted elements (Goldschmidt,1994; Schön and Wiggins, 1992) when generating ideas (Suwa et al., 2000). Designers also detect unintended relationships and features even from sketches depicted for different purposes (Suwa and Tversky, 2002). It is also argued that increased levels of visual ambiguity presented to designers facilitate their interpretative activities and effective concept design behaviours (Tseng and Ball, 2010). The ambiguous nature of visual representation produced by the designers, encourages them to explore multiple interpretation of ideas (Do and Gross, 1996). Thus, designers are naturally required to cope with the lack of resolution of ideas (Lawson, 2006), and purposefully keep the visual information they address as incomplete, uncertain, indeterminate and/or ambiguous. This is essential in order to enhance their imagination at the early phase of the design process.

### 2.3.3 Incompleteness and Design Fixation

Generally, designers have a tendency to seek visual inspirations within the design process. They actively gather visual reference materials from a wide variety of media e.g. posters, notes, artefacts, books/magazines, catalogues or material samples and then these are stored electronically in their computer or physically in the cupboard or bookshelf in their office (Keller, Pasman and Stappers, 2006). The combination of these inspiration sources derived from their memory and their design problem triggers the generation of new design elements (Eckert, Stacy and Clarkson, 2000). Designers fundamentally manipulate visual means in their research activity (Hanington, 2003), and such pictorial information acts as stimuli and enhances their creative performance (Goldschmidt and Smolkov, 2006). Thus, visual inspiration plays an important role for the designer's idea generation in their design process. However, visual inspiration as stimuli can sometimes be a negative factor for a designer's creative imagination sometimes.

Many design researchers have identified how a designers' mind might unconsciously adhere to existing ideas or concepts during the time when they engage in seeking solutions to a problem (Jansson and Smith, 1991). Designers sometimes limit their creative output because of an overreliance on a specific body of knowledge directly associated within a problem, or within the features of pre-existing designs (Youmans and Arciszewski, 2014). This behavioural characteristic of the designer is known as *"Design Fixation."* The study of fixation in the design field, was first conducted by Jansson and Smith (1991). They illustrated that presenting design students and professional designers an example of a solution to a problem, in advance of a design session negatively fixated their idea exploration and impeded their creativity. The pictorial representation given to the designers as an example of a solution, played a role as precedent. This encouraged them to adhere to it and even conform to the negative aspects of the presented example design. This characteristic was also confirmed in further investigations (Purcell and Gero, 1992, 1996). For designers, it is not easy to pull out of this unconscious fixation by themselves (Linsey et al., 2010).

Some studies identified strategies to cope with design fixation. Design fixation can be reduced by temporarily putting the fixation out of mind. Putting a fixation aside in the designer's mind allows them to re-address the problem without the counterproductive influences of inappropriately applied knowledge (Smith and Linsey, 2011, p. 84). Or, the use of physical materials in prototyping also reduces the fixation effect (Youmans, 2011). It has also been argued that *"design heuristics"* enables the designer's mind to "jump" from one solution space to another, and can also assists them to reduce design fixation (Yilmaz, Seifert, and Gonzalez et al., 2010). Cheng, Mugge and Schoormans (2014) argued that presenting inspiration sources that contain abstract, ambiguous and incomplete information helps the designers to cope with fixation. Cheng, Mugge and Schoormans illustrated that incomplete pictorial information presented as an inspiration source (i.e. partial photographs of existing products) encourages designers to create more original designs, which suggests that they were less fixated on the product examples (Cheng, Mugge and Schoormans, 2014, p.387). Further, examples represented with more abstract visual (e.g. simple line-drawing) enhanced designer's originality (Cardoso, Badke-Schaub and Luz, 2009). Evidence also suggests that texts represented with a moderate level of abstraction, that also provide enough association links with the design problem, effectively act as inspiration for designers (Gonçalves, Cardoso and Badke-Schaub, 2012). Thus, inspiration sources represented with limited fidelity can play a role in overcoming fixation and inspiring a designer's originality in idea exploration.

Presenting inspiration sources as external stimuli affects the designer's thinking process during idea generation in both negative and positive fashions. When it works negatively, it blocks the flexibility of the designer's reasoning, i.e. fixation, whereas if it performs positively, it can act as an enabler for creative imagination. In order to inspire designers effectively, it is important to consider *the form of the inspiration source, the distance between the inspiration source and the targeted problems, the abstraction level of the information contained in the inspiration source, and the timing of when they are presented to designers* (Cheng, Mugge and Schoormans, 2014, p.376). Incompleteness of information can potentially be a useful tool to avoid design fixation and enhance designer's imagination when presented in an appropriate form.

### 2.3.4 Designer's Capability to Handle Incomplete Information

There have been several investigations that utilised incompleteness of information as external stimuli. For instance, designers are capable of manipulating their imagery even under conditions where visual accessibility is restricted. A blindfolded industrial designer who was not allowed access to sketching can evolve the shape of his/her visualized object, manipulate it, evaluate alternative modifications and add details and colours effortlessly being supported by hand gestures (Athavankar, 1997). Further, this restriction of visual information is valid in design reasoning at the conceptual design stage, and efficient in the way that external representations are used (Bilda & Gero, 2006). Designers are able to find semantic meanings and develop diverse designs even from meaningless geometric forms. Butter's experiment, in Klaus Krippendorff's (2005) book *"The Semantic Turn"* demonstrates that a great number of different electronic products could be designed by combining a set of meaningless geometrical blocks. The participants in Butter's experiment interpreted different meanings from the parts of simplified blocks, in context to each other and so constructed meaningful products. This result implies that designers are capable of carrying out design reasoning from ambiguous shapes, imagining and manipulating them to create meaningful contexts. These studies demonstrate the capability of the designers to develop design imagination under conditions where information available is limited.

### 2.3.5 Deconstruction as a Means to Question

Deconstruction of information can possibly be a form of reduction that designers can benefit from. Deconstruction as a critical approach has inspired the designer's imagination and their design practices. The theory of deconstruction coined by Derrida (1976) has influence across a wide range of design practices such as architecture, graphic design, products and fashion, imbued with ambiguous futuristic overtones (Lupton et al., 1994). Lupton et al. (1994), argued that deconstruction per se is a mode of questioning through and about the technologies, formal devices, social institutions and founding metaphors of representation. Lupton et al. then concludes that design can critically remake the grammar of communication by discovering structures and patterns within the material media. In the context of deconstructivism in architecture, designers fragmented volumes into their constituent components and experimentally reassembled the exploded and fragmented forms (Collins and Papadakis, 1989). However, deconstructivism is not merely architecture of decay or demolition, but rather challenging the very values of harmony, unity and stability (Johnson and Wigley, 1988). If this critical "questioning mode" is purposefully deployed in the process of design reasoning, the researcher hypothesise that it provides the designer with an opportunity to re-think existing artefacts or the meaning of concepts that objects include with critical and fresh perspectives. By utilising deconstructive approach as a form of reduction, it can potentially be a tool that enhances the process of industrial designer's reasoning for idea exploration.

### 2.3.6 Designed Incompleteness as an Impetus for Active Engagement

"Incompleteness" can be considered not only as the potential factor that assists a designer's imagination within the design process but also regarded as a useful element that intensifies the interaction between a designed object and the user. Arguably, some designers utilised "incompleteness" within their design practices. The designers purposefully incorporated the element of "incompleteness" into their designs in order to encourage active engagement with the user of the product. For example, a Spanish product designer Marti Guixé designed a clock, titled *"Blank and sentence Maker"* (2010), with a blank clock face that encourages the user to draw original time indications in their own manner (Figure 13). By providing the user an empty and writable space instead of giving them prescriptive clock dials, it enabled them to interact with the object in more personal way.

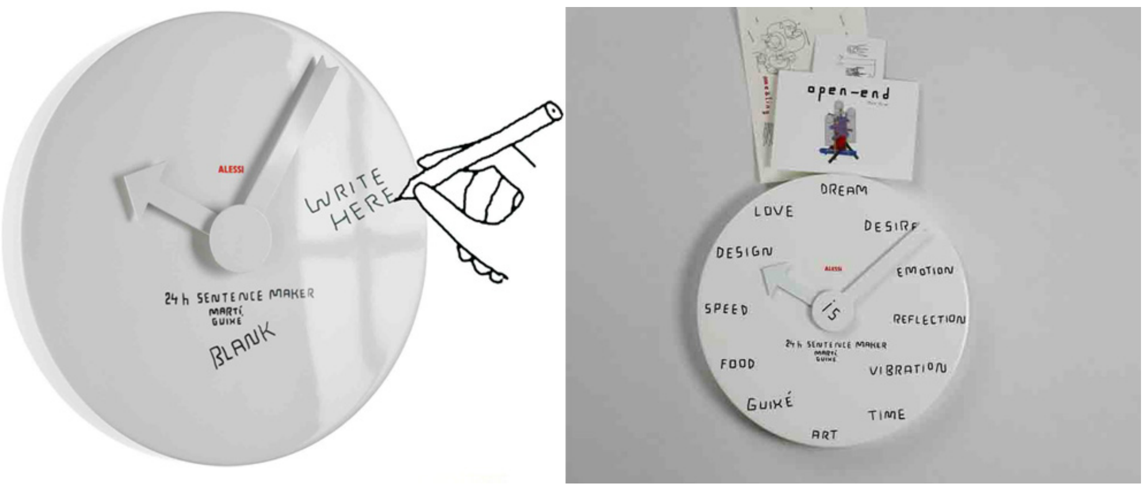



***Figure 13." Blank and Sentence Maker" by Martí Guixé (2010).***

Guixé designed another object based on a similar concept. A lighting object, titled *"do scratch"* designed in 2002, also suggests the user to add their original meaning to the object by scratching off the black coating on its surface (Figure 14). The lighting object itself is not completed until the moment when the user scratches the surface where the light comes through.

***Figure 14. "Do Scratch" by Martí Guixé (2002).***

In these Guixé's practices, "incompleteness" is used as an important design element for encouraging the user's active engagement with the objects for its completion. Guixé explained his design attitude that providing flexible medium as an object to the user is important in such a complex and contemporary product environment and this is achieved by reduction:

> *"Being really contemporary is very complicated. It is about the freedom to use things for reasons that are not representative. (...) Being contemporary is about being mobile, adaptable and customizable, so that you can adapt things to your own necessities and your own surroundings. If something has no fixed shape, it can adapt to any shape. It is about reducing–reduce matter, not complexity. Being schematic and impersonal is important, so no overdesign in finishing or in materials and uses, and the more impersonal it is, the more it fits globally" (Annink and Schwartz, 2003, p.105)*

The work of "Do Hit Chair" designed by a Dutch designer Marijn van der Pol (2000) demands even more radical engagement with the object (Figure 15). The user is provided with the hollow cube constructed of 1.25 mm stainless steel sheets along with a sledgehammer supplied (Droog, 2004). The user then sculpts the shape of the seat by hitting, smashing and pounding the metal surface. As with the Guixé's "Do Scratch," the object is not completed in itself unless the user finalises the form. In other words, the object demands the user to complete it by their intensive engagement.

***Figure 15. "Do Hit Chair" by Marijn van der Pol (2000).***

The utilisation of "information incompleteness" as an impetus for active engagement can be seen in the field of visual communication as well. A Japanese graphic designer Kenya Hara (2007) developed a series of advertisements for Muji, a Japanese retail brand, based on the similar perspective (Figure 16). Hara considered that visual communication could be a receptor rather than imposing a message on the receiver. Instead of presenting a lucid message on the advertising, offering an empty vessel, as a visual communication, to the audiences enables and facilitates them to deposit their individual ideas and wishes into it. Hara described this approach in the visual communication as "emptiness:"

> *"Communication is not dispatching information from one entity or person to another, but facilitating the mutual exchange of information. (…) communication happens when the recipient, offered not a message but an empty vessel, supplies the meaning himself" (Hara, 2007, p241).*


***Figure 16. "Advertising campaign of Muji" by Kenya Hara (2003).***

In the field of interaction design, lack of clarity of information can also be regarded as an opportunity for accepting the individual's personal engagement. Gaver et al. (2003) asserted that the state of information in which it does not represent its identity clearly, i.e. "ambiguity," is a useful factor for design. Gaver et al. described that in the context of traditional HCI (human computer interaction), which considers usefulness and usability as its goals, the concepts such as ambiguity are often regarded as a nemesis (Gaver et al., 2003, p.233). However, Gaver et al. argued that the factor of "ambiguity" can facilitate the user's close personal engagement with systems. They illustrated how it could be deployed in design, referring to his past projects. The work "Projected Realities" that Gaver developed with Anthony Dunne is a design project that aimed to help increase the presence of the older people within their local community, Bijlmer had an extremely poor reputation in the Netherlands. Gaver and Dunne challenged this, to change people's negative perception of the local community by *Projected Realities system, a network of electronic displays with which the elders would facilitate people in expressing their opinions and images of the Bijlmer* (Gaver and Dunne, 1999, p.600).

One of the outcomes of the project "Sloganbench," served as public furniture that contained electronically controlled fabric scrolls inset into its back, displayed hand-written provocative slogans written by older people from the area (Figure 17). Pedestrians were allowed to choose their own slogan to display among thirty, or, watch as slogans change automatically.


***Figure 17. "Sloganbench" by Gaver and Dunne (1999).***

Another outcome was called "Imagebank." Imagebank comprised five monitors set into a wood-veneer structure and displayed images collected by the older people to represent their lives (Figure 18). "Sloganbench" and "Imagebank" are wirelessly connected and the attitudes expressed by the slogans displayed on the Sloganbenches were summarised by the images showing on a single roadside Imagebank. Commuters and travellers were indirectly afforded new views into the area by the combination of words and images displayed on both of the objects.

***Figure 18. "Imagebank" by Gaver and Dunne (1999).***

Gaver et al. explains that the slogans and images were presented with little context to the viewer. The viewers, therefore, had to interpret the attitudes they reflected from the ambiguous representation regarding the area and they were attracted by this ambiguity to engage with the system (Gaver et al., 2003, p.234). Gaver concluded that *"ambiguity" is an important factor in crafting interactive designs that are engaging and thought-provoking*. Also, *"ambiguity of information" impels people to question for themselves the truth of a situation* (Gaver, 2003, p.240).

The examples in this section have included not only products but also a visual communication for branding or a system that intended to tackle a social issue. Such variety indicates how the relationship between incomplete information and the user's engagement can be deployed across different fields of design. Some designers consciously consider and incorporate the triggering nature of incomplete information into their design practices. Deliberately keeping information incomplete is inevitably keeping its nature open or undefined. Designs that evolve highly defined information do not allow much space for interpretations by the user. However, undefined designs *provoke unpredictable and thus per definition one-of-a-kind reactions* of the user (Droog, 2004, p.52). Thus, the factor of incompleteness in information could be exploited as supportive stimuli for encouraging the interaction between an artefact and the user in a variety of ways. This appears to suggest that this interaction is potentially a useful tool in stimulating the designer's imagination if incomplete information is presented to the designer in a certain format.

### 2.3.7 Conclusion of Incomplete Information and Designer

This section argued the characteristics and the significance of the preliminary phase of the product design process, where the designers explore ideas. At this phase, designers are required to quickly produce many ideas through exploratory means e.g. design sketching. Additionally, the productivity of conceptualisation at this phase largely dictates the entire design process. Since the nature of the early phase of the design process is ill-defined and wicked, designers inevitably have to cope with uncertainty or indeterminacy within the process of idea or solution seeking. In other words, addressing uncertainty of information is common place for designers in pursuit of creative solutions. Additionally, good designers are equipped with the ability to deal with this phenomenon. In such an environment, designers have the ability to utilise uncertainty, namely the incomplete character of information as a driving force for idea exploration. The information incompleteness stimulates their imagination, increases the possibility of ideas, enabling them to create more original designs or assists in reducing their psychological fixation. Additionally, some designers are aware of the triggering nature of incomplete information and actively incorporated it in their own design practices as a means to enhance the interaction between the person and an object. Thus, information incompleteness is a familiar and essential factor for the designer's imagination in many valuable ways.

## 2.4 — Conclusion of Chapter 2

This chapter featured a review of the literature from the fields of both cognitive psychology and design research in relation to the cognition of incomplete information. The review of studies in cognitive phycology illustrated the strategic approach of human cognition in order to address incompleteness of information. Our cognition finds meaning from incomplete information by identifying patterns and synthesising the fragments of information perceived: bottom-up strategy. This is also achieved by referencing our schematic knowledge structure, activating our long-term memory: top-down strategy. The process of identification of meaning is attained by the combination of these approaches. This cognitive process of identifying the meaning is highly influenced by the perceiver's personal context such as experiences, memories, expertise or even their socio-cultural background. This suggests that the process of identifying meaning within incomplete information inevitably compels the viewer's reflective reasoning within their personal context. This serves as an important base for the designer's imagination when they explore original ideas, concepts or solutions. Additionally, the researcher considers that the degree of both suggestiveness and ambiguity that incomplete information presents, affects the way the perceiver develops their own reasoning. Accordingly, in the context of design imagination, controlling the optimum balance between explicitness and obscurity of incomplete information is key in effectively inspiring the designer's personal imagination.

Design studies suggested that incompleteness of information plays an important role for designer's imagination particularly at the preliminary phase of the design process. Designers are equipped with the ability to deal with information incompleteness. They are often required to explore solution ideas, dealing with ill-defined problems where they make good use of uncertainty as an impetus for imagination rather than getting rid of it. The incomplete information presented to the designer provides more space for imagination and thus increases the number of interpretations of possible ideas, allowing them to encounter unexpected solutions, making designer's thinking more flexible and enhances their originality in the process of idea generation. Thus, information incompleteness has potential to perform as an enhancement tool for the designer’s imagination if it is deployed as stimuli and presented appropriately within the design process.

As well as theoretical studies, this chapter has also considered the examples that made good use of information incompleteness in the designers’ practices. Some designers were aware of the characteristic of incomplete information that can act as a trigger for active engagement with the user of an object. They utilised this communicative characteristic within their design practices as an impetus for active participation of the user with their work. This illustrates that the potential of information incompleteness can perform not only as a supportive element for the designer’s imagination within the design process but also as a communication strategy of the design practice.

It is legitimate to think that human cognition is familiar with developing imagination in addressing incomplete information and that this incompleteness can act as a useful tool to enhance the process of idea generation for designers. Many investigations have identified ways in which designers address information incompleteness within the process of idea exploration through observation. Or, others have reported that information incompleteness dictates designers’ reasoning when it is presented as external stimuli.

A matrix that shows the scope of Design Reductionism within the relevant literatures identified is presented (Figure 19). The two axes are used in this matrix:

A. Incompleteness in design practice (practical application of information incompleteness)—Design cognition and incompleteness (theorisation of information incompleteness)
B. Active utilisation of incompleteness—Passive reaction to incompleteness

The axis A shows how the literatures identified addressed the role of *“information incompleteness”* within the measurement of “theory” and “practice.” Studies that discussed the function of information incompleteness (e.g. Goldschmidt’s observation study of design representation 2003) are mapped near the bottom of the matrix. On the other hand, the studies that described how “information incompleteness” could be utilised as an important element within design practices (e.g. Gaver’s study of ambiguity) are placed near the top of the matrix.

The axis B shows the designer’s active utilisation and passive reaction to *“information incompleteness.”* The “design fixation” study was placed towards the right side of “passive reaction to incompleteness” since it addresses the designers’ cognitions in which they have a tendency to overly rely on the existing body of knowledge while seeking ideas.

There is little design research undertaken that focuses on the impact in which designers actively manoeuvre the incomplete character of information within their design imagination. The researcher considers this gap of knowledge as important for the investigation. If designers can actively manipulate the potential benefit of incomplete information by themselves, the researcher believes that it provides an opportunity to effectively enhance and expand their idea generation experiences. This research explores the value of information incompleteness for industrial designers, observing their reasoning and behaviour.

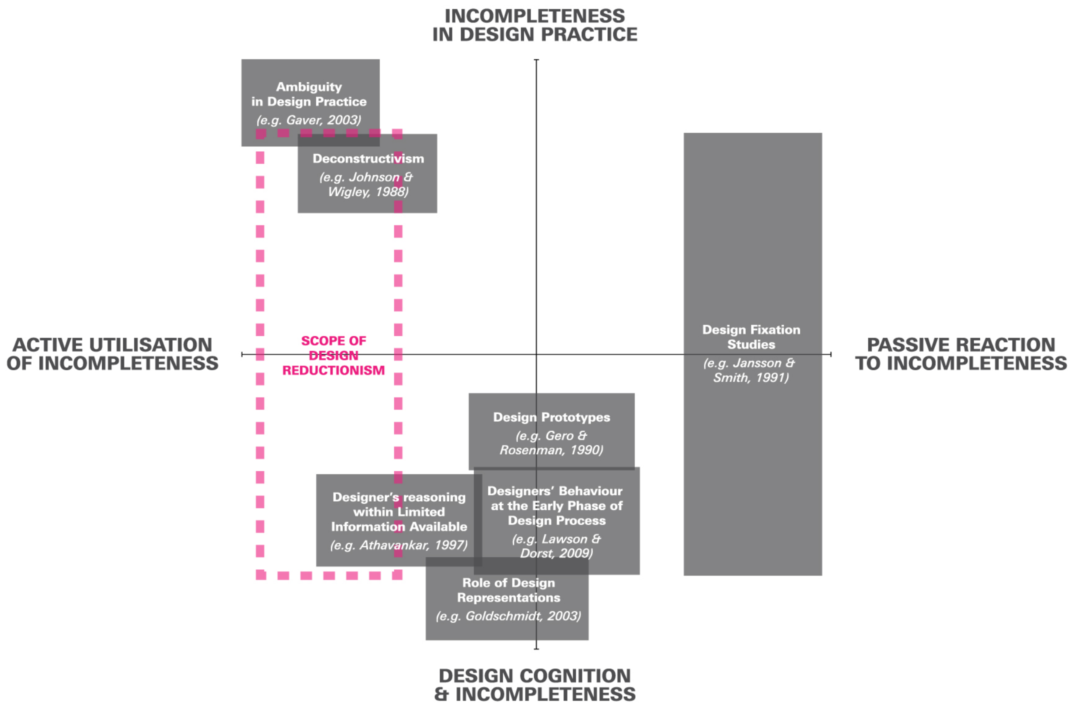



*Figure 19. Mapping of the scope of Design Reductionism.*

Chapter 3

# *m e t h o d o l o g y*

# 3.1 — INTRODUCTION

This chapter describes the method adopted for data collection and the following analysis of the preliminary and main studies. This research comprises a series of developmental studies and the breakdown of these components is as follows: four preliminary studies and a main study that includes two different participant groups (students and professionals).

Before going into the details of the methodology, it is important to set out the researcher's theoretical position as this forms the basis for the entire research study. The epistemological position adopted is of this constuctivism (Crouch & Pearce, 2012). The process of this research can be separated into two phases: understanding and exploring phases. At the early stage of this study, a series of experiments were carried out in order to understand the nature of design practitioners' habitus against reductive prompts. Accordingly, it was important to be open to interpretations towards the reality, and also to obtain insights without any biases – adopting a constructivist approach enabled this.

The ontological position taken by the researcher is constructionism. The approaches or attitudes of the actors involved in this study that are brought from reductive prompts such as interpretation or idea development involve personal factors. Hence, this study considers that the way to construct the reality which the actors recognise is derived from high participation of the actors themselves rather than from the influences of external factors. Further, this research assumes that it is possible to contribute to the development of the current design processes by investigating the data collected from experiments, interviews and case studies. Because of the reasons above, the position this research takes differs from the objectivism that regards social phenomena as independent or separate from actors (Bryman, 2012).

The methods and study environments varied throughout these studies. Therefore, the details of the research methods are respectively described in each section of the studies, laid out in the subsequent chapter. In this methodology chapter, the summary of processes and methods applied through these studies and the subjects that were commonly shared are fully described.

This research investigates the impact of "information incompleteness" on the industrial design practitioner's reasoning as well as exploring the potential values of the "incompleteness" derived from reduced information. This research, therefore, aims to observe and document the design practitioner's behaviours by providing a series of tailored tasks undertaken within a controlled environment, looking for answers to the following key questions:

- ***How do design practitioners behave when they confront reduced and incomplete information?***
- ***How is the process of creative reasoning of the design practitioners facilitated by information incompleteness?***

In order to answer these questions, the research process was incrementally developed utilising an action research methodology, that allows researchers *to have more control over how they work, and opens up possibilities for them to develop or consolidate their practice in ways that better reflect what is important to them* (Crouch and Pearce, 2012, p.143). Since the nature of the research is qualitative and exploratory, the researcher considered that developing the process of producing knowledge following the model of *"reflection-in-action"* (Schön, 1983) is the most suitable approach. As Scrivener (2000) describes the process of *reflection-in-action* is undertaken by a process of iterative reframing within the research practice. The discovery derived from this reframing model becomes the basis for the further reflection-in-action:

> *"(...) the practitioner finds that problem cannot be solved as it has been initially set, so the framing of the problem must be surfaced and criticised, and the problem reframed: a way of shaping the situation to a new frame must be found. The reframed problem becomes the basis for experimentation to discover what consequences and implications follow from it, (...) the situation talks back and the problem is reframed. New discoveries call for new reflection- in-action" (Scrivener, 2000, https://www.herts.ac.uk/__data/assets/pdf_file/0014/12281/WPIAAD_vol1_scrivener.pdf. Accessed 20 August 2014).*

The critical studies, therefore, were designed and conducted in sequence depending on the knowledge, insight and key questions derived from the reflections gained from each of the studies (Figure 20). The key questions and insights that were discovered utilising this process were reflections and actions generated from data derived from each of the previous studies. Following on from this, the next study was designed based on insights and reflections. This process continued up to the third preliminary study where critical insights were identified. After this third preliminary study, a prototype of a multi-faceted, reductive technique was tested out and evaluated using a professional practitioner as subject. The prototype of this reductive technique was then further refined, after review and critique. The revised version of this methodology was then used for the main research study. Thus, the entire research process was developed in an incremental, developmental and sequential manner.

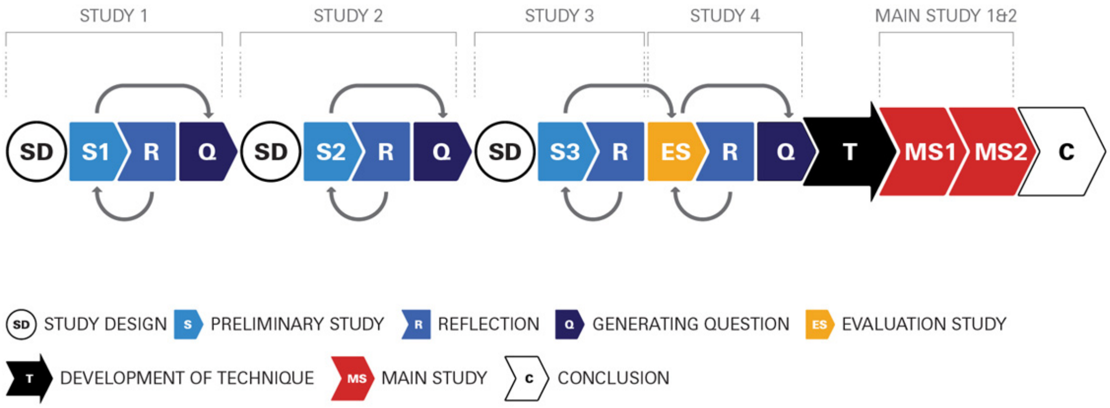



*Figure 20. The development process of the research.*

## 3.2 — Summary of Preliminary Studies

This section describes an overall summary of how the creative exercises conducted as a preliminary study have developed. The details of each of the studies will be thoroughly described in chapter four. The summary of preliminary studies illustrates how the process of investigation has been developed followed by a brief description of data collection and analysis for each of the studies.

The exercises carried out for each of the studies were tailored by the researcher. The studies were prepared as individual tasks and carried out within a controlled environment. The contents of the exercises were designed based on the discoveries and questions raised from each of the previous studies. Accordingly, the process of investigation has been based on a series of incremental developments.

### 3.2.1 First Preliminary Study

The research setting of the preliminary study was prepared based on the sub-research question: *what kind of visual cues do designers rely on for "representation completeness" when they* *imagine an object based on the reduced and incomplete image of the object?* The first approach to the research topic was developed in the following way, the researcher observed the reasoning process where the design students imagined a complete image of an artefact based on the incomplete representations of the same object provided as visual stimuli. The aim of the study was to identify the elements that the design participants consider as important when they address incomplete information of an object. A new product, in the form of a simple armchair, was designed by the researcher and seventeen different types of "incomplete visual representations" of the same chair were produced. Each of the visual prompts was respectively given to a participant and they were asked to visualise their imagined object by sketching and model making using drawing sheets and model making materials provided.

After the completion of the drawing and model making exercises, the participants were interviewed in front of the outcomes they produced. The contents of the interviews were then analysed, following Grounded Theory approach (Glaser and Strauss, 1967). The analysis revealed the characteristics of the participants' reasoning process when they were given reductive visual representations of an object. The following second study was then prepared based on the findings.

### 3.2.2 Second Preliminary Study

The second preliminary study was conducted working with both design and non-design students of Northumbria University. A set of scaled-down tangible components of an existing object was used in the study. In the previous study, the researcher identified some patterns of behaviour that the design students had a tendency to focus on with particular attributes of the object. Additionally, the results also suggested that the expertise of the participants highly dictated their reasoning processes. Accordingly, the aims of the second study were:

1. observing the design practitioner's reasoning when the elements, that were identified in the previous study, were further reduced, and;
2. understanding the impact of prior knowledge upon their imagination, comparing two participant groups that have different backgrounds.

In this study, a famous designer's chair designed in 1918 was chosen and used as a prompt for the task. This chair consists of simple geometric components painted in iconic colour code. The scaled-down components of the chair were first dismantled. Then, three different types of colour patterns of the set of dismantled components were prepared:

1. one set of chair components were prepared in the same colours as the original chair,
2. one set was painted in white, and;
3. the final set was left in their natural material colour.

These three sets of scaled-down and dismantled components were given to three groups respectively. The participants of each group were then asked to visualise the original object and represent it by constructing the components. The same task was given to both the design and non-design participants. The results revealed that particular types of reduced information impacted on the design participants' reasoning. From these studies, the researcher then developed the concept of the participants using the reductive process as a stimulus for their own imagination and ideas development.

### 3.2.3 Third Preliminary Study

The third preliminary study was prepared based upon the insights gained from the previous studies. The researcher confirmed the impact of the reduced information presented as external stimuli on the design practitioner's reasoning process. The results suggested that reduced information diversified reasoning processes of the design participants in conceiving ideas. Reduced information appears to be beneficial to design practitioner's imagination when it is provided externally. This fact encouraged the researcher to consider the approach in which the designers autonomously reduce information as a means of gaining inspiration. The sub-research question, therefore, was: *how does the act of autonomous reduction impact upon the idea generation of the design practitioners who have various backgrounds?*

Following this sub-research question, the researcher developed a set of reductionist work sheets where the designer is invited to explore new design concepts within the process of gradually reducing elements of the original object shown on the sheet. The work sheets consist of two separate sheets called *"Process Sheet"* and *"Idea Sheet." Process Sheet* invites the participant to gradually reduce the elements of the original object, following the levels from 10 to 1 indicated on its front side. *Idea Sheet* offers the participant the opportunity to finalise one of the ideas developed in the *Process Sheet* as the final conclusion of the exercise. A space for writing down how they developed their ideas and describing what the outcomes were, including why they selected the particular idea for the final conclusion were provided on both sheets.

The study was undertaken in Geneva, Switzerland with a group of design masters' level students of both HEAD (Geneva School of Art and Design) and ECAL (École Cantonale D'Art de Lausanne) as the participants. The researcher was given the opportunity to run a workshop with these master students, who had a variety of design-related backgrounds. Within the study, three levels of visual fidelity of the same original prompt (i.e. an archetypical wheelbarrow) were prepared:

1) *the photographic image,*
2) *the same wheelbarrow represented with line drawings, and;*
3) *the wheelbarrow represented with dotted lines.*

The participants were randomly divided into three groups, with each group given one of the prompt images. The contents of both sheets collected were then treated as a primary data source for the analysis. The results revealed that the process of reduction and the types of ideas conceived within this reductionist technique were dictated by the fidelity levels of the visual prompts provided during the session.

### 3.2.4 Fourth Preliminary Study

The fourth preliminary study was conducted as a short evaluation of the *reductionist technique* developed in the third study, using a professional practitioner. The aim of this study was to gain a critical review of the proposed technique from a professional practitioner perspective. The study was conducted using the same worksheets, creating the same working conditions as those applied in the previous study. After the completion of the exercise, the professional participant was interviewed and asked to describe how they developed their ideas and to review the process itself. From this, the researcher gained critical insights from the professional participant and these insights were subsequently applied in a revision of the technique. The revised reductionist technique used for the main study has been developed based on the findings from the professional participant's review.

# 3.3 — Data Collection of Preliminary Studies

In an attempt to understand the relationship between the incomplete state of information and the designer's reasoning, a series of *semi-structured observation* studies was undertaken. These observations were carried out by providing creative exercises along with study prompts that acted as stimuli. Within the process of observation, the researcher applied the approach of *laboratory-style studies* (Koskinen et al., 2011), where the participants are invited to take part in an experimental task within a controlled environment, to maintain the focus of the research. The studies needed to be conducted without the risk of external influences impacting on the process of observation in order to allow the researcher to focus purely on the relationship between designer's reasoning and reduced and incomplete information. Koskinen et al. (2011) describes that the approach of *laboratory-style studies* helps the researchers in seeking cause-and-effect explanations regarding "relationships" of things:

> *"The trouble with studying a phenomenon in the real world is that usually many things shape it. This makes it difficult to find what causes something one sees; there are typically several possible explanations, and it is impossible to rule any of them out with a high degree of certainty. (...) Studying a phenomenon in a laboratory helps with this problem. The laboratory gives the researchers an opportunity to focus on one thing at a time. Most typically, this "thing" is a relationship (...). The laboratory also helps researchers study alternative explanations and competing hypothesis; doing this is far more difficult in natural settings" (Koskinen et al., 2011, p. 55).*

Conducting observation studies within a controlled environment was considered critical for designing the contents of the exercises as well as planning the processes and methods used for data collection.

This, *semi-structured observation* approach allowed the researcher to comprehensively understand the subject without rigid planning (Morra and Rist, 2009). Meanwhile, the *semi-structured observation* needs to be carried out by attentive observations and systematic recording of people, artefacts, environments, events, behaviours and interactions, using a multiple recording media e.g. *notes, sketches, photographs or raw video footage*, in order for capturing detailed information effectively (Martin and Hanington, 2012). Therefore, the studies were documented using a voice recording device, video cameras, photos and notes taken by the researcher, whilst sketches and tangible models were produced by the participants during the exercises.

As well as the documentation of the study undertaken during the exercises, *semi-structured interviews* were chosen as the main method for data collection within each of the studies except for the third study. *Semi-structured interview* enables the researcher to explore a wide range of issues that may arise during the interview session with a certain degree of flexibility by means of pre-determined but open ended questions (Flin and O'Connor, 2017). Additionally, within the process of *semi-structured interview*, the researcher is allowed to modify the order of the questions, change the way they are worded, give explanations or leave out particular questions which seem inappropriate with a particular interviewee, depending on what seems most appropriate in the context of the conversation (Robson, 2002). Since the reasoning processes of each participant, within the study, were highly complex and idiosyncratic, the flexible nature of *semi-structured interview* assisted the researcher in understanding and exploring how ideas were developed during the creative exercises. All the contents of the interviews were transcribed and the transcriptions were used in the subsequent analysis.

The data used for analysis was collected from multiple sources. Although the primary data source was the contents of *semi-structured interview*, other types of data, such as sketches, models and notes produced during the task were also used as supportive data. Accordingly, the preliminary studies adopted a *data triangulation* method (Martin and Hanington, 2012) that allows researchers to gather information by combining multiple sources for data collection. Martin and Hanington (2012) describes that triangulation method allows researchers to ensure the accuracy of information collected:

> *"The primary reason for triangulation is to ensure accuracy of information by combining sources and mitigating the weaknesses of any single method or source. When collected using various means, data can be compared to confirm whether the same results are being obtained, regardless of method" (Martin and Hanington, 2012, p.188).*

The *semi-structured interview* primarily seeks the account of the process in which the participants developed towards the outcomes. Therefore, combining the contents of the interviews and other visual representations, e.g. sketches produced by the participants, enables the researcher to accurately investigate the process in which the participants developed ideas from one end to the other.

Thus, the data collection from the preliminary studies was conducted through a series of observation studies consisting of multiple tasks. Additionally, the data was gathered through the combination of multiple sources.

## 3.4 — Analysis of Preliminary Studies

This section describes the method applied in the analysis of the preliminary studies. As aforementioned, the primary data source for the studies, except for the third study, was from the contents of the *semi-structured interview*. The contents recorded by the recording devices were transcribed and treated as raw data. The method in which the transcriptions were analysed varied depending on each study.

### 3.4.1 Analytical Approach to First Study

In the first preliminary study, Grounded Theory approach (Glaser and Strauss, 1967) was used for the analysis of the transcription. Grounded Theory approach is the method that enables researchers to generate a theory to discover and explain the central issue addressed within the data collected (Robson, 2002). Generally, the process includes the following stages of categorisation:

1. find conceptual categories in the data;
2. find relationships between these categories;
3. conceptualise and account for these relationships through finding core categories.

According to Strauss and Corbin (1998), these three stages are achieved through the following coding processes:

- open coding *to find the categories;*
- axial coding *to interconnect them;*
- selective coding *to establish the core category or categories.*

The contents of the transcriptions were thoroughly read and initial categories were developed, segmenting words, sentences, phrases or paragraphs, within the process of *open coding*. The purpose of this process was to understand *fine discrimination and differentiation among categories* by *closely examining data for both differences and similarities* (Strauss and Corbin, 1998, p.102). This process was repeated until the point where the data that can be categorised becomes saturated. After the completion of the *open coding* process, the categories that emerged within the *open coding* were further sub-categorised through the *axial coding* process. The purpose of axial coding was to *reassemble data that was fractured during open coding* and to seek *more precise and complete explanations about the phenomena* (Strauss and Corbin, 1998, p.124). In the coding model of Strauss and Corbin (1998), the coding process on *Grounded Theory approach* is completed by conducting the further *selective coding* process. The subcategories, emerged through cross-linking among the multiple categories identified in *axial coding*, are further reduced to a single essential aspect in order to reveal the core category that represents the main theme within the process of *selective coding*. *Selective coding*, however, was not conducted within the first preliminary study. The information structure identified within *axial coding* appeared to suggest an important key insight within the study and, therefore, the researcher decided not to continue *selective coding*.

Within the coding process, the visualised outcomes produced by the participants (i.e. sketches and models) were also used as a supportive element for the analysis. The descriptions of the object envisaged or the reasoning process stated by the participants were often abstract and unclear. Therefore, these visualised representations allowed the researcher to fully understand exactly what the description exactly meant.

### 3.4.2 Analytical Approach to Second Study

In the second preliminary study, the contents of the interview were analysed through a *general inductive approach* that allows *research findings to emerge from the frequent, dominant, or significant themes inherent in raw data, without the restraints imposed by structured methodologies* (Thomas, 2006, p. 238). The aim of the analysis in the second study was to seek for generic characteristics of the design participants' reasoning under the condition where they were provided with a prompt where particular elements of information were reduced. Although the findings are inevitably influenced by the research question within the study, the process of analysis needed to be conducted without unnecessary biases, such as priori expectations or models (Thomas, 2006, p. 239). Accordingly, *a general inductive approach* was considered the most suitable method for analysis to be undertaken.

The process of coding was carried out following the Thomas's analytic procedure:

1. Close reading of the texts derived from the transcription of the interview: the raw text was read in detail until the researcher is familiar with its content and gains an understanding.
2. Creation of categories: the researcher identified and defined categories or themes.
3. Overlapping coding and uncoding text: coding multiple categories within one segment of text or dismissing irrelevant quotations to the evaluation objectives.
4. Continuing revision and refinement of category system.

The characteristics of the reasoning process of the design participants, such as *"types of thinking approach," "reference objects"* or *"assumed materials"* during the process of model making were identified through the analytic procedure. Within the process, the researcher first developed coding themes working from the contents of the first interviews of the *design participants*. Following this, the coding themes that emerged within the transcription of the *design participants* were then used in the analysis of the *non-designers* as a comparison. As part of the first preliminary study, the visualised outcomes produced by the participants (i.e. sketches and models) were also used as a supportive element within the analysis.

### 3.4.3 Analytical Approach to Third Study

The third preliminary study did not employ interviews, due to its large sample size. Instead, the analysis was carried out based on the contents of a set of work sheets, developed by the researcher, provided during the creative session: *Process Sheet* and *Idea Sheet*. These work sheets were used as a means of collecting data in which the participants challenge the *reductionist method* proposed.

The contents written down on both the work sheets *Process Sheet* and *Idea Sheet* were digitally transcribed and used for the analysis, by partly showing the attributes of the object envisaged in the tables. Additionally, the images of the *reductionist process* depicted in the *Process Sheet* and the drawings of the final idea presented on the *Idea Sheet* were laid out and arranged on a large desk, depending on the fidelity groups, in order to compare the contents. The images of the final ideas depicted by the participants were then arranged in an analytical matrix, developed by the researcher. The characteristics of each fidelity-level, such as type, or attributes of the objects, were revealed through the analytical matrix. Also, this analysis allowed the researcher to identify the limitations of the *reductionist technique* proposed.

### 3.4.4 Analytical Approach to Fourth Study

The analysis of the fourth preliminary study was conducted, focusing on the contents of both the work sheets and the interviews. The transcribed contents of the interviews were analysed, using video recording. This recorded the reductionist process and was used as a supportive element within the analysis. The researcher could identify problems in the *reductionist technique* trialled, through the critical review of the participant. The insights gained from the critical review of the participant were further used to improve the *reductionist technique*.

## 3.5 — Summary of Methodology of Preliminary Studies

The researcher explored the relationship between reduced and incomplete information and the design participants' reasoning, through a series of preliminary studies. These studies allowed the researcher to observe how information incompleteness provided as external stimuli affected the design practitioners' reasoning. The results suggested that the design practitioners were capable of envisaging ideas derived from incomplete information around an object. Also, this reduced information appeared to impact on their reasoning. Additionally, the insights derived from the preliminary studies allowed the researcher to generate a hypothesis;

> ***"The process of reducing information by the designers themselves stimulates their design imagination."***

This hypothesis encouraged the researcher to propose the idea of *reductionist technique* and the refined version of this method was then used for the main study.

# 3.6 — DATA COLLECTION AND ANALYSIS OF MAIN STUDIES

The preliminary studies aforementioned illustrated the designer's capability of addressing reduced and incomplete information for their imagination. The results of the studies provided the researcher with an insight that the *act of reducing meanings by the designer themselves could potentially be a useful tool to stimulate their design reasoning*. In other words, the information incompleteness derived from abstraction of the elements of an existing object used by the designers themselves potentially assists their creative reasoning. The reductive process might play a role as an impetus for the designer's creative imagination if they purposefully confound their recognition of an object by reducing information. In order to investigate the potential of this self-reductive approach (the researcher calls this is the *autonomous reduction*), the main study was prepared and conducted.

The means by which the data was collected in the main study was by using the improved version of this proposed technique, *autonomous reduction*. The design of this reductionist technique was revised based on the critical review undertaken by the professional practitioner in the fourth preliminary study.

The main study composed of two different groups: design students and professional designers. The first main study was carried out working with the participant group of design students. The researcher investigated how the technique of autonomous reduction dictates the design students' design reasoning. Following this, the technique was trialled and evaluated by a group of experienced professional designers.

As with the preliminary studies, the details of the methodology adopted within the main study were thoroughly described in the subsequent study chapter (see chapter 4, section 4.7.2 and 4.8.3). Accordingly, the following sections in this chapter describe the outline of the methodology used to gather, display and analyse the data.

### 3.6.1 Summary of Main Studies

The main study comprised of two sessions, each session had a different participant group. This section describes the overall summary of each study.

#### 3.6.1.1 Summary of the First Study

The first study was conducted, aiming to understand how the design participants develop their reasoning under the constraints in which they are asked to reduce the elements of an existing object and to explore new design ideas simultaneously. Additionally, the study was conducted as individual tasks so that the researcher could focus on the details of the process with each participant. The researcher, therefore, exhaustively investigated the process in which the participants reduced the elements of an existing object i.e. a classical French Rococo clock.

In this study, two different fidelity levels of the same Rococo clock were prepared as a visual prompt. The first image was the clock represented with a photographic image of the bracket clock, without background, printed in full colour. This represents the high-fidelity prompt conveying richer attributes. The other image uses the same bracket clock, but depicted as a visual of black dotted lines. This became the low-fidelity prompt representing limited information. One of these visual prompts was provided to the two separate groups (Figure 21). By comparing these two fidelity levels, the researcher investigated how information richness of the artefact presented influenced and affected the design participants' design reasoning.

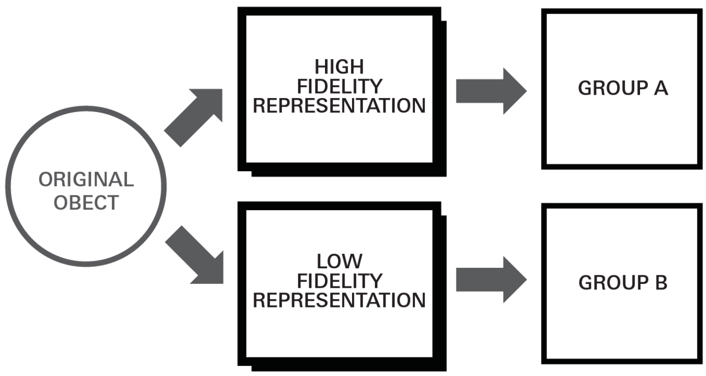



*Figure 21. High-fidelity and low-fidelity representation of an existing object given.*

The revised version of the work sheets, namely *Process Sheet* and *Idea Sheet*, were provided to each individual participant. The image of the original artefact as a visual prompt was printed on each *Process Sheet,* where the participant explored ideas, reducing the elements of the image. Also, the two different fidelity levels of the original image were printed on *Process Sheet* given to the two groups. The participants were then asked to select one of the ideas developed within the *Process Sheet*, and to further develop this idea as a final design proposal on the *Idea Sheet*.

The participants were asked to think aloud throughout the work process and the subsequent commentary was recorded. After the completion of the exercise, the participants were interviewed by the researcher.

#### 3.6.1.2 Summary of the Second Study

The second study was conducted using exactly the same technique of *autonomous reduction* with the professional designers. The aim of the study was to understand how professional industrial designers engage with this process of *autonomous reduction* and how they might evaluate the technique proposed. Additionally, it also aimed at understanding how the technique potentially contributes to the context of professional design practice.

Although the task used during the session with the professional participants was as far as possible the same as the one adopted within the first main study, there were some different conditions applied in this study. The professional participants were informed about the research through a short introductory presentation before the commencement of the task. This meant that the participants undertook the task with some understanding of the aims of the research. This was considered important as it enabled the participants to take part in the task with a critical view of the process during the session. Additionally, only the high-fidelity image (photographic) was used due to the smaller number of participants available. Furthermore, the *Idea Sheet* was not provided to the professional participants due to time limitation the participants were prepared to give to the study. The aim of the study with the professional participants was to observe and understand the process in which they address the reductive process rather than trying to develop any design solutions. The method applied in this study was modified in accordance with the study environment and the aim of the investigation.

As with the first main study, the professional participants were also required to think aloud throughout the process followed by the post-production interview.

### 3.6.2 Purposive Sampling

The purpose of the main study was to observe the impact of *autonomous reduction* on the designer's reasoning and also to understand the values and limitations of this technique, within the context of professional design practice. The sampling was conducted with this purpose in mind. The following sub-sections describe the sampling criteria for the first and the second main study.

#### 3.6.2.1 Student Participants

The first main study considered how the act of *autonomous reduction* dictates the design practitioner's reasoning. The study thoroughly observed the participants' reductive processes, aiming at understanding how they interpret the concept of *"reduction,"* explore design concepts and develop the final idea. The study, therefore, necessitated a group of participants who have a high level of design skills in conceptualising ideas and developing a product. Meanwhile, the nature of intensive observation of this study inevitably required the volunteer participants to engage with the session for up to three hours. The researcher conducted this study with a group of the mature industrial design students at Northumbria University.

For this study, eight participants, of senior students were involved. Within the selection process of the participants, the researcher asked senior staff members to nominate students that they considered were equipped with high design skills in the participation of this exercise. All the participants were final year industrial design students near to completion of their major study and conducted just before their graduation. Accordingly, they can be regarded as matured industrial design students who have an advanced level of design expertise and are equipped with the skills for designing products.

#### 3.6.2.2 Professional Participants

The aim of the second main study was to understand the way in which professional industrial designers develop their reductive process and identify values and limitations in using the technique of *autonomous reduction* through their critical evaluation.

Four world-renowned Industrial Design businesses were selected, both in England and the Netherlands, in accordance with the following sampling criteria:

- *The company allowed the research evaluation to take place within their normal work environment.*
- *The company was in a position to offer several volunteer participants for the study.*
- *The company has been established for more than 10 years.*
- *The company has at least one design director able to participate in the study.*

For the purpose of the study the researcher requested that the selection of the participants within each organisation was made by the design director(s). Although the researcher conducted this study with a total of nine professional designers, for data collection, the four participants who hold the design director position within the company were selected from these nine case studies. The remaining data is recorded and will form the basis of further post-doctoral research.

### 3.6.3 Method for Data Collection

This section describes the summary of the method used for gathering data. Although different conditions were applied in between the first and the second studies, they shared some approaches in common.

#### 3.6.3.1 Work Sheets

As aforementioned, the data was collected through the two different work sheets prepared: *Process Sheet* and *Idea Sheet*. In the first study, both sheets were used as a means of collecting data during the exercise. Additionally, all the reductive processes were recorded with video cameras set next to the participants.

The role of *Process Sheet* was to capture the reductive process developed by the participant. The sequence of sketches connected with arrows visually describes how the reductive process developed and how each of the thinking avenues related. On the other hand, the role of *Idea Sheet* was to capture the final idea as a conclusion of the exercise. The drawing that represented the participant's final design proposal conveyed the attributes of the product. The participants were allowed to use these sheets with their own interpretations. These sheets were completed through sketching and, with annotations jotted down by the participants. In the second study, only *Process Sheet* was given to the professional participants.

### 3.6.3.2 Think Aloud Method

The participants were asked to think aloud whilst they engaged with the *Process Sheet*. The method of *think aloud* allowed the researcher to *identify the information concentrated on during problem solving and how that information was used to facilitate in the problem solution* (Fonteyn et al., 1993, p.430). Fonteyn et al. (1993) also stated that the investigator can *make inferences about the reasoning processes that were used during the problem-solving task think aloud* based on the information derived from the verbal report. There are two types of verbal report: concurrent and retrospective (Elicsson and Simon, 1980). *Concurrent* verbal reporting results from the researcher's instruction given to the participants to "think aloud" during the reductive process. This provides *direct verbalization of cognitive process and thus is believed to be consistent and complete* (Fonteyn et al., 1993, p.431). *Retrospective* verbal reporting results from the researcher's asking the participant to recall what they were thinking at an earlier point in time. This *requires retrieval of information from past learning experiences thus might provide inconsistent or incomplete information about one's thinking during a specific problem-solving task* (Fonteyn et al., 1993, p.431). Although the accuracy and consistency of *retrospective* verbal reports have been questioned (Fonteyn et al., 1993; Simon and Elicsson, 1980; Elicsson and Simon, 1993), both of these types of verbal report were accepted during the data collection. The reason for this is that this research considerers the use of memory during the participants' design reasoning as very important. The creative exercise within this study naturally demanded the participants seek a variety of memory sources for imagination. Additionally, as Elicsson and Simon (1993) argued, even if a retrospective report is given by the participant immediately after the task is completed, the verbal data can be considered to be valid, as much information is still in their short-term memory and can be directly used as a retrieval cue. Therefore, providing the participants with a freedom of choice in expressing their thoughts was significant in this study.

Verbal data recorded through the think aloud method was transcribed and used as a primary data source for subsequent *Protocol Analysis*. This will be described in the subsequent section.

### 3.6.3.3 Semi-structured Interview

The participants were also interviewed after the completion of the exercise. The focus of the semi-structured interviews was different for the first and the second studies. In the first study, the interview focused on the attributes of the product designed by the participants and also on the aspects of their thinking processes. The commentary derived from the interview allowed the researcher to better understand the following:

- *The details of the object conceived.*
- *The elements that the participants considered as important during their reductionist process.*
- *The overall experiences itself.*

On the other hand, the focus of the interview in the second study was primarily on:

- *The reasoning process during the reductionist process.*
- *The potential value and the applicability of the proposed reductive technique to their own design practices.*

The transcribed commentaries were used as supplemental data within the analysis.

## 3.6.4 Method for Data Analysis

This section describes the method used for data analysis. The primary data source for the analysis were the following four media:

- *Visual data represented on the sheets.*
- *Transcription of verbal data derived from think aloud method.*
- *Transcription of semi-structured interview.*
- *Video that captured the development of the participant's reductive process.*

Based on these data sets, the researcher thoroughly investigated the reductive process, the object designed and the impact of the proposed technique on the participant's design reasoning.

### 3.6.4.1 Analysis of Visual Data

The visual data produced during the exercise was used for the analysis. The reductionist process of each participant was represented in drawing on the *Process Sheet*. The developmental process of every thinking avenue was shown using arrows and this visual sequencing allowed the researcher to understand and interpret how the process progressed. Additionally, the drawing of the participant's final design represented on the *Idea Sheet* allowed the researcher to understand the object, its materiality and attributes. Further, the images of the final design were also accurately reproduced with CAD software by the researcher with the consent of the participants. The purpose of this reproduction was to allow the researcher to fully understand the objects and also to be able to compare all the design results with the same visual qualities.

### 3.6.4.2 Protocol Analysis—Verbal Analysis

The transcribed verbal protocols derived from *think aloud method* became one of the primary data sources within the analysis. The other data sources, video, drawings produced by the participants and notes taken by the researcher were used to validate the analysis in order to comprehensively understand their reductionist processes and its chronology.

Protocol analysis (Ericsson and Simon, 1993) relies on the verbal accounts given by the subjects on their own cognitive activities (Cross et al., 1996) and allows investigators to understand how they build the relationship with the artefact, revealing the meaning of their actions (Krippendorff, 2006). This analytical method that seeks to expose human's cognitive behaviours has been widely adopted in the field of design cognition studies, such as *Delft Design Protocols Workshop of 1994* (Cross et al., 1996), and has become *the most likely method to bring out into the open the mysterious cognitive abilities of designers* (Cross, 2006, p.77).

In this study, the analysis was conducted following *verbal analysis method* proposed by Chi (1997). *Verbal analysis method* is a sort of protocol analysis. In fact, Chi describes that *verbal analysis* method shares many characteristics with *protocol analysis* such as the coding processes and the amount of context to use. The difference, however, between *verbal analysis method* and *protocol analysis*, that this study considers as important, is that the focus of *verbal analysis method* is primarily on the *representation of the knowledge* that the person engaging with the task has, rather than merely on the process of their decision making and problem solving (Chi, 1997, p.277). Protocol analysis, in the Ericsson and Simon's view, addresses defined problems that have an ideal template model for solution such as a task of mathematical game, e.g. the simple task of *Tower of Hanoi* (Ericsson and Simon, 1993). The analysis was conducted comparing the path that a solver took and the sequence of states that a simulation model generates in order to identify the difference (Chi, 1997). *Verbal analysis model*, in contrast, seeks the model that the solver has in their mind without creating an ideal a priori (Chi, 1997, p.277). This allows investigators to uncover what the subject is actually thinking and doing rather than to test the model. Additionally, *verbal analysis model* considers the verbalisation of explanations, descriptions, justifications and rationalisations of what the subjects are doing whereas protocol analysis deems these as negative factors that affect the subject's performance. This analytical framework was particularly important to the researcher because the task of the exercise used in the study was initially a far more ill-defined, abstract and explorative process, than a defined problem space. The participants' reductionist processes did not have goals, aims or ideal models for solution. These objectives spontaneously emerged or were discovered within the process. Thus, allowing the participants to have opportunities to describe their knowledge representations, explanations or even irrelevant stories as significant in addressing the range of information. This was a key to analysis of their design reasoning. Following this critique, the researcher considered that the *verbal analysis model* as the most appropriate method for analysis.

The transcribed verbal protocol data were analysed following the steps:

1. *Reducing or sampling the protocols.*
2. *Developing a coding scheme.*
3. *Operationalising evidence for coding.*
4. *Seeking patterns.*
5. *Interpreting the patterns.*

First, the transcription data derived from verbal protocols were thoroughly read and the sentences that represent the participant's particular actions were sampled. Second, the segmented data was then coded. Third, the researcher decided key elements in the verbal data that constitute evidence belonging to a specific category. Fourth, patterns were identified, seeking patterns of inter-linkages amongst the coded data. Fifth, the patterns identified were interpreted. These patterns represented the characteristics of the participants during their reductionist process.

#### 3.6.4.3 Data Visualisation—Mapping System

The data derived from the verbal protocol during the reductive/ideation process was visualised. The researcher developed a mapping system that thoroughly illustrates and time codes the processes of each participant from the start to the moment when the participant made the decision for a final design proposal. This visualisation allowed the researcher to untangle the complexity of the data and visually identify the characteristic of the reductive process for each of the participants (Figure 22).

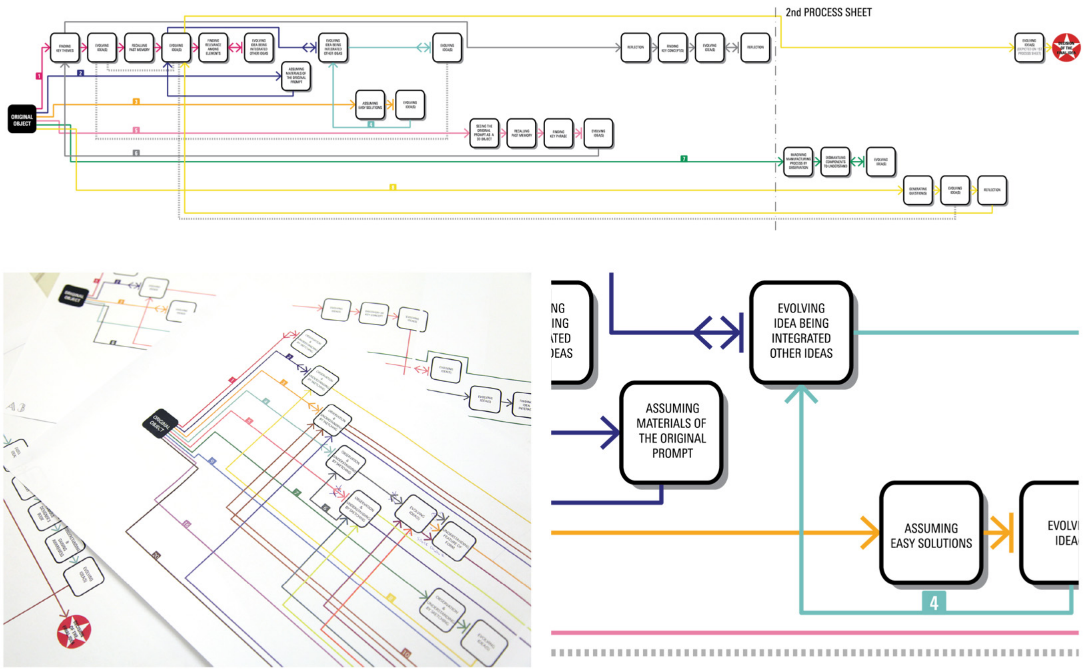



*Figure 22. An example of process mapping.*

In this mapping system, the development process was shown by the use of lines with arrowheads, tracing and time coding the participants' behaviours and decision making as they carried out their reductive/ideation process on the *Process Sheet* (Figure 23).

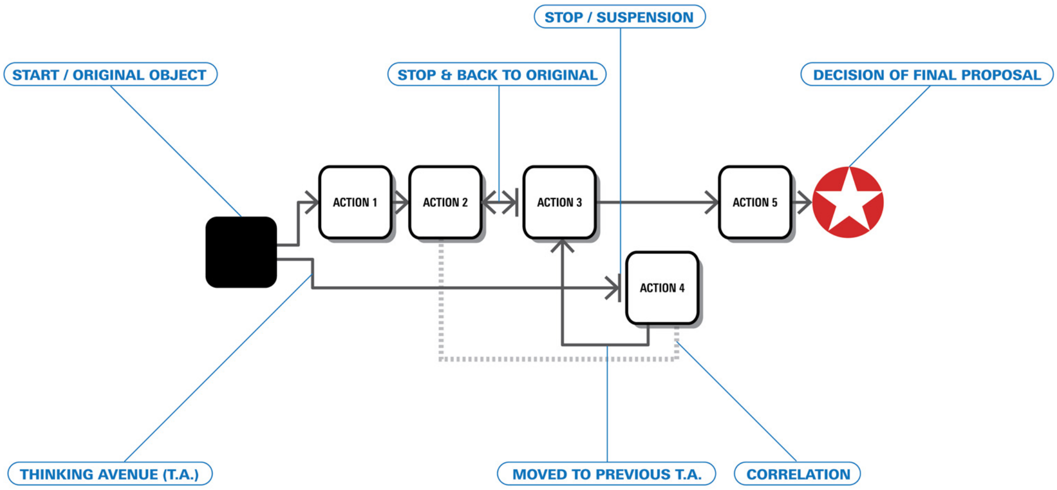



*Figure 23. The explanation of the process mapping.*

The black square represents the starting point of the original prompt, and the red circle with a star signifies the moment when the participant makes a decision for a final design proposal. The white squares represent the actions identified through protocol analysis. The direction of the arrows moves from the left (start) to the right (goal) and each line represents an independent sequence of thinking avenue. The process is aligned in chronological order. The first action always originated from the original prompt. Then, the arrow whose direction is facing towards left represents the action in which the participant returns back to the original prompt and starts a new thinking avenue from it. The lines that end with a vertical bar represent thinking avenues that were stopped or suspended. The dotted line signifies the indirect correlation among multiple actions. For example, when the participant conceived a new idea, they sometimes referred to a previous idea that had been developed within a different thinking avenue. In this case, these ideas are displayed as two separate thinking avenues. The dotted line connects these two and represents the correlation between them.

Further, another display style of the mapping was developed based on the one described above. Although the composition of visual elements was arranged in the same way as the previous mapping, the position of actions is arranged in accordance with the time the action occurred. The process is aligned in chronological order and the time is indicated underneath the mapping.

The contents of the actions identified were further categorised and represented with multiple colours (Figure 24). Similar actions that can be categorised into a group, such as "observation" or "idea generation," repeatedly occurred within the results of the participant. Additionally, these actions were commonly observed amongst the multiple participants analysed. Thus, similar actions were grouped and represented with colours. This allowed the researcher to easily identify the characteristic of each participant and the visualised mappings were analysed by close comparison. The results visually illustrated key types of actions as they occurred at particular phases of the process.

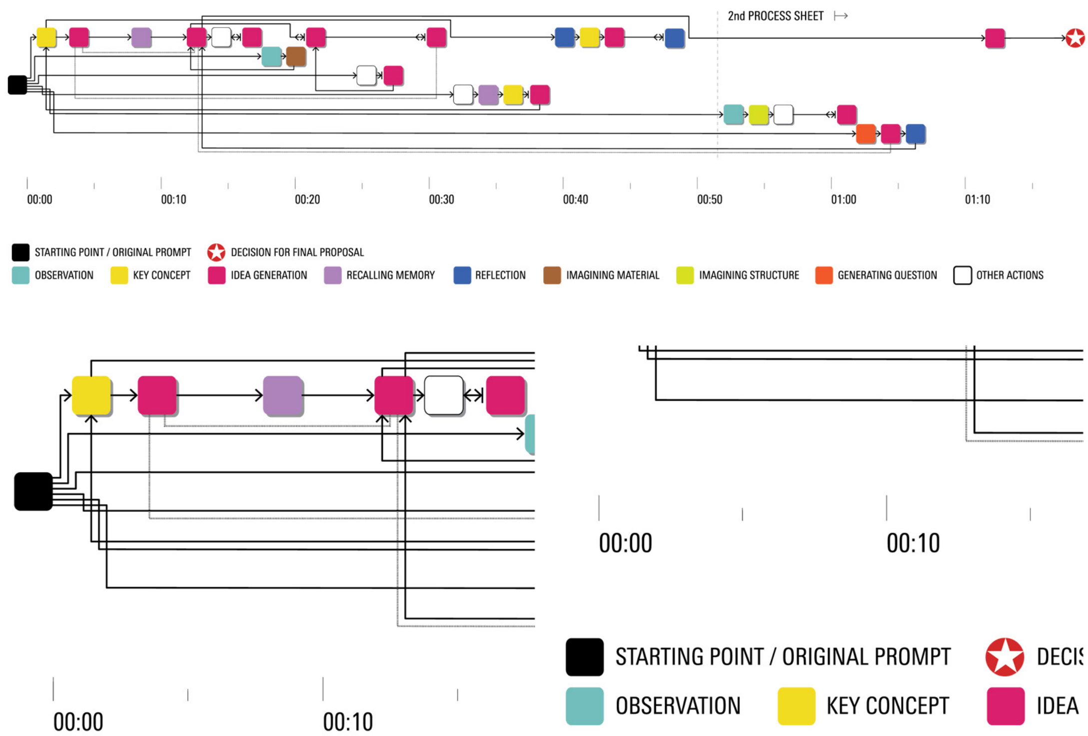



*Figure 24. An example of process mapping 2.*

# 3.7 — CONCLUSION OF CHAPTER 3

This chapter described the approaches in which the preliminary studies and the main study adopted. The overall process of this research has been incrementally developed through a series of the observation studies composed of multiple creative exercises. The process has been developed based on the findings from each of the studies. In pursuit of understanding the designer's cognitive behaviours when faced incomplete information, the research approach of *laboratory-style studies* helped the researcher in understanding the characteristics of the participants' reasoning. Conducting observation studies within a controlled environment allowed the researcher to efficiently investigate the designer's behaviour and collect data. Additionally, the explorative process of the preliminary studies enabled the researcher to consider the hypothesis: *"The process of reducing information by the designers themselves stimulates their design imagination."* This insight became the base for the subsequent main study.

This developmental process also allowed the researcher to propose the reductionist technique composing two types of work sheets named *autonomous reduction* that invites designers to engage with the reductive process, aiming at enhancing their design reasoning. This technique was developed within the process of investigation and was improved through a short evaluation from a professional practitioner. The revised technique of *autonomous reduction* was then used as a primary means of data collection. The set of work sheets (*Process Sheet* and *Idea Sheet*) enabled the researcher to collect rich visual information that became the key data for the analysis.

The first main study was conducted comparing two types of visual prompt that represented different levels of visual fidelity. This comparison enabled the researcher to investing how different visual-richness provided as a stimulus affects the participants' design reasoning. The second study was conducted using only one type of visual prompt and the analysis was carried out, focusing primarily on the process and their critical feedback.

Protocol analysis enabled the researcher to gather in-depth data that represented detailed process of the participants. The results illustrated the characteristics of the participants' thinking approaches during the development of their design reasoning.

The data derived from protocol analysis was represented with visualised mapping. The developed mapping system thoroughly illustrated all the actions of the individual participants. These identified actions and their analysis, visualise the complexity of the reductionist process, transforming it into an intelligible visualisation. This visualisation helped the researcher understand the patterns of the participants' reasoning as they engaged with the technique of *autonomous reduction*. This mapping is shown in the following Chapter 4.

Chapter 4

# *s t u d i e s*

# 4.1 — INTRODUCTION

This chapter presents all the studies conducted including both preliminary and main studies. This chapter consists of four preliminary studies and two main studies. As described in chapter 3, the process of the research was incrementally developed based on the knowledge, insight and key questions derived from the reflections gained from each of the studies. The designs of each of the studies were developed following on from these insights. This process was continued up to the third preliminary study. The collective knowledge obtained through the first and second preliminary studies allowed the researcher to identify a critical and hypothetical insight and this led to the development of the reductionist technique, *autonomous reduction*. This technique was subsequently trialled by the design master students in Switzerland (in the third preliminary study) as well as being tested out with a professional practitioner (in the fourth preliminary study). The first version of *autonomous reduction* was improved, after reflecting upon the results and commentaries gained through the third and fourth studies and this became the prototype of the technique. Following this, the prototype was used in the main studies working with both mature industrial design students and professional industrial designers.

As aforementioned, this chapter also includes detailed descriptions of the methodologies applied in each of the studies. Each study adopted different methodological approaches in data collection and analysis. Therefore, all the relevant information with regards to the research methodology is thoroughly described in each of the study sections within this chapter.

# 4.2— PRELIMINARY STUDY 1: VISUAL REDUCTION–OBSERVATION

## 4.2.1 Introduction

In an attempt to better understand the behaviours of the design practitioner towards reduced and incomplete information, the following fundamental questions were raised: *How is the design practitioner's design imagination affected by reduced and incomplete information?* And *how do industrial design practitioners address and interact with incomplete information for their design imagination?* In order to observe and better understand the design practitioners' process of visual reasoning when they confront the images of an object whose descriptive information has been reduced and incomplete, the researcher conducted the first study working with multiple design students of Northumbria University School of Design. In the study, the student participants were given a task where they are required to visualise the "original object" from the reductive prompt provided that represented the "original object." Then, they were also asked to represent their envisaged ideas of the original object through sketching and model making. The aim of the study was to learn how the design students read and interpret the reductive prompt provided, and also visualise the original object from their imagination.

### 4.2.2 Research Question

As the first approach to the research subject, a sub-research question was set. The research question of the study was: what kind of visual cues do designers rely on for "representation completeness" when they imagine an object based on the reduced and incomplete image of the object?

### 4.2.3 Methodology

In order to observe the design students' behaviour, this study was conducted by providing a visual prompt. The researcher designed a simple archetypal armchair and then created seventeen different types of "reductive representation" that represent the original object to be used for the prompt. Each participant was respectively given one of the reductive prompts and asked to imagine the original object. The participants then visualised their imagination of the original object by sketching and model making. After the completion of these exercises, they were also interviewed. The transcript data of all the seventeen participants were then analysed, following the grounded theory approach. The study was conducted individually in a closed and quiet space within the university premises (Figure 25).

*Figure 25. The environment of the first study.*

#### 4.2.3.1 Participants

In the first study, seventeen undergraduate industrial design students of Northumbria University were involved. The group of participants was comprised of four students in the second year and thirteen in the third year. They were recruited as volunteer participants.

#### 4.2.3.2 Original Object and 17 Reductive Images

The image of the original object used as a prompt was created by the researcher (Figure 26). In this study, it was considered to be important to set up the situation where all the participants engage with the task under the same conditions. Accordingly, it was necessary to provide a prompt image of the original object that none of the participants could identify or have seen before, in order to avoid biases amongst the participants. Additionally, since the focus of this study was on the way in which the design students build their imagination of an object, the prompt needed to be a generic and familiar object that allows the participants to build their reasoning using their own knowledge. The researcher considered that if the object is abstract, complex or totally unfamiliar, it adds pointless challenges in the process of reasoning. Accordingly, the prompt object was carefully prepared following these criteria:

- An object that the participants had never seen before.
- The object is generic and familiar.
- The object is simple in structure.

Following these criteria, the researcher carefully designed a simple armchair using 3D CAD software as a prompt for this study.

*Figure 26. The original object created by the researcher.*

Based on the 3D rendered image of the original object, seventeen different reductive images were created (Figure 27). The intention of the first study was observing the way in which the design practitioners develop their reasoning of an object, when they confronted the reductive images. Accordingly, the researcher attempted to create the types of reductive image in a variety of ways. The seventeen reductive prompts were the following:

- Animated *(flattened image)*
- Pixelated *(disguised image)*
- Dotted *(minimised image)*
- Removed *(physically reduced image)*
- Coded *(simplified image)*
- Outlined *(silhouette)*
- Pointilised *(transformed image into an impressionist look painting)*
- Vandalised *(demolished image)*
- Cubismised *(transformed image into cubism style)*
- Voided *(inverted image)*
- Technically described *(represented image with specifications)*
- Painted *(transformed image into oil painting look)*
- Angled *(image with strong perspective)*
- Sketched *(represented image with hand drawing)*
- Dismantled *(deconstructed image)*
- Exploded *(image without proper spatial arrangement of the components)*
- Roughly sketched *(represented image with rough hand drawing)*

All images except for "Sketched" and "Roughly Sketched" were made using computer-graphic software based on the original image. The two hand drawn images (Sketched and Roughly Sketched) were created by the researcher.

#### 4.2.3.3 Semi-structured Interview

After the completion of the activities of both sketching and model making, a semi-structured interview was conducted for each participant in order to understand the participant's behaviour and approach. The questions were prepared aiming to capture the participants' opinions about the experience in a broader context. The participants were asked to respond to the following:

- *What did you do first when you saw the image?*
- *What kind of visual characteristics in the provided image did you use as a clue for your sketching?*
- *How many ideas did you have while you are imagining?*
- *How did you identify the category of the object in the provided image?*
- *How do you feel about the gap between the image you created and the original image?*
- *Have you referred to an image of existing object as a reference during the imaging process?*
- *What was the most exciting thing while you are imagining?*

- *What was the most difficult thing throughout the process?*
- *Did you use the provided image after sketching?*
- *Do you have anything else to tell about this study?*

The contents of the interview were transcribed and used for the subsequent analysis.


*Figure 27. The seventeen reductive images used as a prompt created by the researcher.*

### 4.2.3.4 Materials for Model Making

During the task, the participants were given the following basic materials for sketching and model making exercises (Figure 28): A3 paper, pens, a clay, cardboards, plastic sheet, a foam board, balsa sheet/rod/stick, a metal rod craft knife, as well as handsaws, pliers, a knife and some glues.


*Figure 28. The materials provided to the participants.*

### 4.2.3.5 Procedure

This study was carried out in accordance with the following procedure:

1. A reductive image was provided to the participant.
2. The participant was informed that the visual prompt provided is reduced image of the original object by the instructor (the researcher).
3. The participant was asked to envisage the original object based on the image of the reductive prompt.
4. The participant was then asked to represent their object through sketching and model making, using the provided materials within 30 minutes.
5. The participant was interviewed after the completion of the task.

#### 4.2.3.6 Data Collection and Analysis

The data were collected from the three sources:

1. the sketches produced,
2. 3D models constructed based on the drawings, and
3. the contents of the transcription of the interviews.

The sketches represent the way in which the participant developed the ideas as well as some key elements that were used for the model making. The 3D models represent the proportion of the object visualised within the participant's sketches and how the idea is physically constructed, suggesting its materiality by the choice of the materials available. The content of the transcript of the interviews retrospectively describes the participant's thought during the task. The transcription of the interviews was addressed as the main data source within the analysis and, the other two visual data sources (sketches and models) were used as supportive data. All the outcomes produced within the task, as well as the reductive image as a prompt, were available during the interview so that the participants responded to the questions, referring to them when necessary.

The data analysis was conducted following Grounded Theory approach (Glaser and Strauss, 1967). Within the analysis, the researcher identified the characteristics in the reasoning of the participants, following through the two stages of coding process:

— *Open coding to find the categories*

— *Axial coding to interconnect them*

The key sentences that the researcher considered as important, were highlighted and collected. The collected key sentences were then categorised as the first reduction (the open-coding process). The categories emerged within the open-coding process were then further reduced and the subcategories were also identified (axial-coding process). The researcher identified aspects that the participants were primarily concerned with within their visual reasoning process, using the object through these coding processes.

## 4.2.4 Results

All the participants envisaged the original object from the reductive prompts provided. Additionally, they were also able to represent their imagined object with models. In this section, the results are described, focusing on the two aspects:

- the outcomes of both sketches and models that the participants produced during the study and
- the coding processes derived from the contents of the interviews.

### 4.2.4.1 Outcomes

The outcomes and all the processes that the participants developed by sketching and model making are presented here (Figure 29 and 30). The result shows that all the participants, except for the one participant who was given the image of "Vandalised," reproduced the model of a chair. Thirteen participants created armchairs, and six of them (Exploded, Cubismised, Dismantled, Sketched, Pointilised and Animated) produced models that are fairly similar to the original object. Surprisingly, even the participants who were given the reductive prompts that the researcher considered as the most difficult images to work with, i.e. "Exploded" or "Dismantled," could reproduce very similar armchairs. Despite the fact that the positional relationship amongst the components of the original chair was shown separately within these images, the participants still could read and understand the compositions and then create armchairs. The only participant who was given the image of "Vandalised," (in which the image of the components was completely fractured), created a desk that was in a different category from the original armchair.

*Figure 29. The processes of development including the sketches and the models.*

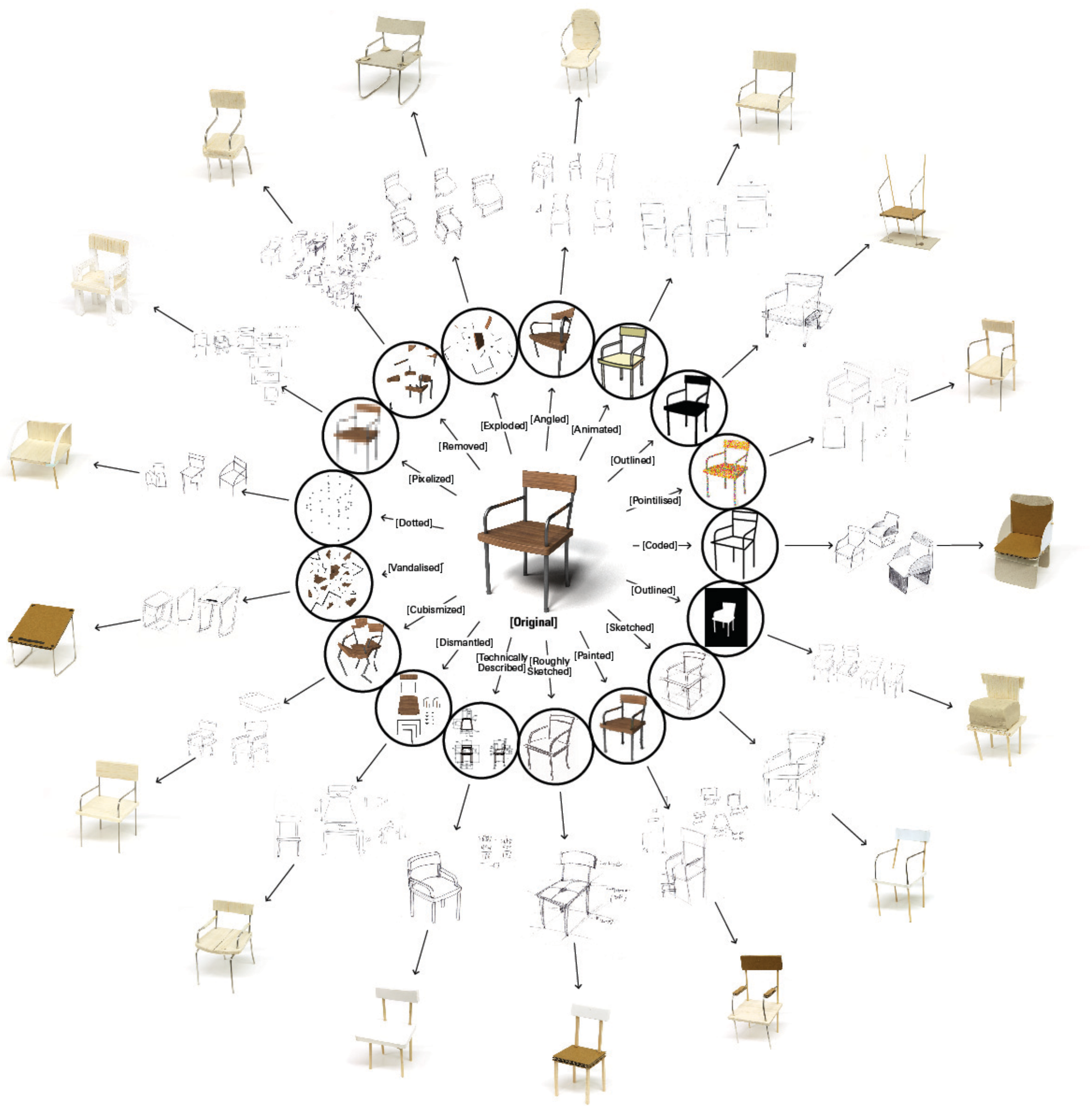



*Figure 30. The models that the participants created as an outcome.*

### 4.2.4.2 Coding Scheme Emerged

The transcribed contents of the interviews were treated as raw material data and the highlighted key sentences were gathered from the transcriptions (Figure 31). Following this, these collected sentences were then categorised in the first open-coding process, finding correlations and patterns amongst each other. As a result, the following six open-coding categories emerged:

1. *The First Action*
2. *Constituent Identification*
3. *Material Association*
4. *Prior Knowledge*
5. *Constituent Arrangement*
6. *Visual Cues for Object Recognition*

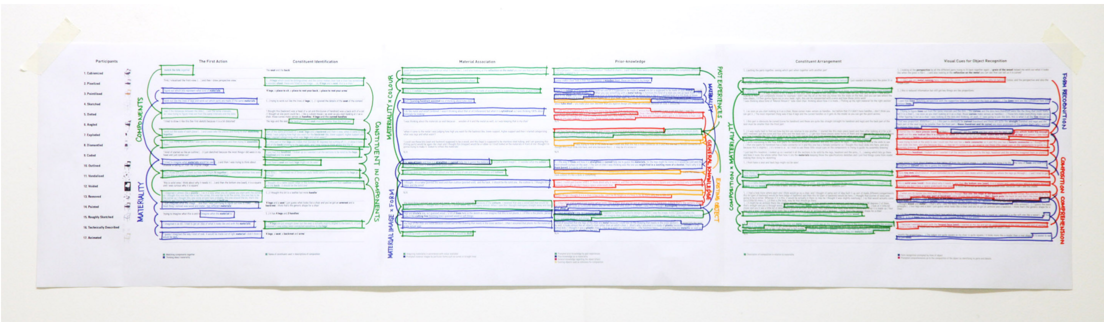


***Figure 31. Coding Process.***

Then, the further reduction was conducted within each open-coding category and several axial-coding subcategories emerged (Table 1). The details of each category/subcategory are described in this section.

***Table 1.*** *The open-coding categories and axial-coding subcategories.*

| **The First Action** | **Constituent Identification** | **Material Association** | **Prior Knowledge** | **Constituent Arrangement** | **Visual Cues for Object Recognition** |
|---|---|---|---|---|---|
| combining components | distinguishing components within compositional relationships | imagining materials based on the colours available | knowledge prompted by past experiences | composition and material | understanding form using particular lines |
| thinking about materiality | | imagining materials by forms | knowledge regarding materiality | | understanding composition of components by identifying details |
| | | | knowledge regarding chairs | | |
| | | | knowledge regarding existing object's construction | | |

#### 4.2.4.2.1 The First Action

The descriptions that were extracted from the first participation were gathered in this category. Within the open coding process, the two axial-coding subcategories emerged: *"combining components"* and *"thinking about materiality."* The participants considered ways to assemble the separate components from their imagination. It appeared that the positional disarrangement of the components of the object, shown in the prompts, encouraged the participants to assemble them. Within the follow-on interview, the participants' descriptions and motivations regarding the "assembling of components" often identified with the more deconstructed images (e.g. 'Exploded' or 'Dismantled') For example, the participant who was given "Exploded" attempted to assemble the pieces depicted in the image as the first action:

> *"(...) work out the scale of each piece (...) take the pieces and trying to start matching together' (Exploded).*

Or, the participant who was given "Dismantled" also tried to assemble the components in their mind:

*"I was trying to plan while I was going to cut the components and then trying to assemble them" (Dismantled).*

Additionally, the imagination of the participants, in regarding materiality of the object was prompted when the participants were given the image in which the colours did not explicitly suggest materials. This characteristic appeared to suggest that the reduction of colour information encouraged the participants to assume what materials were possibly used in the prompt images. For example, the participant who was given "Pointilised" identified the materials in each component in order to understand the object:

*"(...) figure out which bits represent what kind of materials" (Pointilised).*

The participant who was given "Outlined" attempted to identify the materials in their imagination:

*"I tried to imagine what materials would be used" (Outlined).*

#### 4.2.4.2.2 Constituent Identification

The descriptions that include the words referring to the constituents of an object were collected in this category. The one axial-coding subcategory emerged: *"distinguishing components within compositional relationships."* This subcategory represents how the participants recognised the object (e.g. as a chair or a desk) through identifying components within the compositional relationship of the object. All participants, except for the one who was given "Vandalised," mentioned the components as belonging to a chair. Also, eight out of seventeen participants referred to these components in relation to the composition of the object. For example, the participant who was given "Pixelised" acknowledged that the prompt image represents a chair by identifying the several iconic components:

*"4 legs which could be distinguished and the colour makes clear look a chair has a wooden sheet, these are fitted in my image... ok, 4 legs and a seat. This is a chair" (Pixelised).*

Another example is that the participant who was given "Exploded" also envisaged the object, identifying what the elements are and how they play a role:

*"(...) sort of the same principals of a seat, legs and a backrest and then it was, when it came to the metal, I was judging how high you want for the backrest like, lower support, higher support and then I started categorising what was legs and what wasn't" (Exploded).*

The participant who received "Vandalised" only referred to the components as a desk. This participant considered the object depicted as a desk, focusing on the black holes in the image (Figure 32). The participant also associated a particular design style of an object with these holes:

*"These tiny dots (...) reminded me of American style desks which is slanted up where the legs go through" (Vandalised).*

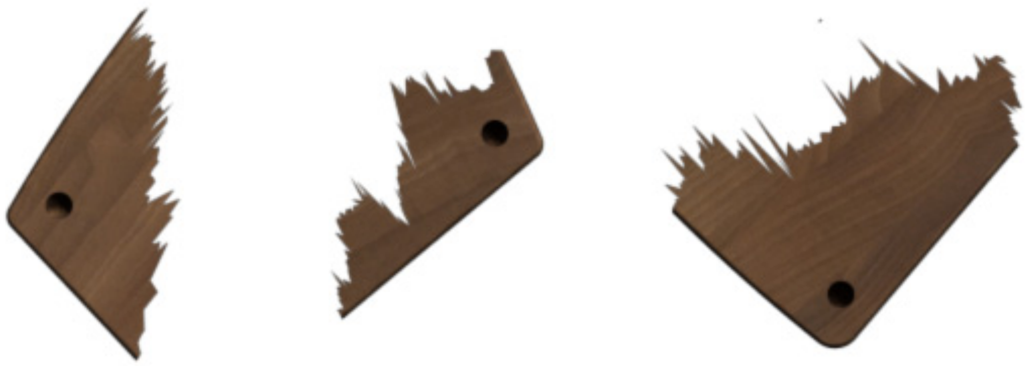


***Figure 32. The holes that the participant used as a clue for imagination.***

#### 4.2.4.2.3 Material Association

The descriptions regarding material association/identification were collected in this category. The following two axial-coding subcategories emerged: *"imagining materials based on the colours available"* and *"imagining materials by forms."* Some participants used the colours available in the image prompt as a visual cue for imagining materials. It seemed that the particular colours suggested materiality of the object within the participants' imagination. In total seven participants stated particular materials, referring to the colours within the image prompts. The participant, for example, who was given "Outlined" depicted in black and white described that they were triggered to imagine a colour because of the monochromatic character of the image:

*"it is just a black image (...) I wonder what the colour is. Because in my head, it was going to be green foam" (Outlined).*

The participant who was given "Pointilised" asserted that the colours helped them in imagining the materials:

*"Mine is in colour so it helps me, and I could tell one bit is supposed to be made of wood one bit is supposed to be made of pipe metal" (Pointilised).*

Despite the fact that the image was represented with the complex multiple colours that do not explicitly suggest wood (such as brown colour), this participant readily assumed that a timber material was used in the object (Figure 33).

***Figure 33. "Pointilised" image that is represented with complex colours.***

Additionally, particular details of form (e.g. the curve of handrail, a straight line or a cylindrical shape) were used in understanding materials. For example, the participant who was given "Sketched" asserted that a particular curve helped them to assume a material:

*"That (curving handrail) assisted me in thinking about tube steel" (Sketched).*

The participant who was given “Outlined” also asserted that the particular lines encouraged them to imagine a material:

> *“The way of lines and how it is straightened or curved helped me to guess the materials” (Outlined).*

#### 4.2.4.2.4 Prior Knowledge

The descriptions regarding the participants’ prior-knowledge were collected in this category. Prior knowledge played an important role in their imagination and assisted the participants reasoning in a variety of ways. The four axial-coding subcategories emerged: “knowledge prompted by past experiences,” “knowledge regarding materiality,” “knowledge regarding chairs,” and “knowledge regarding existing object’s construction.” The memories derived from the participants’ past experiences assisted them to imagine an object. For example, the participant who was given “Cubismised” recalled the past experience when they engaged in a design project:

> *“I did a project (...) about a manufactured product. I looked at chairs (...) and I think there were a lot of metal chairs which are completely different from this… (but) I related to it” (Cubismised).*

The participant who was given “Exploded” also used their expertise derived from the past experiences:

> *“I did a little bit of furniture stuff (...) sort of the same principles of a seat, legs and a backrest (...). When it came to the metal, I was judging how high you want for the backrest (...) and I started categorising what was legs and what wasn’t” (Exploded).*

Additionally, the prior knowledge regarding materiality assisted some participants to conceive how a chair is constructed or what it looks like. For example, the participant who was given “Pointilised” assumed how a chair is constructed with particular materials:

> *“The idea of the steel tube chair with wood base kind of thing working straight from… so almost this is like a (...) applied kind of a list think of those chairs we’ve already know” (Pointilised).*

Or, the participant who was given “Outlined” conceived a particular context in which the chair is placed based on the material assumed:

> *“The sort of chair I was thinking was the one you might find in a waiting room of a dentist. That’s why it is foam based. It is quite soft and warm” (Outlined).*

Generic knowledge regarding a chair was also used for the participants’ imagination. For example, the participant who was given “Dotted” stated that they identified the components as soon as they considered the object as a chair:

> *“As soon as you start looking at it as a chair, those curves make senses as handles” (Dotted).*

Or, the participant who was given “Removed” considered the dimensions of the object, assuming it is a chair:

> *“Certain things I thought… if it is a chair, it has to be… it can’t be 80 height so it has to be 40 that’s why this is 440 mm” (Removed)*

The knowledge regarding the structure of the existing objects was also used as a reference for some participants in their imagination. For example, the participant who was given “Sketched” considered the construction of the famous “Wassily Chair” (designed by Marcel Breuer) (Figure 34) within the imagination:

> *“I was thinking about… kind of Marcel Breuer’s tube steel chair… thinking about how it is made” (Sketched).*

*Figure 34. Wassily Chair designed by Marcel Breuer. (Lorkan, "Wassily Chair also known as the Model B3 chair designed by Marcel Breuer in 1925-1926 at the Bauhaus, in Dessau, Germany." 1st April 2007, via Flickr, Creative Commons Attribution 2.0 Generic)*

The participant who was given "Exploded" also envisaged the famous "Eames Plastic Chair," that is commonly called "Eiffel Tower Chair" due to its iconic chair base structure (Vitra Eames Plastic Chair), (designed by Charles and Ray Eames) (Figure 35) within their imagination. The participant referenced several chair bases whose structure possibly matches the object represented in the prompt image:

> *"I was starting to go through different types of chair bases in my head to see if I can fit them in it. I think I had the image of the Eames's Eiffel Tower" (Exploded).*

*Figure 35. Eames Plastic Chair (Eiffel Tower Chair) designed by Charles and Ray Eames (Photograph by Rama, Wikimedia Commons, Cc-by-sa-2.0-fr).*

#### 4.2.4.2.5 Constituent Arrangement

The descriptions regarding the arrangement/layout of the constituents of an object were collected in this category. One axial-coding subcategory emerged: "composition and material." In total eight participants mentioned about the relationship between the composition of constituents and materiality of an object. For example, the participant who was given "Pointilised" envisaged the structure of the object identifying materials:

> *"One bit is supposed to be made of wood one bit is supposed to be made of pipe metal kind of thing. So, there were a few clues there towards the structure" (Pointilised).*

Or, the participant who was given "Technically Described" identified the materials based on the structural information of the object available in the visual prompt:

> *"I kind of assumed that the legs of the chair are metal because I could see on the drawing that meets in the cross-section. It looks like screwed to keep in the place" (Technically Described).*

#### 4.2.4.2.6 Visual Cues for Object Recognition

The descriptions regarding the visual cues were collected in this category. These 2 subcategories were identified: "understanding form using particular lines" and "understanding composition of components by identifying details." In total eight participants asserted that they used the lines (e.g. straight lines or curves) available in the prompt image as a clue for understanding forms. For example, the participant who was given "Sketched" understood the form of the depicted object, focusing on the particular lines:

> *"I used that lines sketching perspective with the supportive lines to understand the form of object" (Sketched).*

The participant who was given "Dotted" understood the form of the object by making the lines visible connecting the dots:

> *"Trying to figure lines out from the same intervals and the dots" (Dotted).*

Additionally, eight participants comprehended the compositions of the components regarding the object by figuring out the details. For example, the participant who was given "Pixelised" figured out how the components were organised focusing on the positional relationship among the constituents:

> *"I don't see any metal running here, I mean in the corner. So, the metal should be a little bit behind" (Pixelised).*

The participant who was given "Dismantled" considered how the particular parts can be composed, focusing on the details:

> *"I was trying to look at the ends to see… I could see that one has a male connector on it and this one has a female connector so I thought this must slide into here" (Dismantled)*

## 4.2.5 Findings

This section describes the findings derived from the previous coding processes. The particular characteristics emerged within the analysis and these illustrate what elements the design students considered as the key for their imagination.

### 4.2.5.1 Material and Compositional Information

In the axial-coding process, in total thirteen subcategories have emerged (Table 2). The researcher identified that the aspects of both "materiality" and "composition" regarding an object were frequently mentioned within the transcriptions. The participants appeared to consider the aspect of materiality of an object as an important clue for imagination. In fact, the aspect of "materiality" was featured four times within the open-coding categories: "the first action," "material association," "prior-knowledge" and "constituent arrangement." Meanwhile, the participants also seemed to consider the aspect of composition of an object as another important clue for imagination. The information regarding how the object is constructed or how each component is structured played an important role in envisaging an object. The aspect of "composition" was featured five times within the open-coding categories: "the first action," "constituent identification," "prior-knowledge," "constituent arrangement" and "visual cues for object recognition." These results appeared to suggest that the information "material" and "composition" played an important role when the design students built their imagination of an object based on the reductive prompts.

***Table 2*** *The characteristics emerged within the axial-coding subcategories.*

| The First Action | Constituent Identification | Material Association | Prior Knowledge | Constituent Arrangement | Visual Cues for Object Recognition |
|---|---|---|---|---|---|
| combining components | distinguishing components within compositional relationships | imagining materials based on the colours available | knowledge prompted by past experiences | composition and material | understanding form using particular lines |
| thinking about materiality | | imagining materials by forms | knowledge regarding materiality | | understanding composition of components by identifying details |
| | | | knowledge regarding chairs | | |
| | | | knowledge regarding existing object's construction | | |

#### 4.2.5.2 The Influence of Prior Knowledge

The other fact found within the coding processes was that the participants' prior knowledge significantly supported their reasoning when they considered the aspects of both materiality and composition. The researcher realised that many sentences collected within the multiple open-coding categories overlapped with the ones gathered in the category of "prior

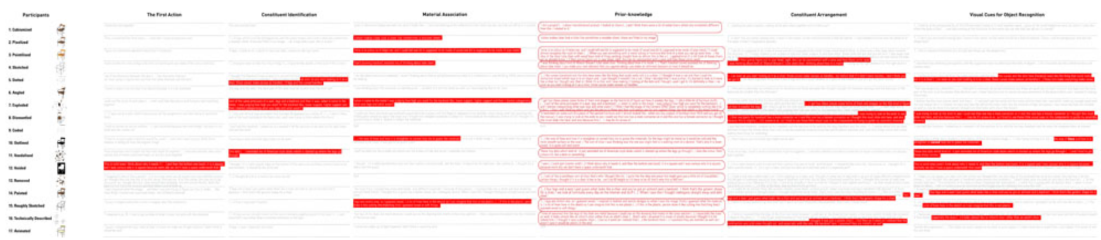


*Figure 36. Highlighted quotes (red) overlapped with the sentences collected in the category "Prior knowledge."*

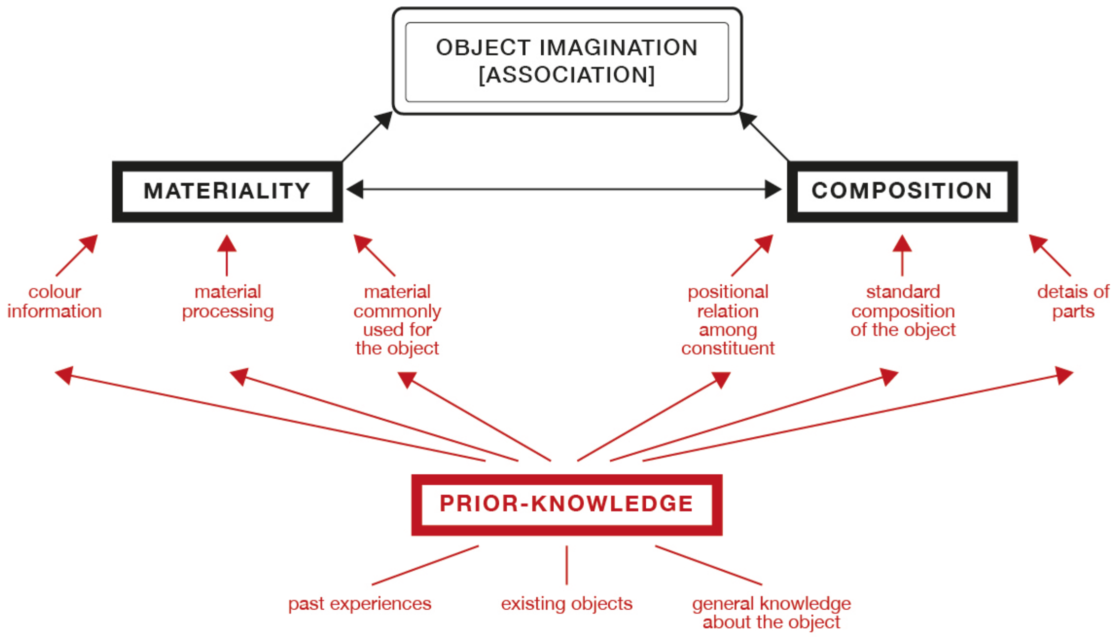
knowledge" (Figure 36). Many participants developed their reasoning processes depending on different types of prior knowledge, e.g. association between particular colours and materials, their past design experiences, the knowledge regarding a chair or their technical expertise regarding structures of an object. Accordingly, the participants' prior knowledge underpinned their consideration of materiality and composition within the reasoning process. Thus, prior knowledge is considered as another important factor when the participants envisaged an object based on the reductive prompts.

### 4.2.6 Conclusion of the Preliminary Study 1

The aim of the first study was to observe how the design students, regarded as design practitioners, address the reductive image prompts that represent the original object. Also, the researcher explored what elements play an important role when the design participants were given a reductive image of an object. The result showed that the design students could envisage an object from reductive visual prompts. Some of the participants who were given images that seemed to be relatively difficult to figure out (i.e. Exploded or Dismantled) could replicate armchairs that are similar to the original. During the reasoning process, the participants mainly considered aspects of both "materiality" and "composition" of an object. In other words, identifying “what materials are used” and understanding “how the elements are composed” provided them with a clue in developing their reasoning about an object. Further, these considerations were highly supported by their prior knowledge in a variety of ways (Figure 37).

The researcher leant that the design participants were capable of imagining an object from the less resolved visual information. However, the researcher also learnt that the design students have a certain level of skills in reading or interpreting information when they build on their imagination of an object from the reductive image prompts. This fact suggested that a strategic intervention is necessitated if the reduced incomplete prompt aims to stimulate a design practitioner’s imagination for unexpected design ideas.

*Figure 37. The information set that describes the findings.*



# 4.3 — Preliminary Study 2: Reduced Red & Blue Chair–Comparative Study

## 4.3.1 Introduction

The previous study demonstrated the design practitioner's capability of building imagination of an object when they faced the reduced visual information. Many of the participants could reproduce an object that is fairly similar to the original armchair even from very distorted images such as "dismantled" or "exploded". The study revealed that the design practitioners considered and obtained the information of both "composition" and "materiality" within the provided reductive images and developed their imagination of object, using them as a key clue. Additionally, when they consider these aspects in their reasoning, their prior-knowledge played an important role. This fact appears to suggest that certain types of information that suggests a hint for the object's attributes enabled the design students to develop design reasoning of an object within their imagination.

The subsequent second study was designed based upon the findings of the first study. The researcher wondered, if the design practitioner was given a prompt regarding an object whose "compositional" and "material" information were reduced, how their imagination is affected. Also, the second study focused on how design practitioners' processes of reasoning is characterised when they are given different levels of reduced information of an object in comparison to a group of non-designers. In order to answer the questions, the second study was conducted using deconstructed and scaled-down components of an existing object.

## 4.3.2 Research Questions

As aforementioned, the second study was conducted, focusing on the reduction of "material" and "compositional" information. In particular, the authors focused on the fact that colour information suggests materiality of an object within the design students' visual reasoning. Also, the impact of prior-knowledge on the participant's reasoning process was examined. Therefore, the authors focus on the two questions in this study:

- *How are the reasoning processes of design students affected when they are given different levels of "colour" and reduced "composition" information?*

- *How do different kinds of prior knowledge affect the participants' visual reasoning when dealing with reduced levels of in-formation?*

### 4.3.3 Methodology

In order to observe the impact of the reduction of "compositional" and "material" information on the design practitioners' reasoning, a set of prompt materials were prepared. This study used a one-tenth scale-model of Gerrit Rietveld's famous Red and Blue Chair designed in 1918 (Figure 38). The components of this chair were dismantled and arranged in the order of size. Then, they were provided to the participants. This deconstruction obscures the original construction of the object so that the participants were required to imagine the object by assembling the components. Also, different levels of colour-code that represent the same components were prepared. The first group comprised of the multiple colour-code components whose colours painted on its surface were exactly the same as the ones used in the original Red and Blue Chair. The second group comprised of the single colour components painted in white. The third group comprised of the natural timber colour that has no paint on it. In this study, the researcher focused on the fact that the design students used colour information as a clue for envisaging materials. Therefore, this study investigated the impact of different levels of colour information provided (multiple-colour coded, painted in white and without paint) on the participants' imagination in terms of materiality. Further, this study also employed two participant groups that have different backgrounds in order to investigate how prior-knowledge affects their reasoning processes in composition and material information. Thus, this comparative study was conducted through providing the same set of tasks to both groups.

*Figure 38. Red and Blue Chair designed by Gerrit Rietveld (1918).*

#### 4.3.3.1 Selection of Original Object as Prompt

The Red and Blue Chair used as prompt in this study was carefully selected. The prompt object ought to be composed of primitive geometric components. The researcher felt that the image of chair used in the first study as a prompt was somewhat too suggestive. The participants could well read and interpret many information within the details of the image e.g. the form, materiality, construction and so on. Accordingly, the deconstructed components should not suggest any particular styles or symbolic meanings in its form. The neutrality of forms allows the participants to engage the task in a less biased manner and also helps the researcher to purely observe the process and the outcomes of the participants on the same conditions. Therefore, the Red and Blue Chair met this criterion due to its anonymity in its forms of the components.

This chair consists of 2 standard flat panels (seat and backrest), 2 armrests, and 13 slats joined in the simplest possible way (Dettingmeijer et al., 2010) painted in red, blue, yellow, and black. All the geometric components ensure that no part dominates or is subordinate to the others (Zijl, 2010). Thus, the researcher purposefully adopted this object in this study because of its neutrality in form of the components that allows the participants to interpret in diverse ways.

### 4.3.3.2 Components

All the components used in the study were made of spruce. These wood materials were cut into the exactly the same proportion as the original Red and Blue Chair (one-tenth-scale) and painted carefully by hand. The colours painted on the surfaces of the components, for the multiple colours group, were accurately reproduced with black stain, cadmium-yellow-lemon, vermilion and dark ultramarine (Drijver, 2002). For the single colour group, the components were painted only in matt-white, and the last group had no additional paint on the surface of the timber. In total 36 sets of components were prepared (Figure 39).

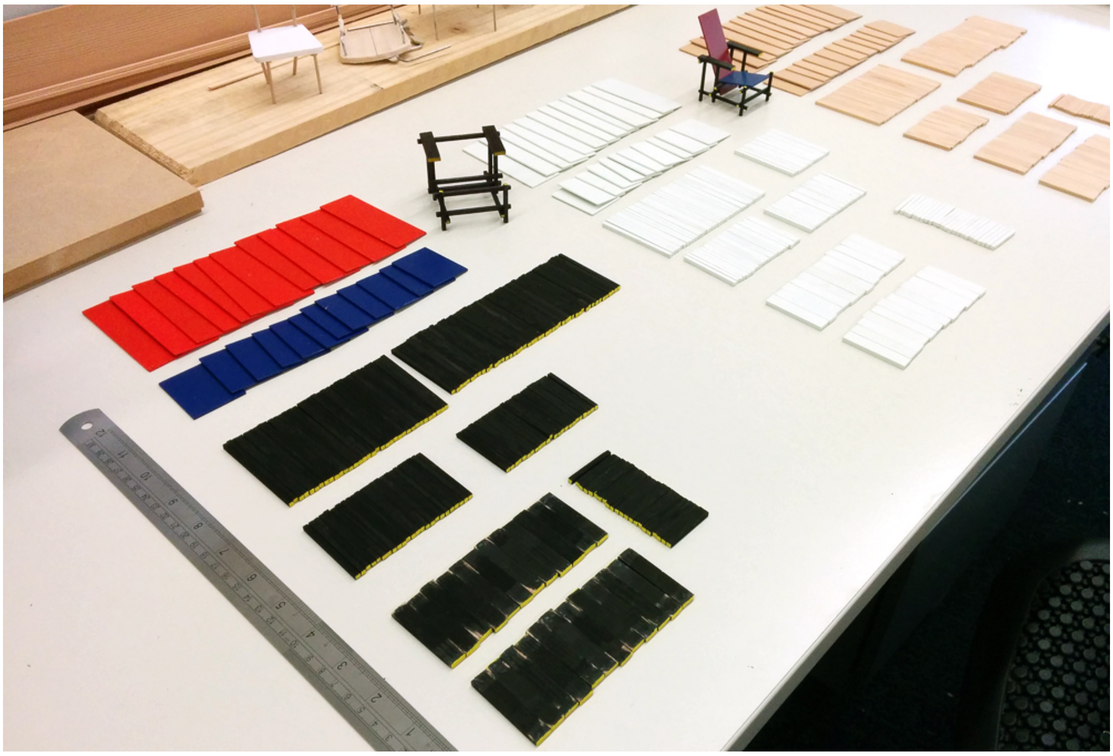


*Figure 39. The making process of the components.*

In order to reduce the compositional information of the object, the components were arranged in order of size. In addition, as aforementioned, the material information was reduced with 3 different types of colour coding (Figure 40):

- one set of chair components were prepared in the same colours (red, blue, yellow and black) as Rietveld's original Red and Blue Chair
- one set was painted in white (obscuring material information) and,

- a final set of components were left in their natural colour (indicating its materiality).

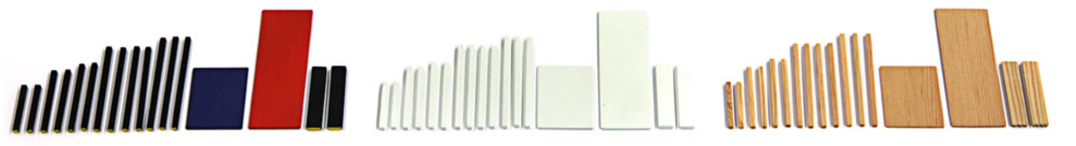


*Figure 40. 3 chair components sets (left to right: original colours, white colour, natural colour)*

The components painted in the original Rietveld colours suggest some material information to the participants whereas the components painted in white give less material information to them. The focus here is on observing the impact of reduced levels of colour information. The study sets out to detect how the difference in colour across the 3 sets of components affects the participants' imagination of an object (including the material aspects). Additionally, the study also sets out to observe how the process of visual reasoning based on the components that explicitly indicate its materiality differs from the other two painted sets.

#### 4.3.3.3 Participants

In this study, thirty-six voluntary participants of Northumbria University were involved. Eighteen fourth year Industrial Design students from the School of Design and eighteen third year non-design students from Newcastle Business School. The design student participants were regarded as having knowledge and experiences of industrial design as they were in the final year of their degree whereas none of the non-design participants had any knowledge or experience in design.

The eighteen design students were divided into three groups comprised of six participants each. The other eighteen non-design students were also divided into three groups of six participants. The study was conducted individually and each participant was given one set of chair components. Then, each participant was asked to complete the task of making a 3D model of their visualised object.

#### 4.3.3.4 Procedure

The study was conducted individually in a quiet and closed room. Each participant completed their task following the instructions provided (Figure 41). During the task, however, the participants were not interrupted by the instructor (the researcher) so that the circumstance allowed them to concentrate on their thinking and making a model. Then, the instructor interviewed the participants after the completion of the model making exercise. The detailed procedure is as follows:

1. *The deconstructed materials were provided.*
2. *The instructor informed the participant that the materials are scaled-down components of an object.*
3. *The participant was asked to visualise the object, and then to represent his/her idea using all the given components. Different types of glues were provided for constructing materials as well.*
4. *The participant was interviewed focusing on the object created and the way they evolved the ideas after the completion of the model-making exercise.*

***Figure 41. Study environment of the 2nd preliminary study.***

#### 4.3.3.5 Semi-structured Interview

Semi-structured interviews were conducted after the completion of model making. The focus was on understanding the participants' visual reasoning processes and their outcomes. The participants were asked to respond to the following:

1. *Please describe the object you created.*
2. *Please describe the way this object would be used.*
3. *Where did your idea come from?*
4. *What was the important clue(s) that helped you to imagine the object?*
5. *What is this object made out of?*
6. *Please specify the number of ideas which you came up with.*

After being asked these questions, the interviewer unveiled the complete scaled-down model of the Red and Blue Chair to the participants. Then, the participants were also asked to describe the difference between the object they created and the original chair.

#### 4.3.3.6 Data Collection and Analysis

Two types of data were collected in this study: (i) 3D scale models that represent the participants' final idea, and (ii) the contents of the interviews that describe their processes of reasoning. The interviews were recorded by a sound-recording device, and later transcribed for analysis.

The analysis covered both the 3D outcome and reasoning processes. The photographed images of the 3D outcomes allowed the researcher to analyse the variation in the participants' model visually. The comparison of the differences and similarities within the outcomes enabled the researcher to interpret the impact of the different reductive levels of information in the participants' final ideas. Additionally, the visual nature of the outcomes describes specific features of each participant's idea even if some of the created objects are in the same category. At the same time, focusing on the process of the participants' reasoning was also important to reveal how they had evolved their ideas and to identify the elements they had considered as meaningful clues. Dealing with these aspects together allowed the data to be compared and constructed to derive the findings.

The analysis of the contents of the interviews was carried out, focusing on the result of the design participants in the first place. Afterwards, the contents of the non-design participants were analysed based on the same focus. Fundamentally, this study aimed to investigate how the reduced information impacts particularly on the designers' reasoning and to identify how their specific characteristics differ from the non-designers. Therefore, the same categories that emerged within the group of design participants were used as a basic framework for the coding process of the non-designers' transcripts. The written data of the design participants were analysed using a general inductive approach (Thomas, 2006) in order to capture the similarities and differences of the participants' thinking processes. Next, the non-designers' transcripts were searched and coded, using the same focus as the design students. Details of the coding procedure are as follows:

1. All the transcribed raw data were read through until certain categories emerged within the contents of the design participants' interviews.
2. The categories identified in step 1 were revised and refined in order to find the common themes that can be applied across the groups.

3. The contents of the design participants' transcripts were reviewed over and over again and data recollected through the refined categories until the authors gained a thorough understanding.
4. The design participants' transcripts were categorised in different colour-coding groups.
5. The category system used for the design participants was then applied to the contents of the non-design participants to collect relevant data.
6. The gathered contents based on the same category system were compared between the design and the non-design participants.

Comparing the 2 groups, using the same coding system, allowed the researcher to identify whether the design participants' reasoning was unique to design participants or if their reasoning was generic. This process also revealed the influences of the design participant's prior-knowledge.

### 4.3.4 Results

The results appear to suggest that there are both differences and similarities between design and non-design participants in the outcomes and in their reasoning processes.

#### 4.3.4.1 Outcomes

All the images and the names of objects stated by the participants are provided below (see Figure 42 and Table 3 and Table 4). The result of the outcomes shows the clear distinction between the design and the non-design participants.


*Figure 42. The outcomes of both the design students and the non-design students.*

The results from the design student participants appear to indicate that the types of the outcomes became more diverse when the multiple colours are reduced to a single white colour. The types of outcome in the group of natural colour were the richest in variety. In the group of the original 4 colours (top row), four out of six participants (67%) created a chair. When the painted colour-pattern is reduced to one colour, two out of six participants (33%) made chairs. Further, in the result of the group of natural colour, none of them (0%) made chairs (Table 3). The participants who made an object that could be described as "furniture" were six (100%) in the group of 4 colours, four (67%) in the 1 colour and zero in the natural colour (the miniature desk is regarded as a category of toy rather than furniture). The intended scale of visualised objects became more diverse in accordance with the decrease of the painted colours. In the group of 4 colours, the intended scales of outcomes were all in furniture-sized. In the group of 1 colour, the assumed sizes of outcomes became more diverse. This tendency was even more explicit in the natural colour group as they stated the objects from a miniature desk to a large opera house. These results appear to indicate that as the reductive level of color-coding information increases the types of outcomes become more diverse.

***Table 3*** *The name of the objects stated by the* ***design*** *participants.*

| Participant | D1 | D2 | D3 | D4 | D5 | D6 |
|---|---|---|---|---|---|---|
| **Original colours** | School desk & stool | Table with bookshelf | Chair | Chair | Chair | Chair |
| **Participant** | **D7** | **D8** | **D9** | **D10** | **D11** | **D12** |
| **White colour** | Throne to be carried | Journey of my thought process (sculpture) | Architectural sculpture / building / pavilion | Table with sextant for a star finding device | Piano | Medieval looking chair |
| **Participant** | **D13** | **D14** | **D15** | **D16** | **D17** | **D18** |
| **Natural colour** | Miniature desk | Boat / raft | Large opera house | Canopy | Rabbit / weathervane | Switch for workshop |

On the other hand, the result of the outcomes of the non-design participants shows no significant characteristics among the color-coding groups. The types of outcomes were varied regardless of the reductive levels of painted colour. The participants who made a chair as outcome were only one (17%) in the group of 4 colours, 2 (33%) in the 1 colour, and one (17%) in the natural colour. The non-design participants who made furniture related objects were one (17%) in the 4 colours, three (50%) in the 1 colour, and 1 (17%) in the natural colour. Additionally, the scales of imagined objects do not seem to be affected by the amount of the painted-colour information provided (Table 4). Thus, the result of the outcomes in the non-design participant groups seems to be relatively random compared to the one of the design participants. In other words, the different information of painted colour has only affected the final ideas of the design participants.

*Table 4 The name of the objects stated by the **non-design** participants.*

| Participant | ND1 | ND2 | ND3 | ND4 | ND5 | ND6 |
|---|---|---|---|---|---|---|
| **Original colours** | Zoo cage | Entrance of restaurant | Chair & little table | Symbol | Temple | Terrace |
| **Participant** | **ND7** | **ND8** | **ND9** | **ND10** | **ND11** | **ND12** |
| **White colour** | Little bench | Big white church | Monument | Table | Creative house | Reclining deck chair |
| **Participant** | **ND13** | **ND14** | **ND15** | **ND16** | **ND17** | **ND18** |
| **Natural colour** | Royal chair / baby chair | Stair / portion of a big room | Brandenburger Tor | Entrance of café | House with chimney | Key holder storage device |

### 4.3.4.2 Categories Emerged Within Data Analysis

The analysis of the processes of the participants' visual reasoning was conducted based on the content of the interviews. The total number of categories that emerged in the group of the design participants was twenty-six. Further, these categories were subsequently used to collect data in the group of the non-design participants to compare the differences. These four features were identified as prominent characteristics (described in following sections):

- *Thinking approach for making*
- *Reference objects*
- *Assumed materials other than wood*
- *Key elements as clue*

#### 4.3.4.2.1 Reasoning Approach for Making

The patterns of the participants' thinking approach were revealed through the analysis. The researcher focused on how the different levels of colour information affected the participants' reasoning approach for the visualisation of their ideas. The result shows that the approaches that the participants took can be divided into two ways: (i) top-down (image driven) and (ii) bottom-up (thinking by making). The top-down process commonly known as theory-driven or conceptually-driven processing (Galotti, 2013) is the way to perceive an object depending on our prior knowledge. On the other hand, the bottom-up process is the way to form complex visual-patterns in meaningless features and then to construct a meaningful image of an object (Ware, 2008). In this study, the approach where a participant started making an object based on their visualized idea was regarded as top-down. The approach where a participant started building the components to think without clear ideas was regarded as bottom-up.

The results appear to indicate that the reasoning approaches of both design and non-design participants were fairly similar (Figure 43). The participants had a tendency to take a top-down approach for reasoning when they were given a certain color-coding with 4 colours: four participants (67%) in both the design and non-design students. The participants who were given the components of both 1 colour and unpainted took bottom-up approaches: four design participants (67%) and five non-design students (83%) in the 1 colour, and four participants (67%) for both students in the natural colour.

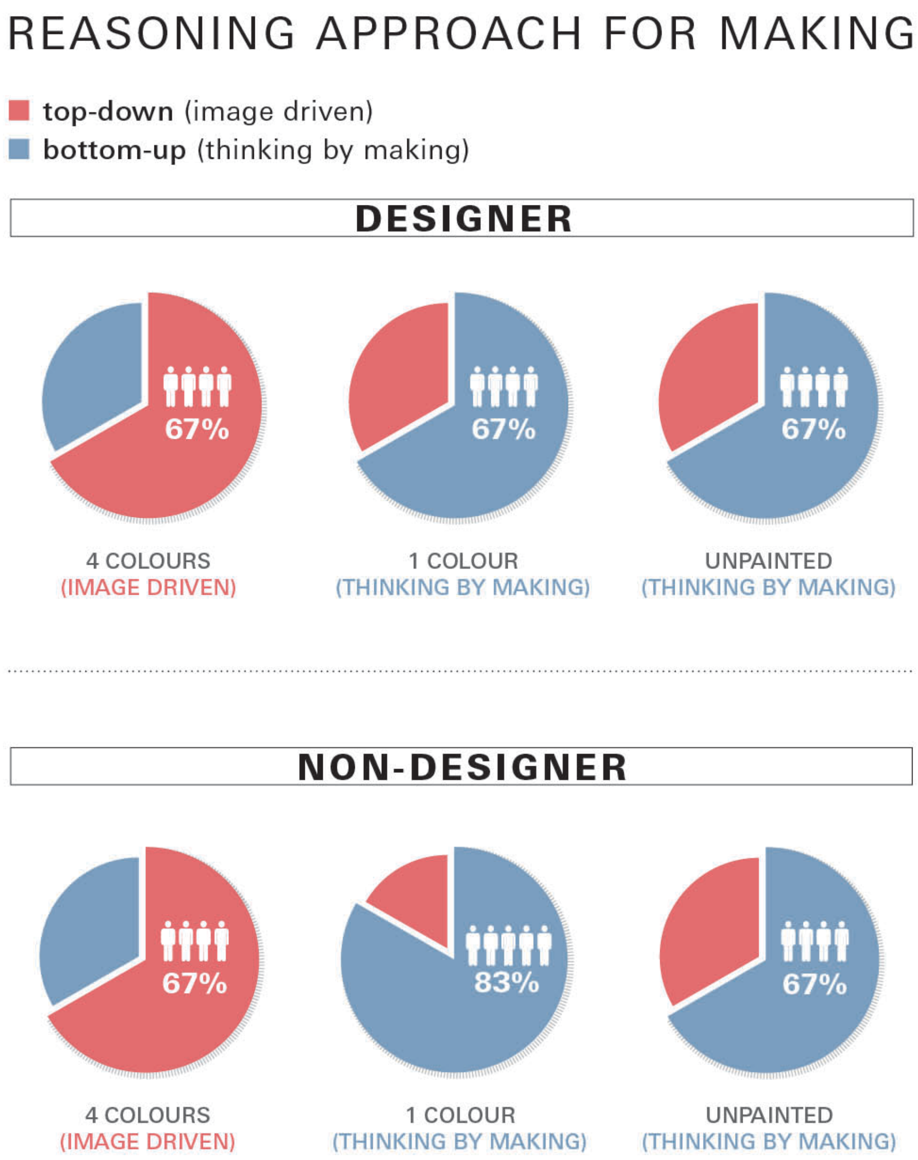



*Figure 43. The outcomes of both the design students and the non-design students.*

The colours used in Rietveld's chair are very iconic and well known in a design context. Therefore, it is assumable that the original colours informed the design participants about the original chair's design so that they made a model using their design knowledge. At the same time, although none of the non-design participants knew the original chair, the original colours still suggested concepts of an object as well. On contrary, when the painted colour is reduced to white or when the material is natural coloured, the components challenged the participants to visualise their ideas.

#### 4.3.4.2.2 Reference Object

The participants referred to existing objects as a source of reference in their reasoning. In the groups of design participants, the results show that the more information of colour-coding given, the more participants referred to the classic chair as a clue for their reasoning (Table 5). In the group of 4 colours, five out of six participants (83%) associated with classic design chairs such as the original Red and Blue Chair or the Charles Rennie Mackintosh Chair. In the 1 colour group, two participants (33%) associated with classic design chairs. Just one participant (17%) referred to a classic chair in the group of natural colour. This result suggests the types of objects that the design participants referred to can be more diverse when the colour code was reduced to a single white colour. The components that indicate wooden material informed the participants about existing objects the least in the group of design participants.

**Table 5** The reference objects used by the **design** participants.

| Participant | D1 | D2 | D3 | D4 | D5 | D6 |
|---|---|---|---|---|---|---|
| **Original colours** | Stool & desk in science lab | Red & Blue Chair | Red & Blue Chair | Red & Blue Chair | Charles Rennie Mackintosh Chair | Red & Blue Chair |
| **Participant** | **D7** | **D8** | **D9** | **D10** | **D11** | **D12** |
| **White colour** | Ancient pope mobile, chairs with decoration on the back & chairs for bride | N/A | Richard Serra's sculpture | Eileen Gray's table, Lego, Tamiya models & Red & Blue Chair | Matchbox, biplane & grand piano | Platform for mountain bike, Red & Blue Chair & wheelbarrow |
| **Participant** | **D13** | **D14** | **D15** | **D16** | **D17** | **D18** |
| **Natural colour** | N/A | Sail of a ship & boat | N/A | N/A | Wing of plane & Charles Rennie Mackintosh chairs | N/A |

On the other hand, not one participant mentioned Rietveld's iconic chair in the non-design participant groups (Table 6). Other than the design classic chairs, however, the non-design participants referred to existing objects in the 1 colour group the most. The results appear to show that the particular colours used in Rietveld's chair did not prompt their association with this object. Additionally, the components that indicate the materiality of wood (natural colour) informed them less about existing objects when compared with the results of the group of 1 colour.

**Table 6** The reference objects used by the **non-design** participants

| Participant | ND1 | ND2 | ND3 | ND4 | ND5 | ND6 |
|---|---|---|---|---|---|---|
| **Original colours** | N/A | N/A | N/A | N/A | Japanese temple | N/A |
| **Participant** | **ND7** | **ND8** | **ND9** | **ND10** | **ND11** | **ND12** |
| **White colour** | American trophy | Spanish & Philippine churches | Vietnamese ancient building | N/A | N/A | Framework of aeroplane, house & phone |
| **Participant** | **ND13** | **ND14** | **ND15** | **ND16** | **ND17** | **ND18** |
| **Natural colour** | N/A | N/A | Old German style house | N/A | Typical house in Vietnam | N/A |

These results imply that the red, yellow, and blue colours of the components prompted the prior knowledge of the design participants. However, when the painted colours are reduced to one or removed, the design participants referenced random objects other than classic chairs. This feature could not be seen in the group of non-design participants. As for the types of objects that the participants referenced, both design and non-design associated with them in a variety of ways only when the painted colour is reduced to a single white colour.

#### 4.3.4.2.3 Assumed Materials Other Than Wood

In the result of design participants, the group that mostly prompted their association of different materials other than wood was the 1 painted colour (Table 7). Three out of six participants (50%) stated different materials other than wood in the 4 painted-colour group. When the painted colour was reduced to one colour, five participants (83%) referred to different materials other than wood. In the group of natural colour, again, 3 participants (50%) mentioned different materials. This result suggests that when the colour is reduced to a single white colour, the participants imagined more material choices. In the group of natural colour that indicates its materiality, half of them still stated different materials other than wood. Actually, in the natural colour group, four participants (67%) stated that the wood material informed their reasoning. However, five of them (83%) explained that they attempted to avoid making an object that can be easily assumed. This result implies that the components that explicitly state its material property of wood afford some ideas about possible objects to the many participants in the group of natural colour. At the same time, however, that circumstance also discouraged them to take those easy options on their decisions.

**Table 7** The assumed materials stated by the **design** participants.

| **Participant** | **D1** | **D2** | **D3** | **D4** | **D5** | **D6** |
|---|---|---|---|---|---|---|
| **Original colours** | Plywood / MDF & **metal piping** | **Acrylic / plastic /ABS** | **Aluminium tubes** / wood & **aluminium** & wood / **plastic** | Pinewood | Hardwood | Wood |
| **Participant** | **D7** | **D8** | **D9** | **D10** | **D11** | **D12** |
| **White colour** | Plywood | Hard-board / wood & **Metal** | **Metal** | **Brass / patina** & wood & **welded steel** | Wood / **metal / aluminium sheet** | Hardwood / **plastic** |
| **Participant** | **D13** | **D14** | **D15** | **D16** | **D17** | **D18** |
| **Natural colour** | Wood | **Steel** & **copper** & **glass** | Hardwood & bamboo & plywood | Wood / **oxidized aluminium** | **Metal** | Wood |

On the other hand, in the result of the non-design participants, the group of natural colour seems to be the one that prompted the imagination of different materials the most (Table 8). In the other two painted groups, the participants who stated the different materials other than wood were more or less the same scores: four participants (67%) in the 4 colours and three of them (50%) in the 1 colour.

**Table 8** The assumed materials stated by the **non-design** participants.

| Participant | ND1 | ND2 | ND3 | ND4 | ND5 | ND6 |
|---|---|---|---|---|---|---|
| **Original colours** | **Brick / metal / glass** | **Brick / iron / cobble stone / old broken brick** | Wood | **Obsidian / space fabric /** wood | Wood | Wood / **stone** |
| **Participant** | **ND7** | **ND8** | **ND9** | **ND10** | **ND11** | **ND12** |
| **White colour** | Wood | **Cement / concrete / ceramic / bronze / glass / metal** | **Crystal** | Wood / **metal** | Wood | Wood |
| **Participant** | **ND13** | **ND14** | **ND15** | **ND16** | **ND17** | **ND18** |
| **Natural colour** | Wood / **fabrics / sponge / plastic / metal** | **Glass / metal** / wood / **concrete** | **Stone** | Wood / **stone / metal** | **Stone / brick /** bamboo / **glass** | MDF / **plastic / acrylic** |

The results of the design and non-design participants appears to indicate that the reduced information of the painted colour to one only impacted on the assumption of materiality of the design participants. This feature was not seen in the group of non-design participants.

#### 4.3.4.2.4 Key Elements As Clue

The types of information as key element that the participants used as clue were identified through the analysis. In the process of analysis, in total four themes that the participants frequently mentioned in terms of their reasoning process emerged:

- *Shape / size*
- *Colour*
- *Material*
- *Association with object*

In the result of the design participants, the elements that seem to be considered as clue were different among the three groups of the color-coding (Figure 44). In the group of 4 colours, the identified elements are 'Shape/size', 'Colour' and 'Association with objects'. Five participants (83%) mentioned shape/size information and all of them (100%) considered colour information as a clue. Additionally, Five participants (83%) associated with existing objects. In the group of 1 painted colour, the participants mainly considered the elements of 'Shape/size' and 'Association with objects'. All the participants (100%) stated that they considered shape/size information as a clue. Four of them (67%) associated with existing objects during the process of reasoning. In the group of natural colour, they mainly considered the elements of 'Shape/size' and 'Material'. All the participants (100%) mentioned shape/size information was used as a clue. Four of them (67%) stated that material information was important.

The result of the non-design participants appeared to be similar to the one of the design participants. In the group of 4 painted colour, the participants mainly focused on the elements of both 'Shape/size' and 'Colour'. All the participants (100%) considered the information of shape/size and 5 of them (83%) used the colour information as a clue. The element of 'Association with objects' that was one of the elements the design participants considered was not identified in this group. This fact implies that particular color-coding encouraged only the design participants to associate with existing objects as reference. In the group of single colour paint, the elements of both 'Shape/size' and 'Association with objects' are identified as prominent characteristics. Five participants (83%) considered shape/size information as important clue, and four of them (67%) associated with objects. In the group of natural colour, the identified elements were 'Shape/size' and 'Material'. All the participants (100%) stated both the elements were used as an important clue.

The patterns of the identified features seem to be similar, except for the results of the 4 colour groups, in the result between design and non-design participants (Figure 44). The particular colour-coding activated the prior knowledge of the design context and hence 83% of the design participants associated with the design classic chairs in the 4 colour group. Other than that, the impact of the prior knowledge was not so prominent on the result of the elements the both groups of the participants used as clue.

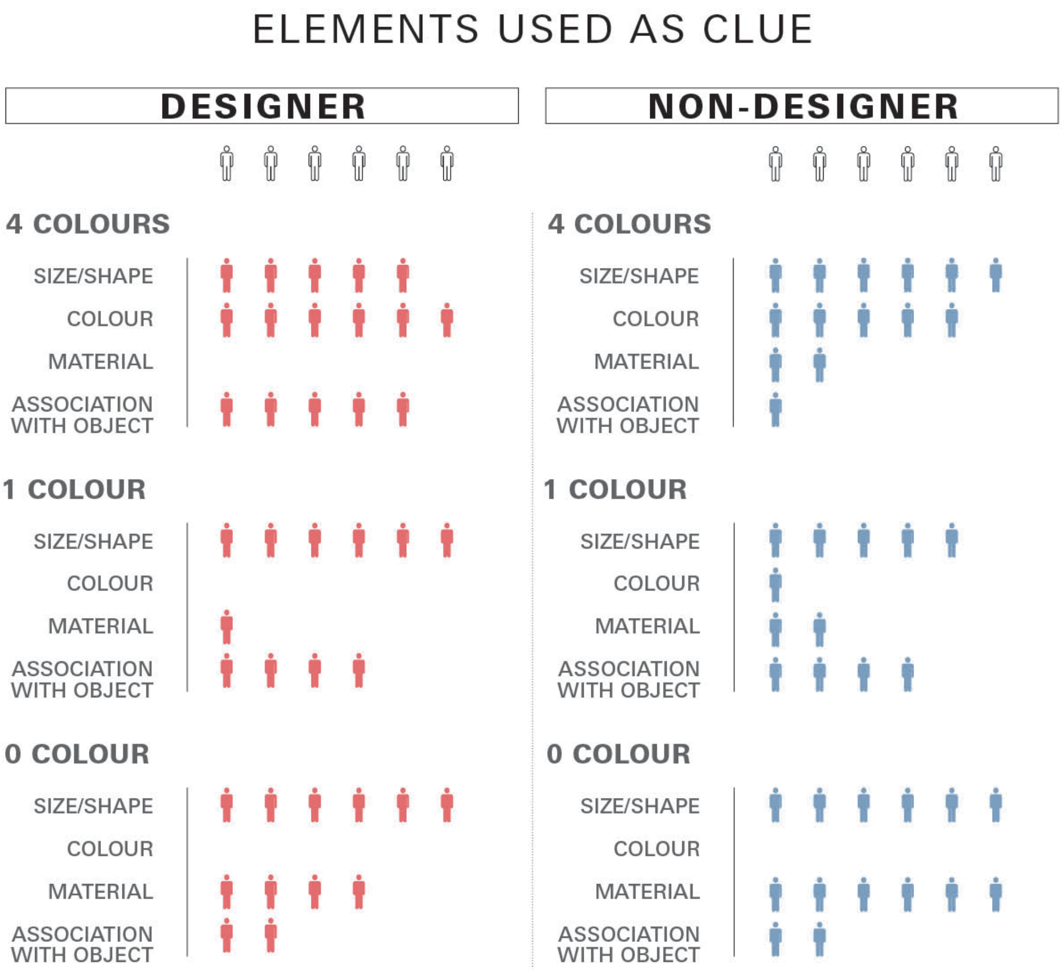



*Figure 44. Key elements used as a clue.*

## 4.3.5 Findings

This study has shown how a group of design participants' visual reasoning is characterised in comparison to a group of non-design participants, when they are given reduced information of an object. Additionally, it also showed how prior knowledge affects a group of design participants' reasoning processes. The results show there are some similarities and differences between the participants' use of prior knowledge in their visual reasoning.

The types and intended scales of outcomes of the design participants became more diverse when the color-coding is reduced to a single colour. This characteristic became even more prominent when they were given the components that indicate the object's materiality. For the non-design participants, the types and the intended scales of outcome were just random regardless of the different levels of information given. This result suggests that giving the components reduced to a single colour and the natural colour led only the designers to more unpredictable and diverse outcomes. On the contrary, the multiple-coloured components activated the designer's prior-knowledge and brought similar types of outcomes.

As for the process of reasoning, the multiple colours used prompted an 'image driven' approach for making models for both design and non-design participants. On the contrary, when the amount of colour information is reduced or removed, the participants had a tendency to take a 'thinking by making' approach regardless of the differences of their prior knowledge. With regards to reference objects, the single colour prompted the association of objects the most regardless of prior knowledge. The natural colour components encouraged neither the designers nor the non-designers to reference existing objects in their reasoning processes. In terms of material, the single colour components prompted the diversity of the designers' imagination whereas they did not impact on the non-designers' reasoning processes. The natural colour components did not particularly prompt the imagination of materiality for the designers, as the result was the same as the one of the multiple colours. Additionally, the natural colour prompted the imagination of materiality the most in the result of the non-designers. This result appears to suggest that the designers tend to stick to the idea of wood material in their reasoning process. Finally, the types of elements that the participants used as a clue were more or less the same regardless of the differences of their prior knowledge except for the group of multiple colours. Particular colours given seemed to only prompt the design participants' prior knowledge of design so that they associated with design classic chairs as a reference in their reasoning.

Thus, reduced information of both painted colours and composition certainly affected the design student's reasoning in many ways. Particularly, the reduced information to a single colour brought the diversity to the designers' reasoning process regarding reference objects and materiality. Further, although prominent features were not identified in the designers' reasoning processes in the group of natural colour the types and the intended scales of outcome became the most varied. Thus, the reduced information appears to assist the designers to diversify the outcomes and reasoning processes.

### 4.3.6 Conclusion of the Preliminary Study 2

The aim of this study was to observe how the design practitioners build their imagination when they are given different levels of reduced information of an object. The results have illustrated certain patterns of design participants' reasoning processes when faced with the reduction of particular parts of information. Through the study, the researcher could confirm that the reduced information certainly affected the reasoning process of the participants under the controlled condition and environment where a well-known design masterpiece was used. The researcher, however, acknowledges the limitation of the study setting as the result might be varied depending on the conditions. Also, the act of imagining an original object differs from designing. However, the researcher could develop the conviction that incomplete information derived from reductive approach can affect and potentially prompt design practitioners' diverse imagination as a stimulus. Therefore, the researcher felt the necessity to consider the design situation where the design practitioners can utilise the benefit of reduction within the process of their own design practices. This insight encouraged the researcher to form a hypothesis:

> ***"The process of reducing information by the designers themselves stimulates their design imagination."***

The design participants appeared to be equipped with the ability to address information incompleteness and this "incompleteness" can play a role in diversifying their imagination. What if they are asked to explore design concepts within the process of reduction? This question became the basis of the consideration to the subsequent preliminary studies.

The previous two studies mainly investigated the impact of reduced information upon their design imagination in the form of being asked to visualise the original object. In the following stage where this thesis primarily concerns, the focus was on how the designers address reduced information for their imagination when they deconstruct the attributes of an existing object autonomously rather through being provided with the ready-made reductive prompts. Also, being asked to imagine the original object scarcely happens in the actual design practice. However, providing external stimuli can still assist the designers' imagination in conceiving unexpected but beneficial ideas during idea generation (Vasconcelos and Crilly, 2016). Accordingly, the researcher observed their reductive and ideation process, in which the design participants were allowed to freely reduce the complete organisation of meanings that an existing object includes through deconstruction, and to explore new design concepts simultaneously. The impact of self-reducing action upon their design imagination was examined based on such perspective.

# 4.4 — Preliminary Study 3: Autonomous Reduction Version 1 with Master Design Students in Switzerland

## 4.4.1 Introduction

The previous studies revealed that the reduced information, presented as external stimuli, certainly impacted on their reasoning process. Some of the results appeared to suggest that incompleteness of information diversified the design students' reasoning in materiality or scale and references of an object under particular circumstances. These facts imply that the reductive prompt potentially enhances the reasoning experiences of the design practitioner when they explore ideas or new design concepts. What then if the design students implement a reductive process by themselves? How do the design students behave when they are asked to reduce the elements of an existing object? Also, how does this autonomous reduction affect their design reasoning in order for conceiving ideas? In order to observe the impact of autonomous reduction on their design reasoning, a study was conducted, providing the tailored work sheets where they reduce the elements of the original object and explore ideas simultaneously. Also, the researcher aimed to explore a potential technique where the design practitioner can exploit the value of reduction in their design practice by the set of work sheets proposed.

In March 2016, the researcher was given an opportunity to conduct a workshop working with the design master students in Switzerland (Figure 45). The researcher was invited as a guest lecturer for the joint programme of the master courses of both Geneva School of Art and Design (HEAD) and ECAL (École Cantonale D'Art de Lausanne) and gave a lecture after running the workshop based on the PhD project titled *"Design Reductionism."* This study was conducted using this opportunity. The students were invited to participate in the workshop after being given a short and generic introduction about the researcher without being informed about this research project. The study was conducted providing a set of working sheets (the *Process Sheet* and the *Idea Sheet*) to the participants where they were asked to conceive ideas of object within the process of autonomous reduction.

*Figure 45. Geneva School of Art and Design in Switzerland*

### 4.4.2 Research Questions for the 3rd Study

The research question of this study was the following: *how does the act of autonomous reduction impact upon the idea generation of the design practitioners who have various backgrounds?*

### 4.4.3 Methodology

The aim of the study was to observe and understand the impact of autonomously reducing information of an object and how this illustrated the design practitioner's design reasoning. Additionally, this study also aimed at observing how the design practitioner finds out ideas within the process of autonomous reduction. This study was conducted using the image of a simple wheelbarrow as an external stimulus. The researcher then prepared three different types of visual fidelity based on this image: i) the photographic image of a wheelbarrow, ii) the image of a wheelbarrow represented with lines and iii) the image of a wheelbarrow represented with dotted lines.

The aim of preparing variations in visual fidelity was to observe how the different amount of information regarding the image prompt available affects the participants' design reasoning processes. Both declined fidelity prompts that are represented with lines or dotted lines did not include material information. Particularly, the elements of the object were represented in a far more abstract way in the dotted line image that did not visually describe the details of its composition. In other words, the declined fidelity images inevitably demanded the participants to compensate the missing information. Accordingly, the researcher considered that the approaches towards reduction possibly would be different between the participants who are given high-fidelity prompt and the others that are given low-fidelity images. Thus, the researcher attempted to understand the characteristics of the act of autonomous reduction within the comparisons among these three levels of visual fidelity.

#### 4.4.3.1 Selection of the Original Object

This study particularly focused on observing how the design practitioners read, interpret and manipulate the meanings of the elements of the object within the reductive process. Accordingly, the object as a prompt needed to be simple, familiar and easy for the participants to engage with. The selection of the original object as an image prompt was made following the criteria:

- The object should be readily identifiable for all the participants.
- The object is composed of simple elements.
- The object has functionality(ies).

The researcher then selected a wheelbarrow that satisfies these criteria (Figure 46).

*Figure 46. The wheelbarrow used as the original object (Photo: Erich Ferdinand).*

This archetypical wheelbarrow utilises the advantages of both the wheel and the lever, and the load is centred just behind a single wheel that allows the user to lift only a small part of it (Lienhard, 1990). The simplicity in the structure of the wheelbarrow clearly shows the functionalities of each component. Also, it is not difficult for the participants to interpret or assume the attributes such as what it is made of, how it is constructed and how it is used.

#### 4.4.3.2 Prompts Provided in the Study

As described before, the researcher prepared the three types of visual prompt that represent the same object but were presented with different fidelity levels:

1. the photographic image,
2. the same wheelbarrow represented with line drawings and
3. the wheelbarrow represented with dotted lines.

Each prompt was respectively provided to the three groups comprised of twenty participants (Figure 47).

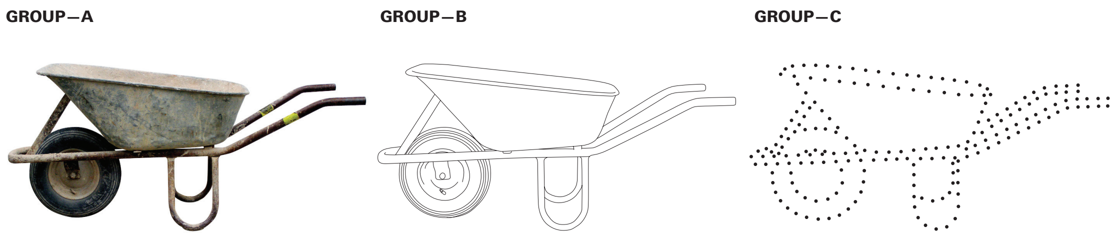



*Figure 47. Three prompts provided to the three groups.*

The photographic image of a wheelbarrow was provided to Group A. This image represented the physical attributes of the wheelbarrow e.g. materials, texture, colour, shadows and so on. Accordingly, this image is deemed as the prompt that represents the richest attributes of the object amongst the three fidelity levels.

The image of the same wheelbarrow represented with line drawing was provided to Group B. This image includes less attribute information comparing to the one provided to Group A. For example, the aspect of materiality is eliminated and the object depicted in the image is flattened. However, the image still suggested some details regarding the form or the structure/composition of the wheelbarrow.

The third image represented the same wheelbarrow with dotted line-drawing and was provided to Group C. The image is highly abstracted and some details regarding the composition of the wheelbarrow were removed. Accordingly, this visual prompt was deemed as having the least visual fidelity. These 3 different fidelity levels of visual prompt were used in the workshop in order to observe the impact of the richness in visual information as an external stimulus on the participants' imagination.

## 4.4.3.3 Design of the Work Sheets

The two workshop sheets, *Process Sheet* and *Idea Sheet*, were designed for this study. The participants were asked to reduce the elements of the original object (wheelbarrow) step by step and select one of the images depicted on *Process Sheet*. The participants were then asked to move to the *Idea Sheet* where the selected idea is finalised. All the written descriptions were in English and both of the sheets were formatted in A4.

### 4.4.3.3.1 Process Sheet

The role of *Process Sheet* was to provide an opportunity for the participants to reduce the elements of the original object by drawing, in a systematic fashion (Figure 48). The participants were asked to implement the reductive process, following the levels from 10 to 1, indicated on the *Process Sheet*. The "level 10" represented the start of the process and the participants gradually reduced the elements of the original wheelbarrow towards the level 1 where a black dot is depicted. Although the image of the original object is different among the three fidelity levels, each *Process Sheet* was designed in the same manner.

On the left side of the front page of *Process Sheet*, the instruction and the image of the original object were displayed. The contents of the instruction are the following:

> *"Read the instruction on the reverse side. And then reduce/deconstruct the elements of the original object towards LEVEL 1. Please select one of your levels and use the image drawn as a prompt for creating a new concept."*

> *"Your task is to explore a new design concept of an object within the transitions of the visual reductive processes. Please visually REDUCE the elements of the original object following the levels indicated on each square. The reduction of the 'elements' is totally up to you."*

On the other side of the sheet, the spaces in which the participant reduces the elements of the original object is indicated in a grid layout. The levels are printed at the corner of each space and the participant was asked to gradually reduce the elements, following the numbers indicated (Figure 49). Additionally, a box with a tick mark was placed on each area of levels. The participant was then asked to put a tick at the level where they selected as an inspiration for the final idea.

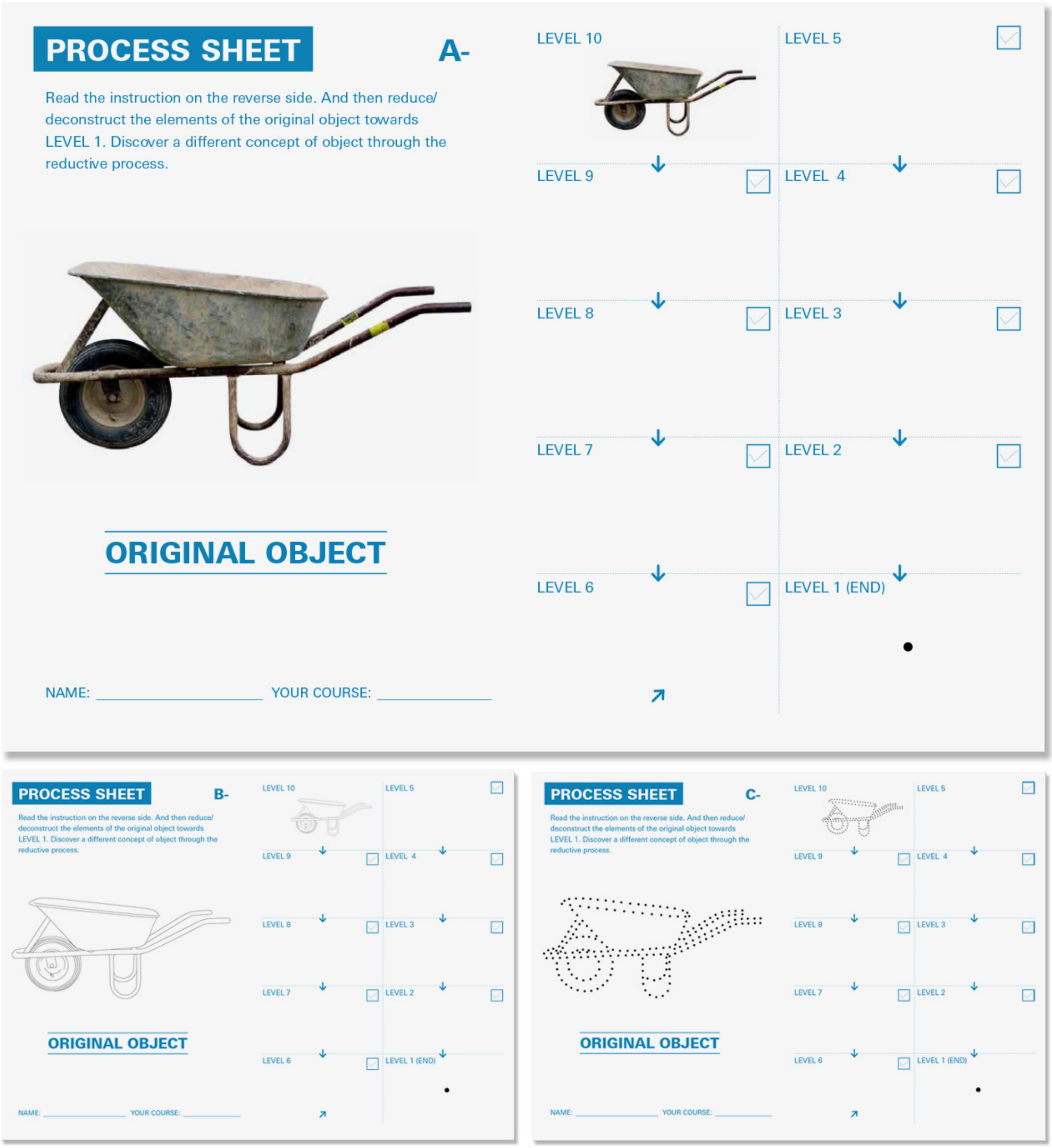



*Figure 48. The Process Sheets for the three groups (front side).*

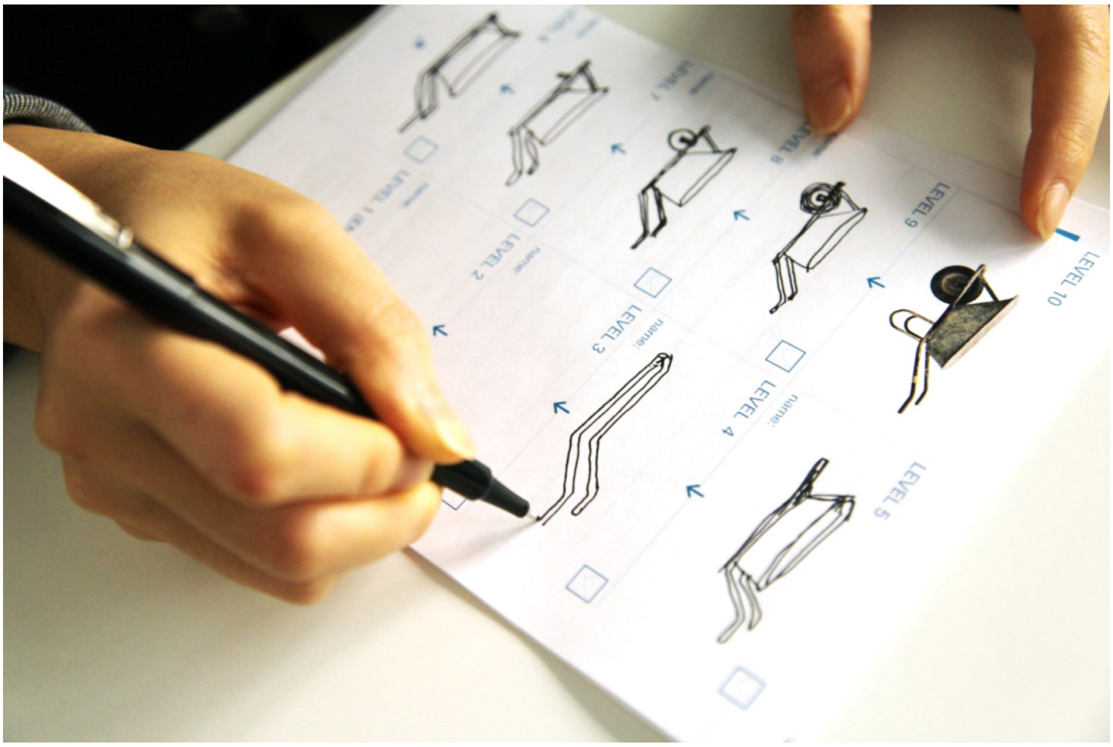


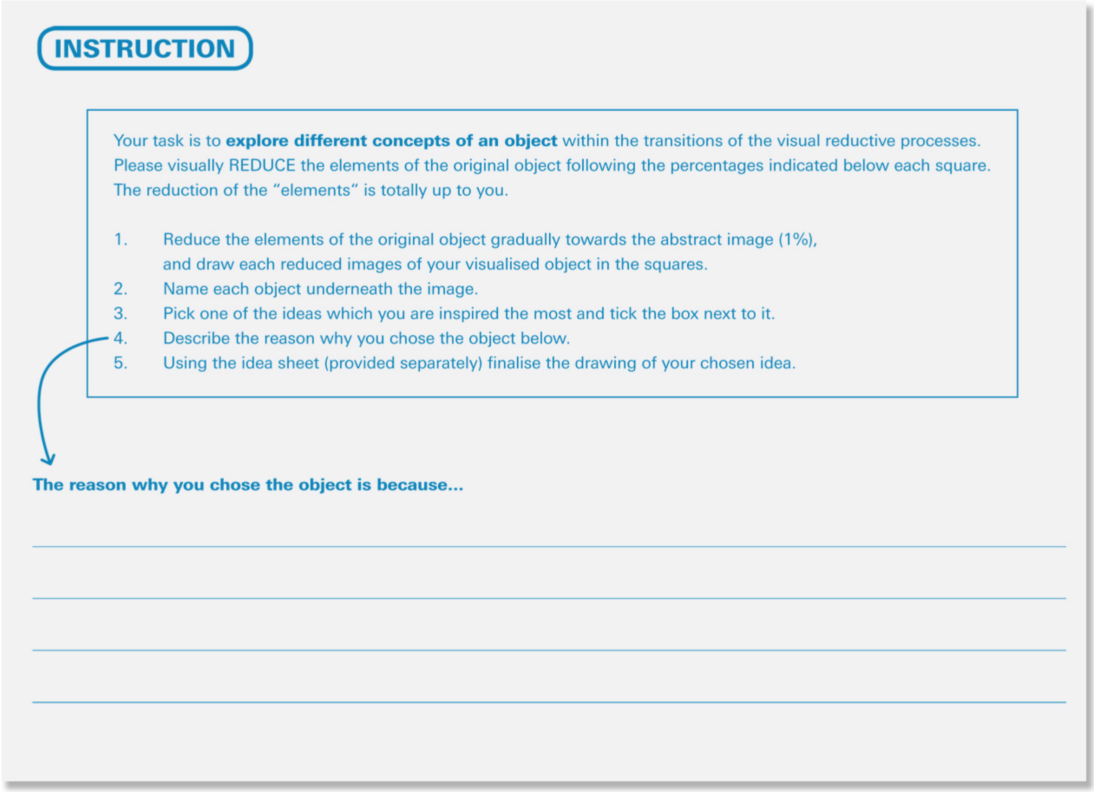

***Figure 49. The example of the use of Process Sheet.***

On the reverse side of *Process Sheet,* the detailed instruction was indicated (Figure 50):

1. *Reduce the elements of the original object gradually towards the abstract image (LEVEL 1), and draw each reduced image of your visualised object in the squares.*
2. *Name each object underneath the image.*
3. *Select one of the levels of reduced images, and use this as a stimulus to develop a new design concept. Ignore other levels of reduced images other than the selected one when you develop your design concept.*
4. *Describe the reason why you chose the level below.*
5. *Using the idea sheet (provided separately) finalise the drawing of your chosen idea.*

As well as the instruction, the participant was also asked to describe the reason why the drawing was selected as an inspiration for the final idea. The participant was then asked to move to *Idea Sheet* where the selected drawing/idea is completed as a final conclusion.

*Figure 50. The reverse side of Process Sheet.*



**INSTRUCTION**

Your task is to **explore different concepts of an object** within the transitions of the visual reductive processes. Please visually REDUCE the elements of the original object following the percentages indicated below each square. The reduction of the "elements" is totally up to you.

1. Reduce the elements of the original object gradually towards the abstract image (1%), and draw each reduced images of your visualised object in the squares.
2. Name each object underneath the image.
3. Pick one of the ideas which you are inspired the most and tick the box next to it.
4. Describe the reason why you chose the object below.
5. Using the idea sheet (provided separately) finalise the drawing of your chosen idea.

**The reason why you chose the object is because...**

#### 4.4.3.3.2 Idea Sheet

The role of *Idea Sheet* was to enable the participant to finalise the idea selected within the process of *Process Sheet* (Figure 51). On the left side of *Idea Sheet*, a blank space for drawing the final idea was provided as well as the short instruction: *"please draw your final idea below and complete the questions on the other side."* On the other side of *Idea Sheet*, two questions regarding the idea that the participant depicted were indicated: *"please describe the object you created (in English)"* and *"list the intended materials used in your object (in English)."* The participant was asked to describe the final idea by drawing and words in the sheet.

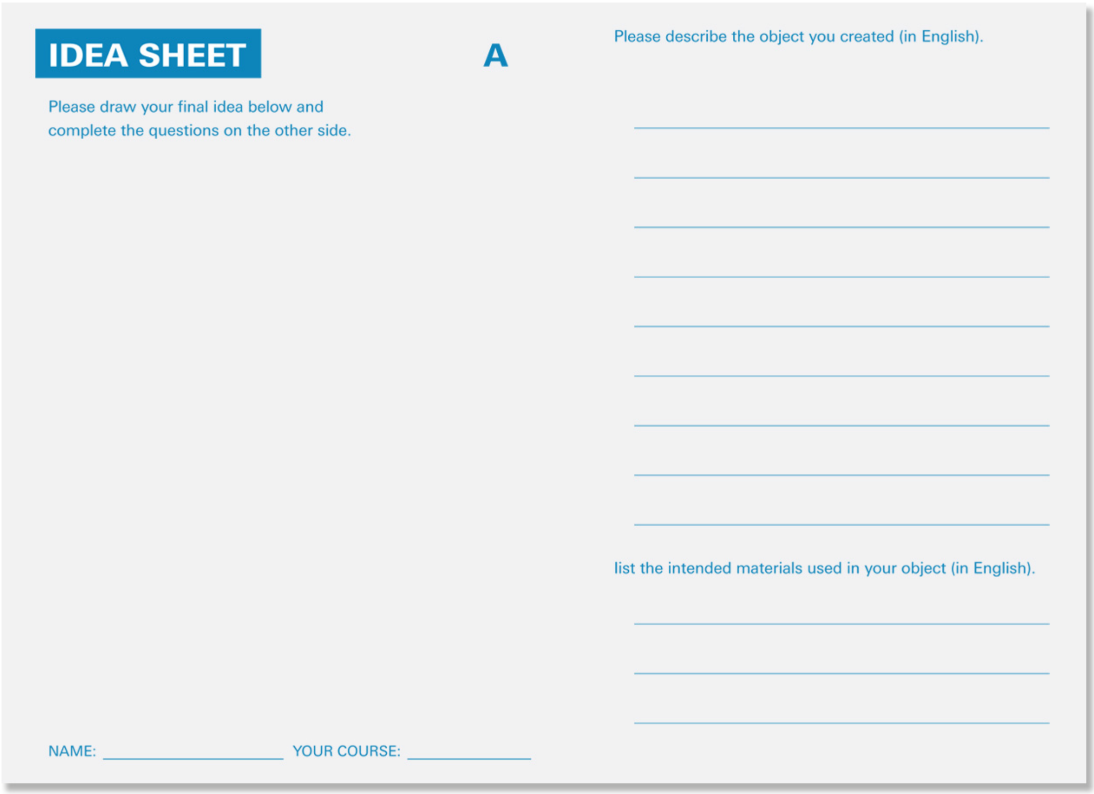



***Figure 51. Idea Sheet provided to each group.***

### 4.4.3.4 Participants

In total 60 design master students of both *Geneva School of Art and Design (HEAD)* and *École Cantonale D'Art de Lausanne (ECAL)* were involved in the workshop. The participants had diverse design backgrounds: Art Direction (ECAL), Fashion & Accessory Design (HEAD), Media Design (HEAD), Product Design (ECAL) and Space & Communication (HEAD). Although they have different expertise in each field all of them are the specialists in design discipline.

The 61 students were then divided into 3 groups:

- *23 students in Group A,*
- *19 students in Group B and*
- *19 students in Group C.*

The reason why the number of participants in Group A is bigger than the others was that the four participants joined just before the commencement of the task. Although the task was individual, the participants were gathered in three separate groups, depending on the fidelity level, and each one was respectively provided with a quiet room (Figure 52). Additionally, each space had an instructor and the participants completed the task following their guidance and the instruction written on the sheets. The master students of Art Direction Programme at ECAL are trained to be designers in photography or type design. The course of Art Direction at ECAL specialises particularly in *"storytelling:" building a narrative, editing and laying out content, creating sequences via printed and/or virtual matter (From ECAL, MAAD website)*. The master students of Fashion & Accessory Design Programme at HEAD are trained to be designers who are *capable of providing new aesthetic impulses, whether running their own clothing, accessory or jewellery brands or as artistic directors of established firms (From HEAD Genève, Fashion & Accessory Design Programme website)*. The master students of Media Design Programme at HEAD are trained for *careers as designers in digital media, interactive visual communication, information design and creative, research and innovation industries (From HEAD Genève, Media Design Programme website)*. The master students of Product Design Programme at ECAL are trained to be designers that *focus on the aspect of both personal practice/research and handling of commissions for clients, companies or producers (From ECAL, Product Design Master website).* Lastly, the master students of Space & Communication Programme at HEAD are trained to be designers that *specialise in signage, urban signs, graphic identities or exhibition labels, documents and catalogues to exhibition spaces and scenography industries (From HEAD Genève, Space & Communication Programme website)*.

***Figure 52. The study environment.***

Thus, the backgrounds of the participants were diverse and the skills in which they specialised were different. However, all the participants were being trained as designers that are demanded to deliver creative concept/ideas. The details regarding the composition of each group are described in the following:

Group A. The number of the Product Design students was the biggest, and the Space & Communication students were the smallest in this group (Table 9).

***Table 9*** *The composition of the participants in the group A.*

| DEPARTMENT | NUMBER OF PARTICIPANT |
|---|---|
| Art Direction (ECAL) | 4 |
| Fashion & Accessory Design (HEAD) | 4 |
| Media Design (HEAD) | 6 |
| Product Design (ECAL) | 8 |
| Space & Communication (HEAD) | 1 |

Group B. The number of the Art Direction students was the biggest, and the Product Design students were the smallest in this group (Table 10).

***Table 10*** *The composition of the participants in the group B.*

| DEPARTMENT | NUMBER OF PARTICIPANT |
|---|---|
| Art Direction (ECAL) | 8 |
| Fashion & Accessory Design (HEAD) | 4 |
| Media Design (HEAD) | 2 |
| Product Design (ECAL) | 1 |
| Space & Communication (HEAD) | 4 |

Group C. The number of the Product Design students was the biggest, and the Art Direction students were the smallest in this group (Table 11).

***Table 11*** *The composition of the participants in the group C.*

| DEPARTMENT | NUMBER OF PARTICIPANT |
|---|---|
| Art Direction (ECAL) | 1 |
| Fashion & Accessory Design (HEAD) | 4 |
| Media Design (HEAD) | 2 |
| Product Design (ECAL) | 6 |
| Space & Communication (HEAD) | 5 |

#### 4.4.3.5 Procedure

The study was conducted following the procedure:

1. The participants were randomly sorted into three groups and invited to each room.
2. Process Sheet and the *Idea Sheet* were provided by the instructors.
3. The participants were asked to reduce the visual elements of the wheelbarrow depicted on the Process Sheet step by step by drawing. In so doing, they were allowed to interpret the definition of the "reduction" in their own ways.
4. The participants were also asked to select one of the levels as an inspiration for the final idea that will eventually be finalised on *Idea Sheet*. Additionally, they were required to describe the reason why they selected the particular level on the reverse side of Process Sheet.
5. The participants were then asked to move to the *Idea Sheet* to finalise the idea and describe about it.

The participants were not allowed to discuss their task with others and this was monitored by the instructors. Each group started at 10 AM at the same time and the workshop was completed within one hour.

#### 4.4.3.6 Data Analysis

All the sheets were collected and the contents were analysed (Figure 53). Two types of data were collected in the analysis of the workshop:

1. drawings depicted on all the sheets provided, and
2. the contents of the description written on both Process Sheet and *Idea Sheet*.

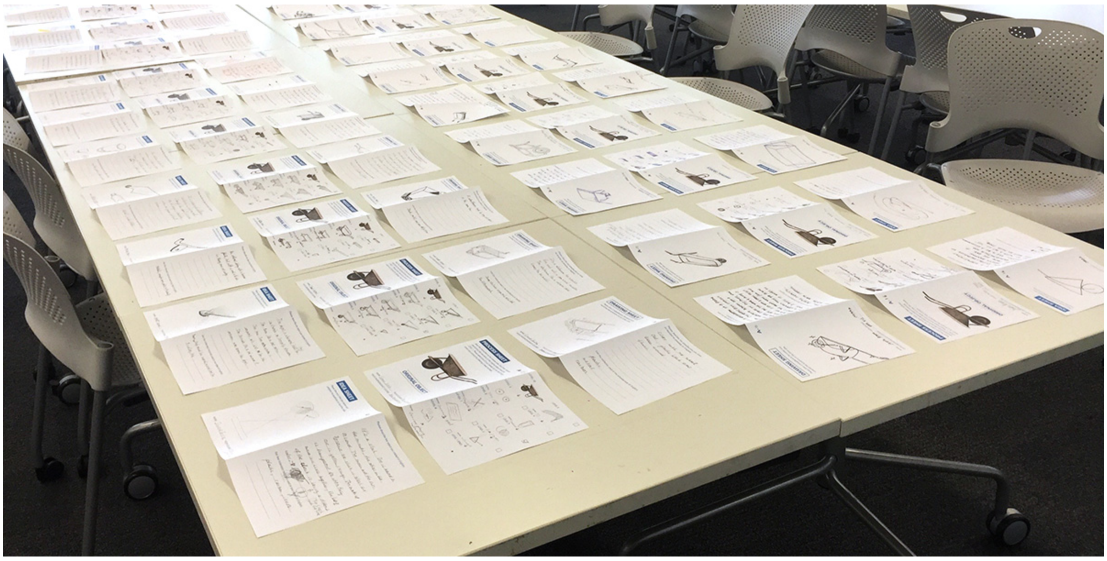


***Figure 53. The sheets collected.***

The drawings depicted on the sheets visually illustrated the idea developed during the task that was difficult to describe in words: appearance, form and volume, the structure, the movement and the narratives of the object. On the other hand, the written descriptions explained the details of the idea such as concept, context, materials, functionality, the process of idea generation and so on. Both types of data allowed the researcher to understand the object from multiple perspectives.

In order to identify the characteristics of the idea, the contents of the outcomes were analysed using a matrix (Figure 54). The images of the drawings showing the final ideas with the names were placed on the matrix. In this matrix scheme, the two axes were set:

A. resemblance to the wheelbarrow—distant from the wheelbarrow
B. functional—abstract

The axis A measured how the act of autonomous reduction encouraged the participants to conceive ideas in a variety of ways apart from the original wheelbarrow. The axis B, on the other hand, measured weather the ideas conceived became abstract (conceptual) or function focused (concrete).

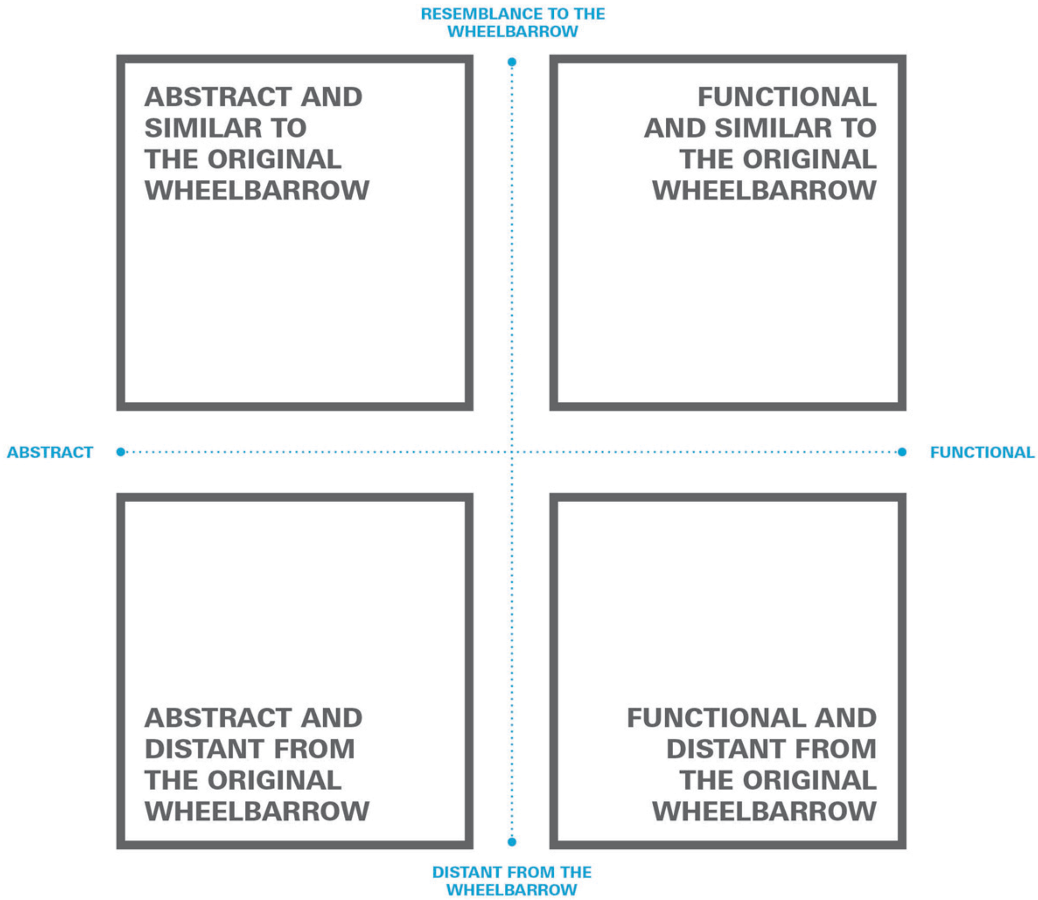



*Figure 54. The matrix used for the analysis.*

The upper-left quadrant represents the outcomes that are abstract but still similar to the original wheelbarrow. The upper-right quadrant represents the outcomes that are function focused but still similar to the original wheelbarrow. The lower-left quadrant represents the outcomes that are abstract and different from the original wheelbarrow. The lower-right quadrant represents the outcomes that are function focused and different from the original wheelbarrow. The positioning process was conducted based on the drawings and their names and descriptions of the outcomes.

### 4.4.4 Results

The result showed that in total twenty-four out of sixty-one participants (39%) conceived ideas of a wheelbarrow in the three groups (Figure 55). The participants who conceived the ideas of an object other than wheelbarrow were in total twenty-eight participants (46%) in the three groups. Within these participants, in total thirteen of them (21%) conceived ideas that cannot be classified into existing object categories. Also, in total eight (13%) participants conceived ideas of a pure concept other than developing an object as an outcome. The characteristics of the result were different amongst the three fidelity levels. The details of the results of each group are described in the following section.

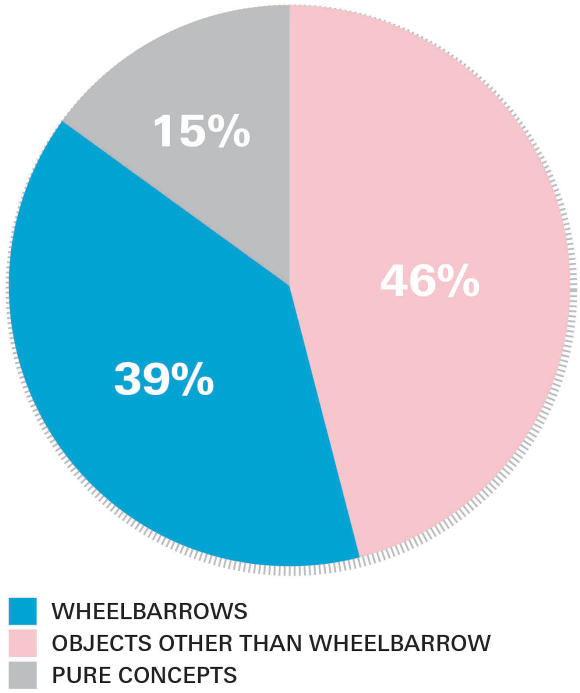



***Figure 55. Results of the outcome of the three groups.***

### 4.4.4.1 Result of Group A

In Group A, the participants envisaged ideas in a variety of forms (Figure 56). Six *(participants A2, A9, A11, A12, A22 and A23)* out of twenty-three participants (26%) conceived ideas related to a wheelbarrow. Two *(A9 and A22)* of them (9%) created objects that kept the similar typology as the original wheelbarrow. Then, the others *(A2, A11, A12 and A23)* conceived ideas of a wheelbarrow, removing parts or modifying details. The participant A16 conceived an abstract *representation* of a wheelbarrow. However, this outcome was not considered as a wheelbarrow as an object. The idea of A16 was conceived based on the inspiration from an Italian proverb related to wheelbarrow: *"if my grandmother had wheels, she would be a wheelbarrow" (translated into English by A16)*.

Other than the ideas relating to a wheelbarrow, seventeen participants (74%) conceived ideas that were classified in different categories. Within these participants, six of them *(A4, A6, A10, A19, A20 and A21)* (26%) conceived ideas of an object that utilise the mobility function of a wheelbarrow. Five participants *(A3, A10 A13 A19 and A24)* (22%)

conceived ideas that cannot be classified into existing object categories. For example, A3 conceived an idea of a large container for flowers that has a function of pouring water. A3 named this object as “a bath for plants.” Or, the participant A13 conceived the idea of a musical instrument with a function of a wrench.

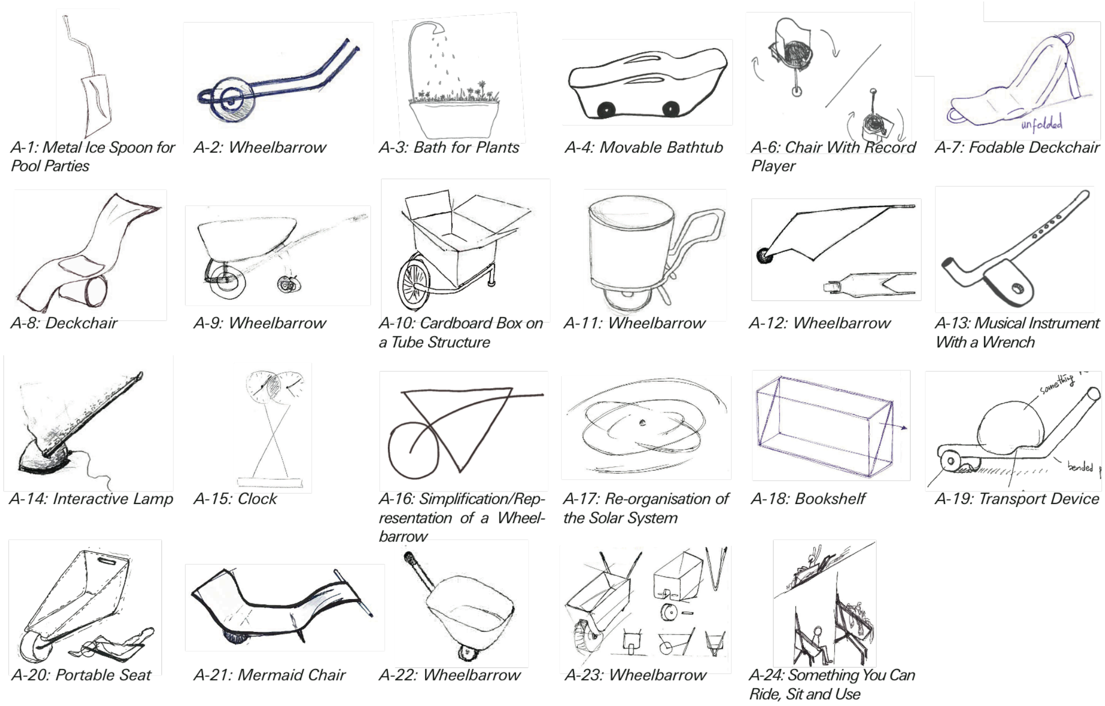



***Figure 56. The results of Group A.***

The list of the outcomes of Group A is presented below (Table 12).

***Table 12*** *List of the outcomes of Group A.*

| | BACKGROUND | CREATED OBJECTS<br>(stated by the participants) | OBJECT CATEGORY |
|---|---|---|---|
| A1 | FA/AC | Metal Ice Spoon for Pool Parties | Spoon |
| A2 | FA/AC | Wheelbarrow | **Wheelbarrow** |
| A3 | FA/AC | A Bath for Plants | *New Category* |
| A4 | FA/AC | Movable Bathtub | Bathtub |
| A6 | SP/COM | Chair with Record Player | Chair |
| A7 | MD | Foldable Deckchair | Deckchair |
| A8 | MD | Deckchair | Deckchair |
| A9 | MD | Wheelbarrow | **Wheelbarrow** |
| A10 | PD | Cardboard Box on a Tube Structure | *New Category* |
| A11 | PD | Wheelbarrow | **Wheelbarrow** |
| A12 | MD | Wheelbarrow | **Wheelbarrow** |
| A13 | MD | Musical Instrument with a Wrench | New Category |
| A14 | MD | Light (interactive lamp) | Lamp |
| A15 | AD | Clock (Minutes + Second) | Clock |
| A16 | AD | Simplification/Representation of a Wheelbarrow | Pure Concept |
| A17 | AD | Re-organisation of the Solar System | Pure Concept |
| A18 | AD | Bookshelf | Bookshelf |
| A19 | PD | Transport Device | *New Category* |
| A20 | PD | Portable Seat | Seat |
| A21 | PD | Mermaid Chair | Chair |
| A22 | PD | Wheelbarrow | **Wheelbarrow** |
| A23 | PD | Wheelbarrow | **Wheelbarrow** |
| A24 | PD | Something You Can Ride, Sit and Use | *New Category* |

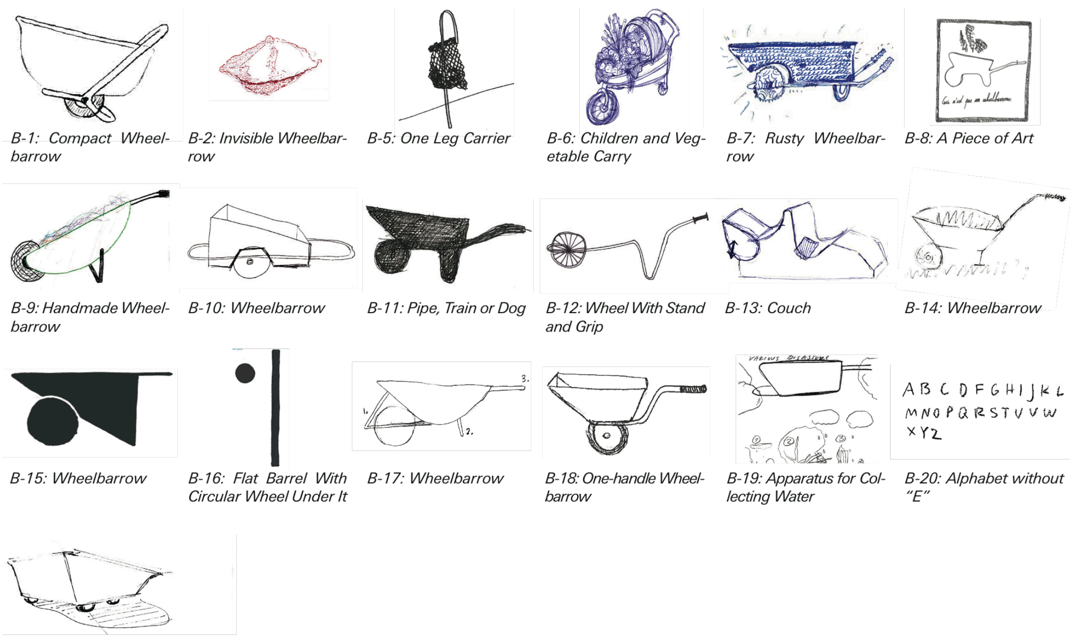
***FA/AC****: Fashion & Accessory Design,* ***SP/COM****: Space & Communication,* ***MD****: Media Design,* ***PD****: Product Design,* ***AD****: Art Direction*

## 4.4.4.2 Result of Group B

The result of Group B is presented (Figure 57). In this group, ten *(B1, B2, B7, B9, B10, B14, B15, B17, B18 and B21)* out of nineteen participants (53%) developed ideas of a wheelbarrow. Within these participants, six *(B1, B7, B9, B14, B17 and B18)* of them (32%) conceived ideas that kept the similar typology as the original wheelbarrow. Most of these ideas were developed by reducing or modifying a few elements of the original wheelbarrow. Others *(B2, B10, B15, B21)* (21%) conceived ideas of a wheelbarrow whose forms were altered. However, except for B2, these objects still kept the functions of container and mobility. The participant B2 represented an invisible wheelbarrow by depicting only the contents of the container.

Other than ideas of a wheelbarrow, nine participants (47%) conceived ideas that were classified in different categories. Within these participants, four of them *(B5, B6, B12 and B19)* (21%) conceived ideas of an object that cannot be classified into existing object categories. For example, B5 conceived an idea of a carrier with one leg. Although the function as a container was taken over from the original wheelbarrow this "carrier" is a never-seen-before object. Or, B19 conceived an apparatus for collecting water. This idea also kept the functionality as a container but used in a different context.

Another characteristic of this group was that four participants *(B2, B8, B16 and B20)* (21%) conceived objects with conceptual approaches. For example, B8 conceived a painting of the outline of a wheelbarrow as an art piece. Or, B20 conceived a set of alphabets without "E."




*B-1: Compact Wheelbarrow* | *B-2: Invisible Wheelbarrow* | *B-5: One Leg Carrier* | *B-6: Children and Vegetable Carry* | *B-7: Rusty Wheelbarrow* | *B-8: A Piece of Art*

*B-9: Handmade Wheelbarrow* | *B-10: Wheelbarrow* | *B-11: Pipe, Train or Dog* | *B-12: Wheel With Stand and Grip* | *B-13: Couch* | *B-14: Wheelbarrow*

*B-15: Wheelbarrow* | *B-16: Flat Barrel With Circular Wheel Under It* | *B-17: Wheelbarrow* | *B-18: One-handle Wheelbarrow* | *B-19: Apparatus for Collecting Water* | *B-20: Alphabet without "E"*

*B-21: Wheelbarrow*

***Figure 57. The results of Group B.***

The list of the outcomes of Group B is presented below (Table 13).

***Table 13*** *List of the outcomes of Group B.*

| | **BACKGROUND** | **CREATED OBJECTS** (stated by the participants) | **OBJECT CATEGORY** |
|---|---|---|---|
| B1 | MD | Compact wheelbarrow | **Wheelbarrow** |
| B2 | PD | Wheelbarrow | **Wheelbarrow** |
| B5 | FA/AC | One Leg Carrier | *New Category* |
| B6 | FA/AC | Children and Vegetable Carry | *New Category* |
| B7 | SP/COM | Rusty Wheelbarrow | **Wheelbarrow** |
| B8 | SP/COM | A Piece of Art | Art Piece |
| B9 | SP/COM | Handmade Wheelbarrow | **Wheelbarrow** |
| B10 | AD | Wheelbarrow | **Wheelbarrow** |
| B11 | SP/COM | Pipe, Train or Dog | Pure Concept |
| B12 | AD | Wheel with Stand and Grip | *New Category* |
| B13 | MD | Couch | Couch |
| B14 | FA/AC | Wheelbarrow | **Wheelbarrow** |
| B15 | AD | Wheelbarrow | **Wheelbarrow** |
| B16 | AD | Flat Barrel with Circular Wheel Under It | Pure Concept |
| B17 | AD | Wheelbarrow | **Wheelbarrow** |
| B18 | AD | One-handle Wheelbarrow | **Wheelbarrow** |
| B19 | AD | Apparatus for Collecting Water | *New Category* |
| B20 | AD | Alphabet without "E" | Pure Concept |
| B21 | FA/AC | Wheelbarrow with Second Function | **Wheelbarrow** |

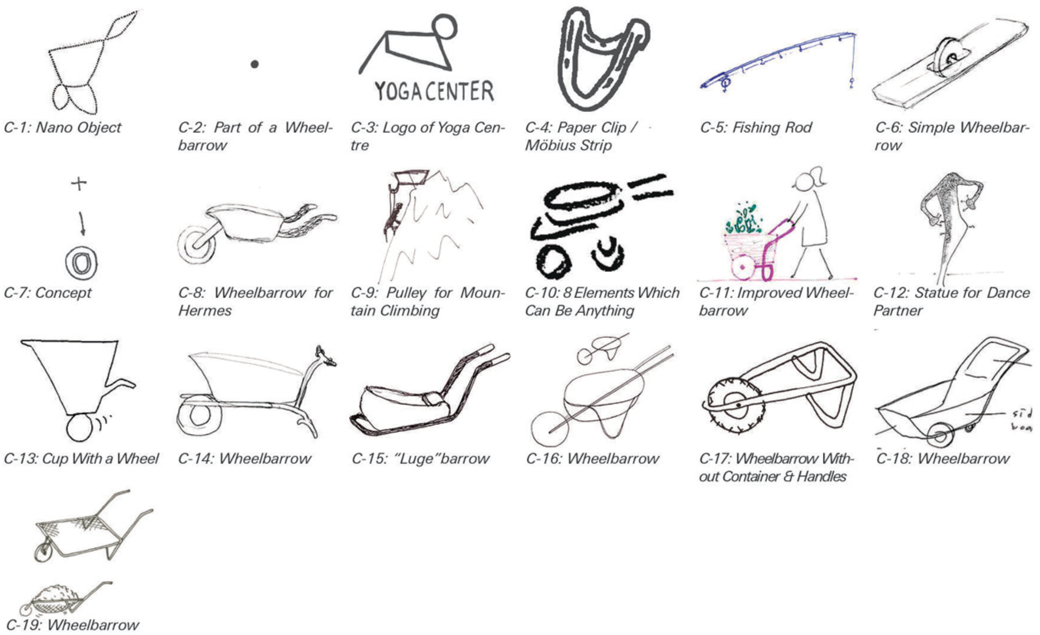
***FA/AC**: Fashion & Accessory Design, **SP/COM**: Space & Communication, **MD**: Media Design, **PD**: Product Design, **AD**: Art Direction*

#### 4.4.4.3 Result of Group C

The result of Group C is presented (Figure 58). In this group, eight *(C6, C8, C11, C14, C16, C17, C18 and C19)* out of nineteen participants (42%) conceived the ideas of a wheelbarrow. Within these participants, six *(C8, C,11 C14, C16, C18 and C19)* of them (32%) conceived ideas that kept the similar typology to the original wheelbarrow. These ideas were mostly developed by altering particular components of a wheelbarrow. For example, C8 conceived a wheelbarrow whose handles were decorated in a particular way. Or, C19 conceived a wheelbarrow whose part of the container was replaced with an elastic net. Although some elements of these ideas were altered, the objects conceived were still maintaining the essential functionalities of a wheelbarrow i.e. having a container and being maneuvered with handles. The other two participants *(C6 and C17)* also conceived a wheelbarrow by removing major elements of the original object. For example, C6 removed most of the elements of a wheelbarrow but just kept a wheel. C17 stated that they conceived an idea of a wheelbarrow by getting rid of a container and handles.

Other than ideas of a wheelbarrow, eleven participants (58%) conceived ideas that were classified in different categories. Within these participants, four of them *(C1, C12, C13 and C15)* (21%) conceived ideas of an object that cannot be classified into existing object categories. For example, C1 conceived *a nano-object that are observed with a microscope*. This nano-object is set in a medical camera and put in our body for the purpose of analysis (C1). C12 conceived an object that is used as a training gear for dancers. The human body-like object with velvet skin plays a role as a dance partner for training (C12).

Some participants in Group C conceived conceptual ideas. For example, C2 conceived a black dot that represents part of a wheelbarrow. Although C2 stated that this black dot is part of a wheelbarrow, the idea did not suggest any concrete object. Similarly, C10 conceived the idea of the deconstructed eight elements. Although the idea seemed to refer to the form of the original wheelbarrow, each element can be transformed into different objects depending on the way they were composed.




C-1: Nano Object
C-2: Part of a Wheelbarrow
C-3: Logo of Yoga Centre
C-4: Paper Clip / Möbius Strip
C-5: Fishing Rod
C-6: Simple Wheelbarrow
C-7: Concept
C-8: Wheelbarrow for Hermes
C-9: Pulley for Mountain Climbing
C-10: 8 Elements Which Can Be Anything
C-11: Improved Wheelbarrow
C-12: Statue for Dance Partner
C-13: Cup With a Wheel
C-14: Wheelbarrow
C-15: "Luge"barrow
C-16: Wheelbarrow
C-17: Wheelbarrow Without Container & Handles
C-18: Wheelbarrow
C-19: Wheelbarrow

*Figure 58. The results of Group C.*

The list of the outcomes of Group C is presented below (Table 14).

***Table 14*** *List of the outcomes of Group C.*

| | **BACKGROUND** | **CREATED OBJECTS** (stated by the participants) | **CATEGORY** |
|---|---|---|---|
| C1 | SP/COM | Nano Object Observed with Microscope | *New Category* |
| C2 | SP/COM | Part of a Wheelbarrow | Pure Concept |
| C3 | MD | Logo of Yoga Centre | Company Logo |
| C4 | SP/COM | Paper Clip / Möbius Strip | Clip/strip |
| C5 | MD | Fishing Rod | Fishing Rod |
| C6 | SP/COM | Simple Wheelbarrow | **Wheelbarrow** |
| C7 | FA/AC | Concept | Pure Concept |
| C8 | FA/AC | Wheelbarrow for Hermes | **Wheelbarrow** |
| C9 | SP/COM | Pulley for Mountain Climbing | Pulley |
| C10 | SP/COM | 8 Elements Which Can Be Anything | Pure Concept |
| C11 | PD | Improved Wheelbarrow | **Wheelbarrow** |
| C12 | FA/AC | Statue for Dance Partner | *New Category* |
| C13 | FA/AC | Cup with a Wheel | *New Category* |
| C14 | PD | Wheelbarrow | **Wheelbarrow** |
| C15 | PD | "Luge" barrow | *New Category* |
| C16 | AD | Wheelbarrow | **Wheelbarrow** |
| C17 | PD | Wheelbarrow Without Container & Handles | **Wheelbarrow** |
| C18 | PD | Wheelbarrow | **Wheelbarrow** |
| C19 | PD | Wheelbarrow | **Wheelbarrow** |

***FA/AC***: *Fashion & Accessory Design,* ***SP/COM***: *Space & Communication,* ***MD***: *Media Design,* ***PD***: *Product Design,* ***AD***: *Art Direction*

## 4.4.5 Findings

The characteristics of both outcomes and the reductive process of the participants are described in this section.

### 4.4.5.1 Outcomes

Each group had different characteristics in terms of the types of the outcomes conceived (Figure X). The result showed that most participants of the high-fidelity group (A) conceived ideas that were not in the form of a wheelbarrow. Also, 9% of the participants conceived abstract concepts. The group that was given the line drawing representation of the wheelbarrow (B) had a tendency to conceive the idea of a wheelbarrow the most. The ideas, however, regarding abstract concepts increased compared to Group A. Group C (given the dotted line drawing of the wheelbarrow) conceived ideas of both a wheelbarrow and other objects. Also, 15% of the participants conceived ideas regarding abstract concepts and 5% of them conceived the idea that was neither an object nor a pure concept, i.e. a company's logo.

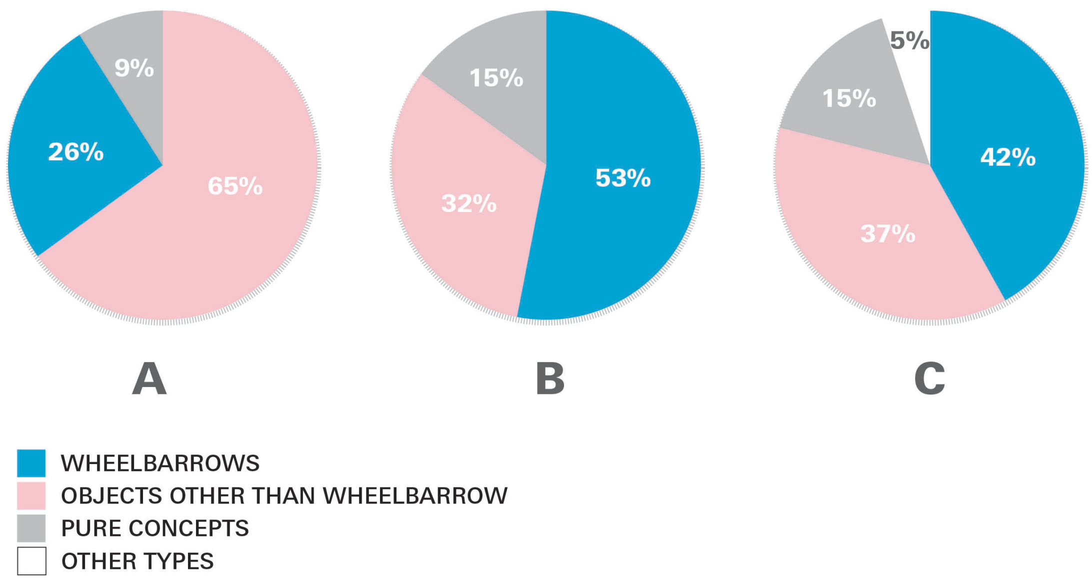
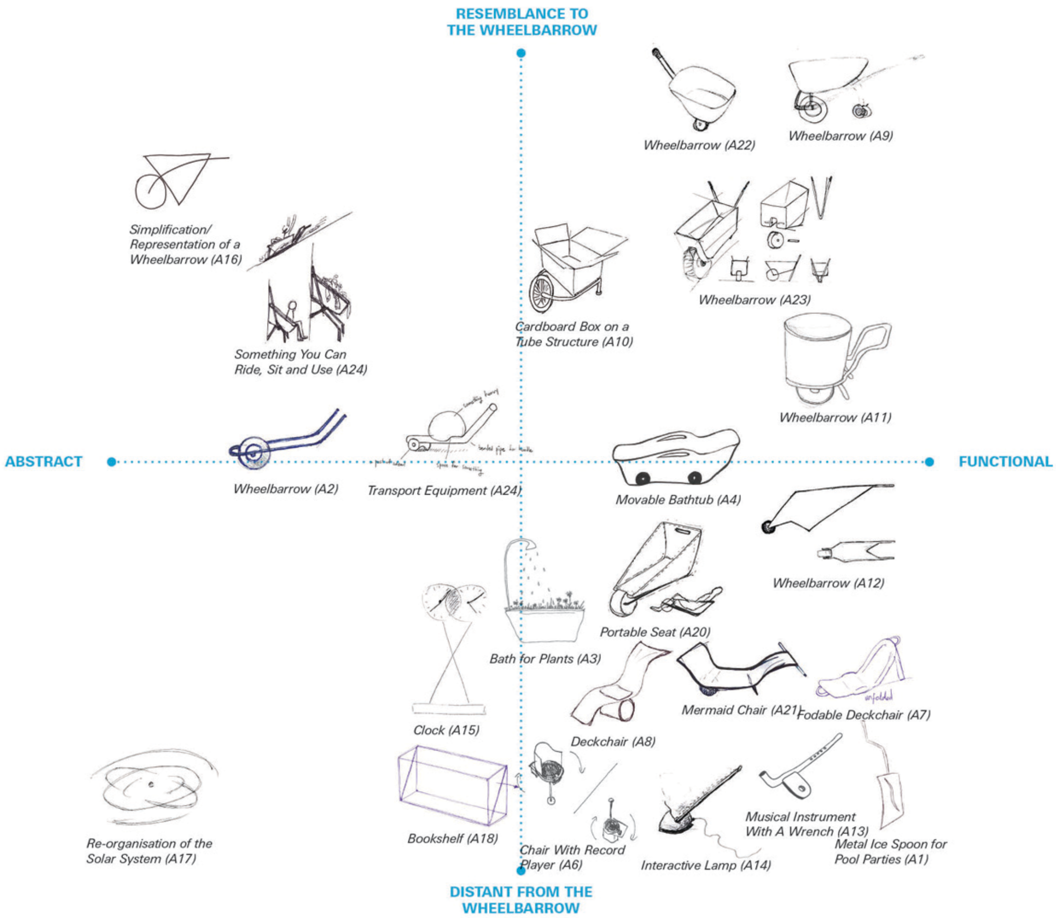



*Figure 59. The type of outcomes among three groups.*

The outcomes were also analysed using the matrix. The participants of Group A had a tendency to conceive ideas of an object that focused on functionality (Figure 60). Many ideas, regardless of the types of object, were located on the right side of the matrix where the ideas that focused on functionality were collected. In fact, some of the ideas included names descriptive of its functionality e.g. *"movable bathtub," "portable seat," "interactive lamp"* *"metal ice spoon for pool parties"* and so on. This appeared to suggest that the participants of this group had a tendency to focus on the aspect of the functionality of an object in their ideation. A few participants conceived very abstract ideas i.e. *"re-organisation of the solar system"* and *"simplification/representation of a wheelbarrow."*

Another characteristic of this group was that many ideas appeared to propose different forms away from the shape of the original wheelbarrow. Even though six participants conceived ideas as a wheelbarrow, some of their forms were altered. For example, A11 conceived the idea of a wheelbarrow whose form was transformed into a cylindrical shape. Or, A12 conceived the idea of a wheelbarrow that has a geometric form. Other than ideas of a wheelbarrow, six participants conceived ideas of an object to sit on (A6, A7, A8, A20, A21 and A24). These ideas appeared to be conceived by transforming the characteristics of the form of the original wheelbarrow. Many of these ideas were composed of flat surfaces that are similar to the original wheelbarrow. Or, they associated the container part of the original wheelbarrow with a seat. Thus, many ideas of Group A seemed to be developed focusing on the forms and this characteristic was prominent only in this group. As a matter of fact, many ideas in Group B and C appeared to be developed by either getting rid of the elements or taking over the features of the form of the original wheelbarrow.

*Figure 60. The outcomes of Group A mapped on the matrix.*




The results of Group B showed that more than half participants (ten out of nineteen) conceived ideas of a wheelbarrow (Figure 61). Many of these participants conceived ideas by removing or altering parts of the original wheelbarrow. The visual prompt represented by line drawing seemed to encourage the participants to stick to the idea of a wheelbarrow.

Despite the fact that many participants of this group conceived ideas that share the same typology of the object as a wheelbarrow, five participants developed very conceptual and abstract ideas. For example, B2 conceived the idea of a wheelbarrow that is not visible so that the form of the wheelbarrow is depending on the way in which the viewer sees. B16 conceived the idea titled “flat barrel with a circular wheel under it” by depicting a black dot and a line. Or, B11 depicted a silhouette of a wheelbarrow and titled it as “Pipe, Train or Dog.” Thus, several participants conceived ideas by taking conceptual approaches and this characteristic was not prominent in Group A.

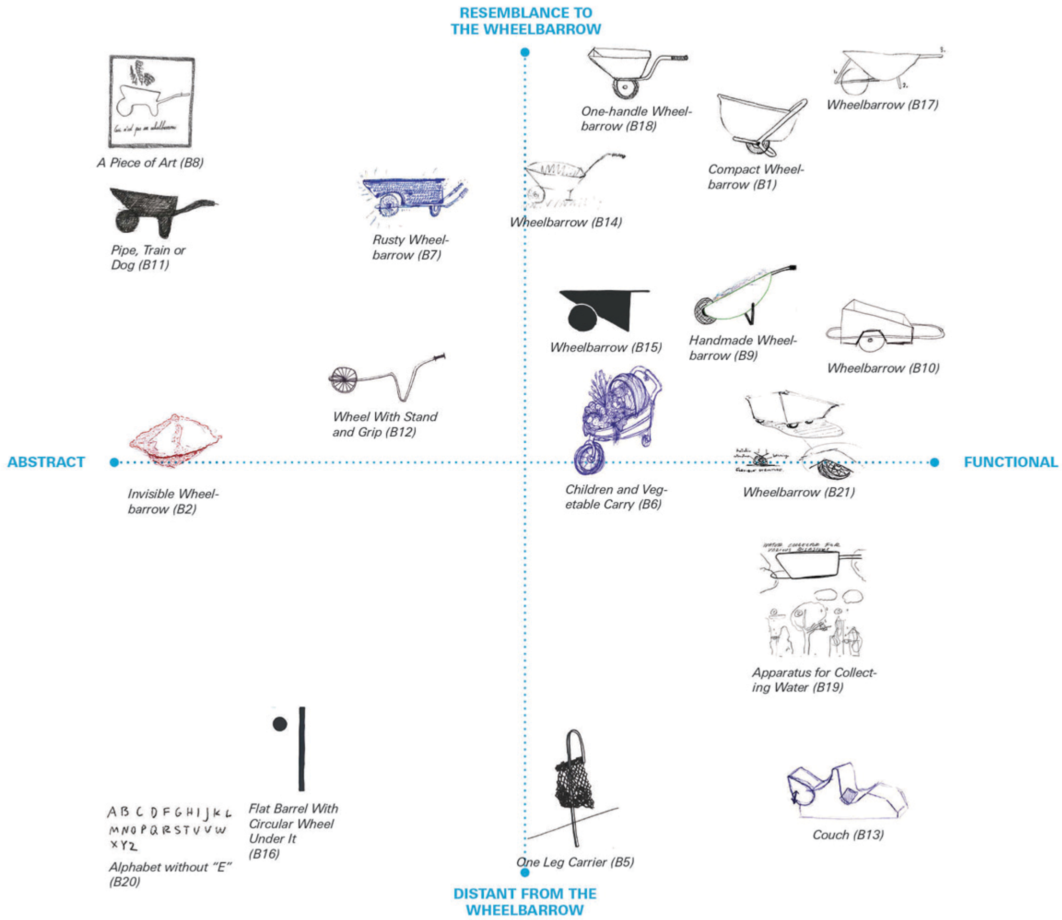
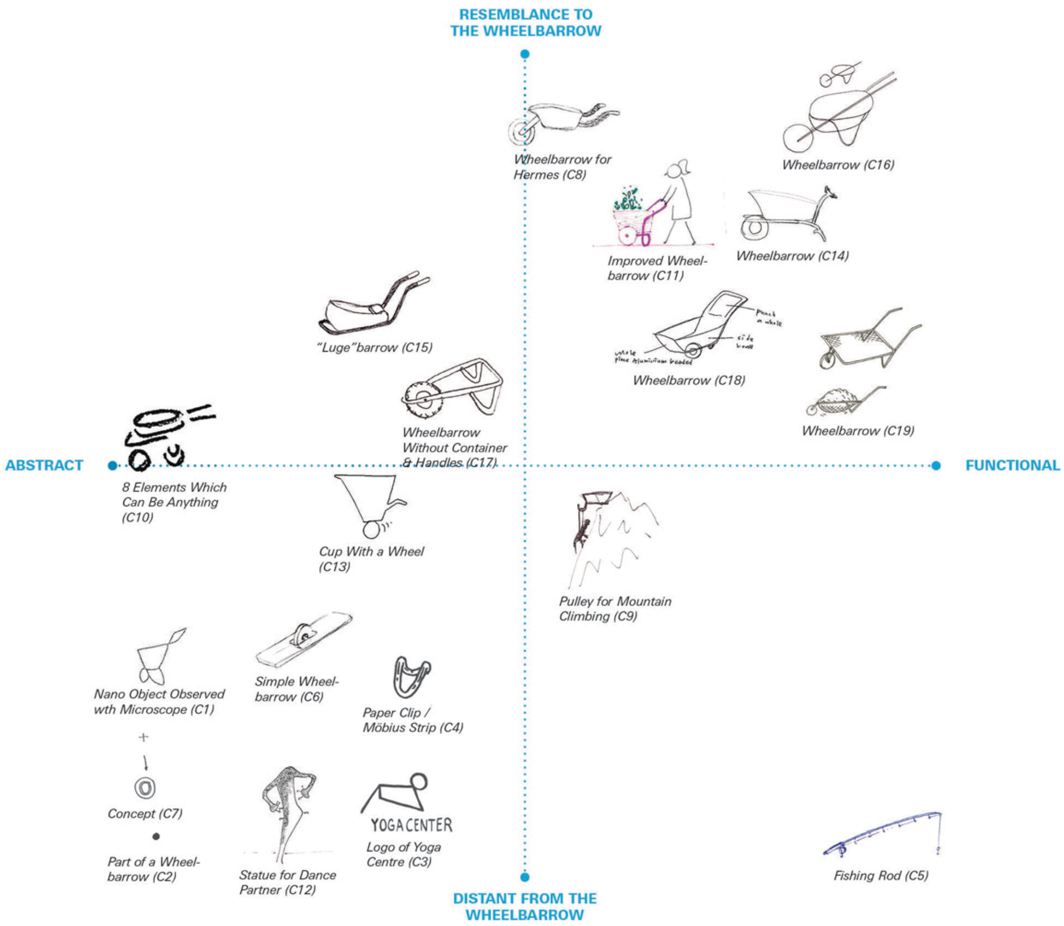



*Figure 61. The outcomes of Group B mapped on the matrix.*

The results of Group C showed that the types of outcomes conceived were clearly split into two areas on the matrix (Figure 62). Eight out of nineteen participants conceived abstract objects or concepts that were far from the original wheelbarrow (C1, C2, C3, C4, C6, C7, C10 and C12). On the other hand, six participants created wheelbarrows that kept the same typology or functionality as the original (C8, C11, C14, C16, C18, and C19). This appeared to suggest that the participants who were given the visual prompt that was represented with dotted lines had a tendency to either conceive ideas conceptually or develop objects focusing on the physical aspects of the original wheelbarrow. In particular, the level of abstractness in ideas appeared to be high in Group C. For example, C1 conceived the idea of a "nano-object" that is put in our body for the purpose of medical analysis. Although the context in which the object is used was concrete, the outcome as an object was still abstract and conceptual. C2 conceived the idea of a black dot that represents part of a wheelbarrow. What this idea suggested was not the idea as an object but more about the approach in which C2 conceived the idea. Instead of conceiving an idea following the rules of the task, C2 purposefully presented the "tricky" answer that can be interpreted in many ways. Or, C7 conceived the idea that represents how the concept of "wheelbarrow" is composed. In this idea, the symbol of "+" represented "barrow" and "o" stood for "wheel." C7's idea represented that the word of "wheelbarrow" consisted of the combination of these two concepts. Thus, what C7 suggested was not an object but the way in which C7 recognise the word.

***Figure 62. The outcomes of Group C mapped on the matrix.***




In conclusion, the outcomes appeared to suggest that the approaches towards conceiving an object were different depending on the fidelity levels of the visual prompt. The participants who were given the high-level of visual fidelity had a tendency to conceive ideas, focusing on the aspect of both *"functionality"* and *"form"* of objects. On the other hand, the number of *"abstract ideas"* increased when the participants were provided with the lower-levels of visual fidelity.

### 4.4.5.2 Reductive Process

All the reductive processes depicted on each *Process Sheet* were used for the analysis. Each process was categorised into groups depending on the reductive approach and five characteristics emerged:

1. *Reduction by gradually removing components*
2. *Reduction by abstracting or simplifying forms*
3. *Reduction by altering sizes of the object*
4. *Reduction by modifying particular details*
5. *Reduction by other actions*

The first pattern was *"reduction by gradually removing components."* Many participants implemented their reductive processes by removing components of the original wheelbarrow, i.e. the wheel, the bucket and so on, step by step. The final idea was conceived based on one of the drawings that was depicted within the reductive process. For example, the participant A13 conducted their reductive process by removing the components one by one (Figure 63). Then, A13 selected the image depicted on the level 3, seeing it as a musical instrument: *"I like the shape and it looks like an instrument" (A13)*. Or, B5 conducted their reductive process by decreasing the volume of the components (Figure 64). B5 reduced the elements until the point where the object became a frame and used the image as an inspiration for the final idea that was a bag with one leg.

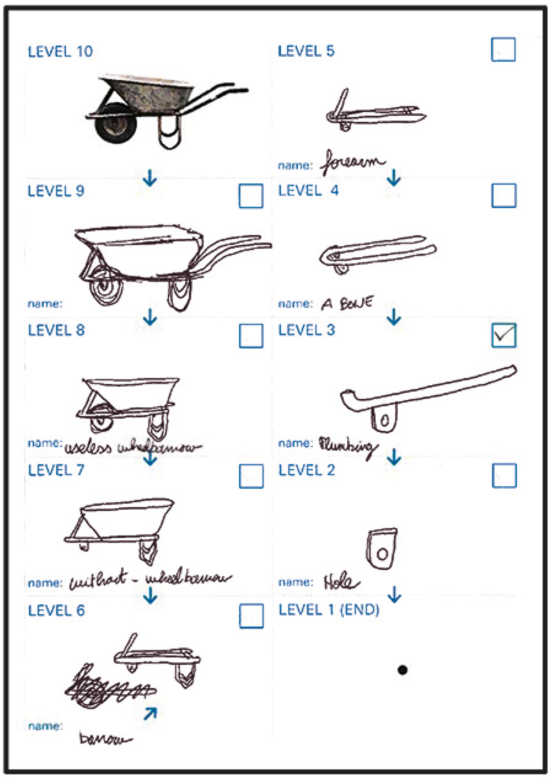



*Figure 63. The process of A13.*

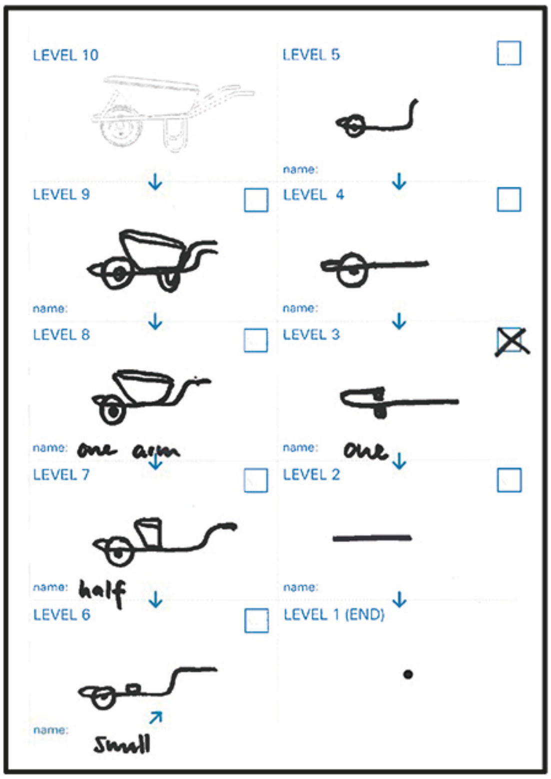



*Figure 64. The process of B5.*

The second pattern was *"reduction by abstracting or simplifying forms."* Many participants also implemented their reductive processes by abstracting or simplifying the elements of the original wheelbarrow into a different representation. For example, the participant C3 implemented their reductive process by changing the dimensions of the way in which the original wheelbarrow was seen (Figure 65). C3 then conceived the final idea that was the visual identity of a yoga centre by turning the figure depicted on the level 1 upside down. A18 implemented their reductive process by abstracting the form of the original wheelbarrow into geometric shape (Figure 66). A18 then discovered the idea of a bookshelf within the process.

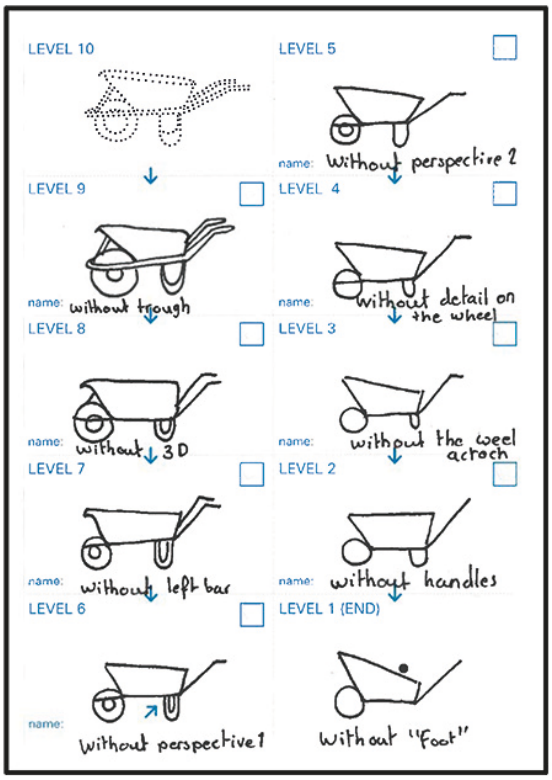



*Figure 65. The process of C3.*

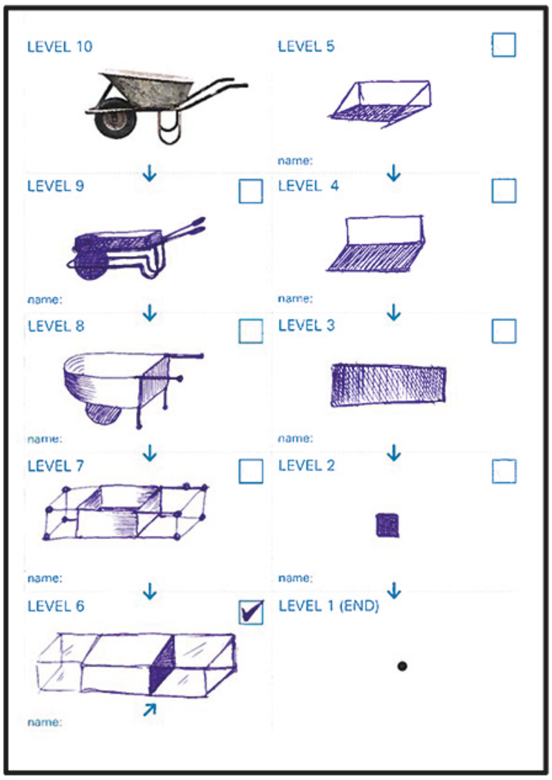



*Figure 66. The process of A18.*

The third pattern was *"Reduction by altering sizes of the object."* Several participants implemented their reductive process by shrinking or expanding the form of the original wheelbarrow. For example, the participant B6 implemented their reductive process by downscaling the original wheelbarrow (Figure 67) and discovering an image of a pram: *"I chose the level 4 because the proportions of this drawing make me think about a children carry" (B6)*. On contrary, C2 implemented their reductive process by expanding the scale of the dotted image of the original wheelbarrow (Figure 68). Then, C2 selected the black dot depicted on the level 1 as part of the wheelbarrow.

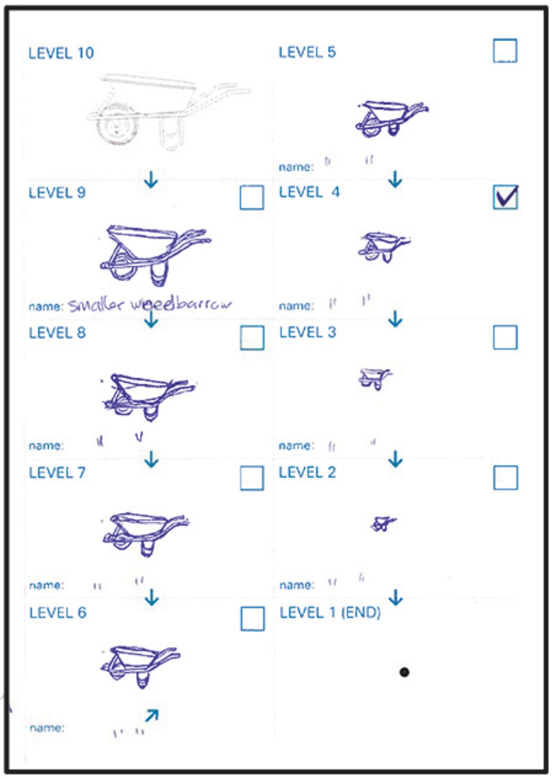



Figure 67. The process of B6.

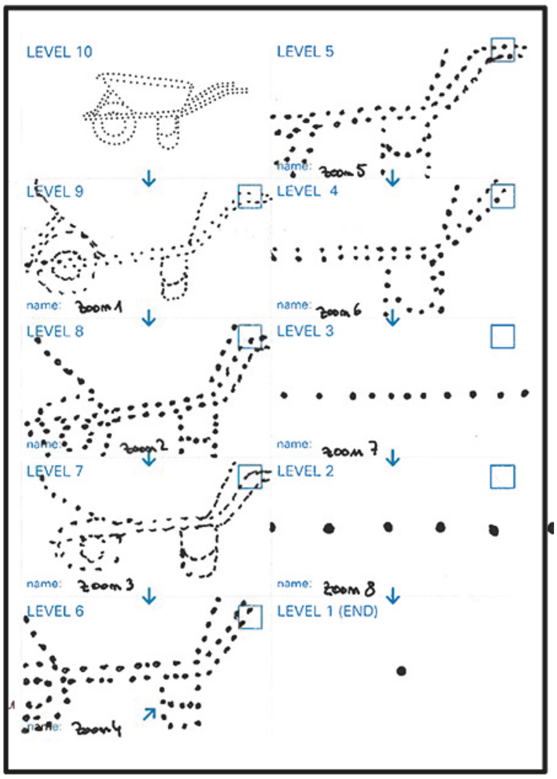



Figure 68. The process of C2.

The fourth pattern was *"Reduction by modifying particular details."* Several participants implemented their reductive process by changing particular elements of the original wheelbarrow. For example, B1 implemented their reductive process focusing on the handles and the position of the wheel of the wheelbarrow. B1 gradually transformed the form of the separate handles into a united tubular shape, and the position of the wheel became centred as the entire volume shrunk (Figure 69). Or, C7 focused only on the shape of the wheel throughout the reductive process. C7 developed their reductive process by reducing the number of dots one by one (Figure 70).

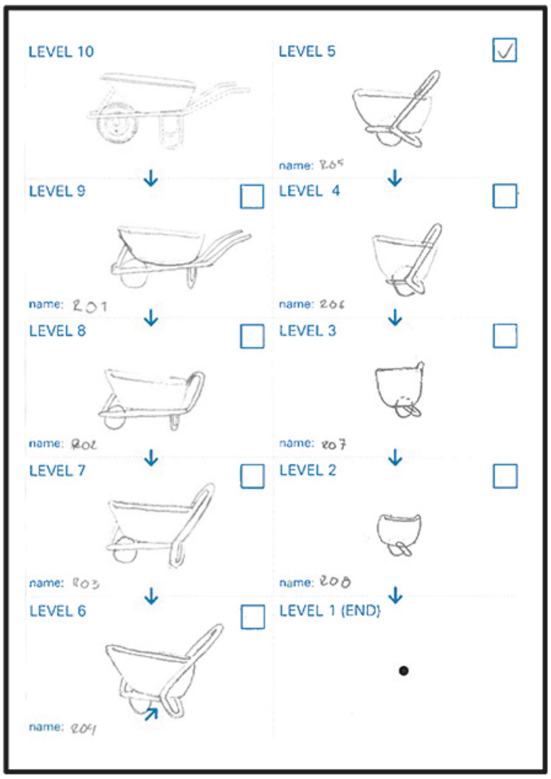



*Figure 69. The process of B1.*

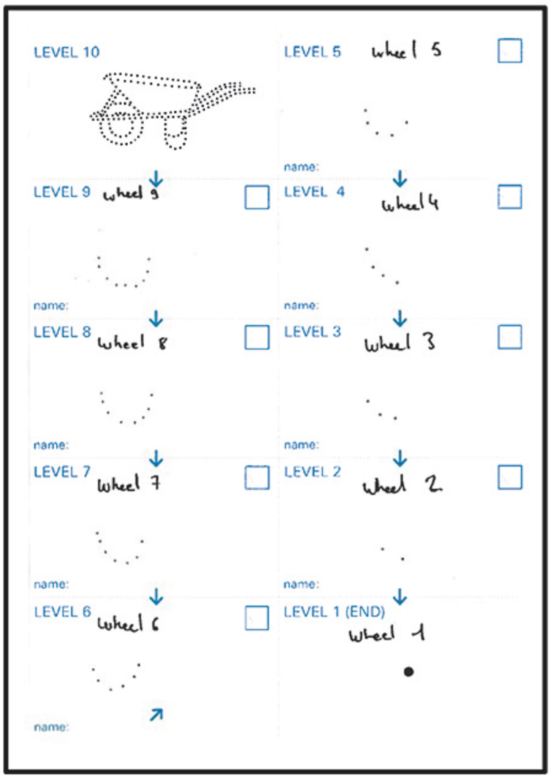



*Figure 70. The process of C7.*

The fifth pattern was *"Reduction by other actions."* Two participants implemented their reductive process by their unique approaches. This characteristic was only observed in Group A. Participant A15 randomly conceived abstract ideas regardless of the reductive levels indicated on the sheet (Figure 71). A15 described that *they wanted to start thinking of ideas from more emotional and mysterious perspective rather than the material dimension (A15)*. A15 appeared to dismiss the rules of reduction from the beginning. A7, on the other hand, separately depicted individual components of the wheelbarrow on each level (Figure 72) A7 then conceived the idea of a foldable deck chair by turning one of the depicted components of the wheelbarrow: *"I chose the level 4 because if you turn it in another way, it made me think of the structure of a deck chair" (A7).*

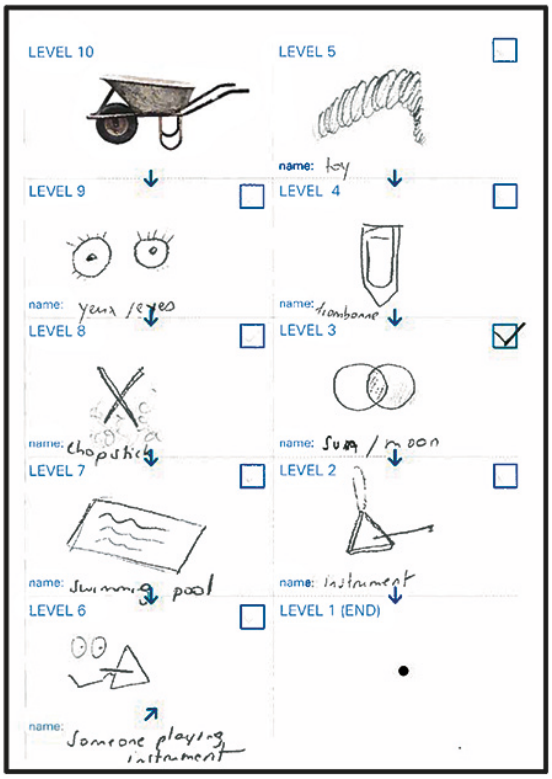



*Figure 71. The process of A15.*

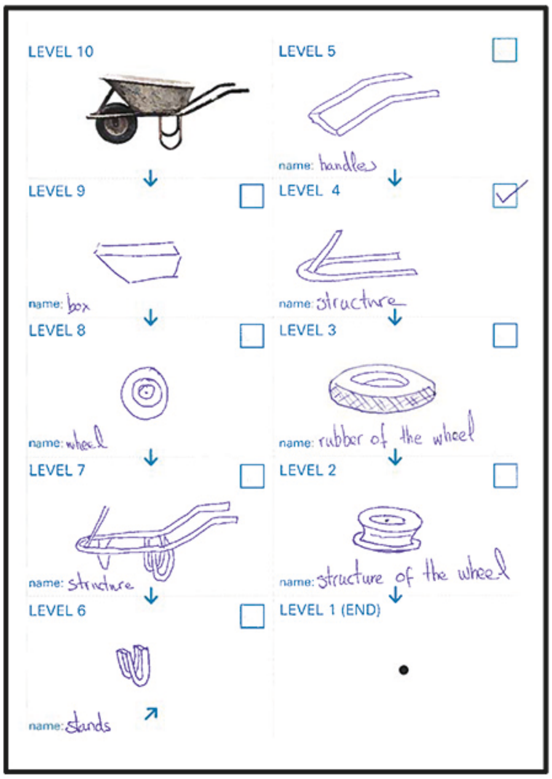
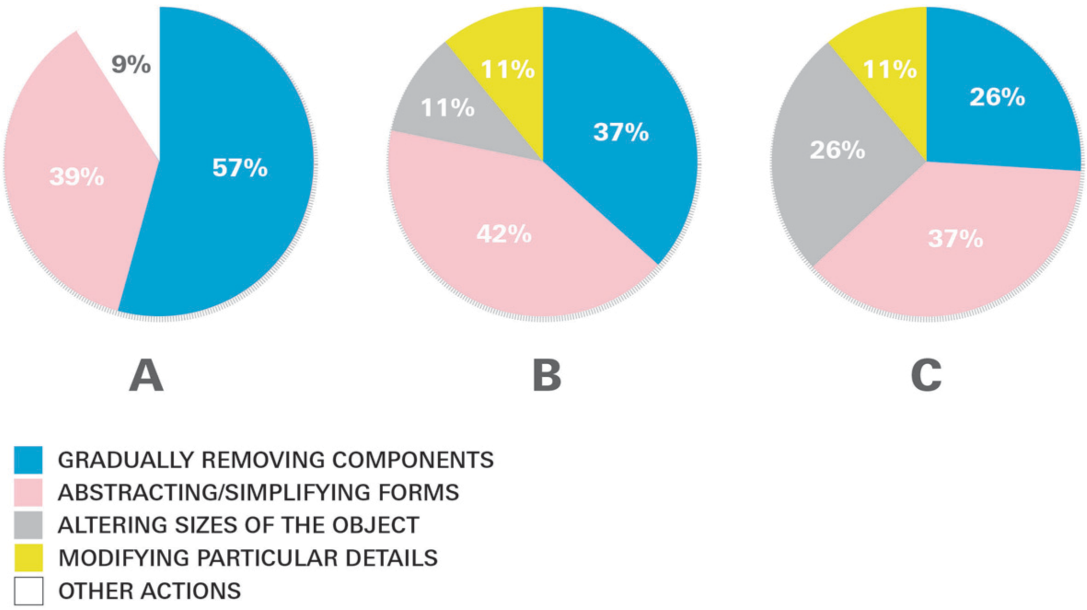



*Figure 72. The process of A7.*

The processes in which the participants reduced the elements of the original wheelbarrow were different amongst the three fidelity groups (Figure 73). In the high-fidelity group, the number of participants who took the approach in which they reduced the elements by gradually removing components was the biggest. As the fidelity level decreased, however, this tendency became less dominant. Instead, the other approaches that are “altering sizes” or “modifying particular details” appeared.

*Figure 73. The difference of the reductive approaches amongst the three fidelity groups.*




## 4.4.6 Conclusion of the Preliminary Study 3

The aim of this study was observing the impact of reductive approach implemented autonomously on the design practitioners' idea generation. The results showed that the aspects that the participants focused on in conceiving outcomes were different amongst the three groups that were given different levels of visual fidelity.

The participants had a tendency to focus on the aspects of *"functionality"* and *"form"* of an object when they were provided with a high-fidelity prompt (Group A). Further, the majority of the participants of this group implemented their reductive process by removing each component of the original wheelbarrow. This characteristic appeared to suggest that the participants considered the composition of the components and developed the reductive process, focusing on the physical aspects of the object.

On the other hand, as the fidelity-level of the original prompt given was reduced (Group B & C), the participants had a tendency to conceive *"concept-driven"* ideas. The reduced fidelity levels appeared to encourage the participants to conceive more abstract approaches in their outcomes. The results also showed that, even though some participants still implemented their reductive process by removing each component, other approaches that focused on the size or the particular element of the object emerged during the process of the participants in the reduced-fidelity groups. This result appeared to suggest that the reduced levels of visual fidelity as a visual prompt affected their reductive process.

### 4.4.7 Limitations

The researcher has identified some characteristics of the design practitioners' behaviour when they engaged with the proposed reductive process. The researcher, however, also acknowledged that there were limitations in this approach.

The participants were asked to reduce the elements of the original object provided as a prompt step by step, following the levels from 10 to 1. However, the researcher could not clearly confirm whether this constraint effectively prompted the participants' design reasoning. In fact, several participants seemed to force themselves to engage with the process. Consequently, the processes of their reduction seemed to be somewhat clumsy.

Additionally, the researcher could not identify exactly why there were differences amongst the multiple fidelity levels of the visual prompt, due to the lack of understanding of the processes where the participants conducted autonomous reduction. It was necessary to meticulously observe individual participant's reductive and ideation processes. Therefore, the researcher felt the need to critically review the entire system of the reductive process.

In order to deepen the understanding of the impact of the process of autonomous reduction on the industrial designer's design reasoning and also to improve the limitations of the current reductive technique, a short evaluation was conducted with a lecturer at the design department who had experiences as an industrial design practitioner. The detail is described in the next section.

# 4.6— PRELIMINARY STUDY 4: SHORT EVALUATION BY PROFESSIONAL PRACTITIONER

## 4.6.1 Introduction

For the purpose of reviewing the proposed reductive approach using the tailored working sheets, a small evaluation was conducted with one of the staff at Northumbria University's Design Department. The participant GA who reviewed the technique was a senior lecturer at the department and has eleven years of experiences as an industrial design practitioner. GA undertook the same task as the one used for the Swiss students, being provided both the *Process Sheet* and the *Idea Sheet*. After the completion of the task, GA was also interviewed. The contents of the interview were transcribed and used for the subsequent analysis.

GA reduced the elements of the original wheelbarrow, focusing mainly on the composition of components of the object (Figure 74). GA developed the process by removing the elements of the wheelbarrow and altering the shape of each component little by little. GA then selected the image depicted on the level 5 and conceived the idea of an object in which the functions of both a barrow and a bench were combined (Figure 75). GA found the possibility of multiple functions of the object at the point where the hopper was removed on the level 5. GA explained the object as follows on the *Process Sheet*: *"By eliminating the carrier element, it opens up new possibilities. It is less about carrying things and more of a platform that suggests mobility (GA)."*

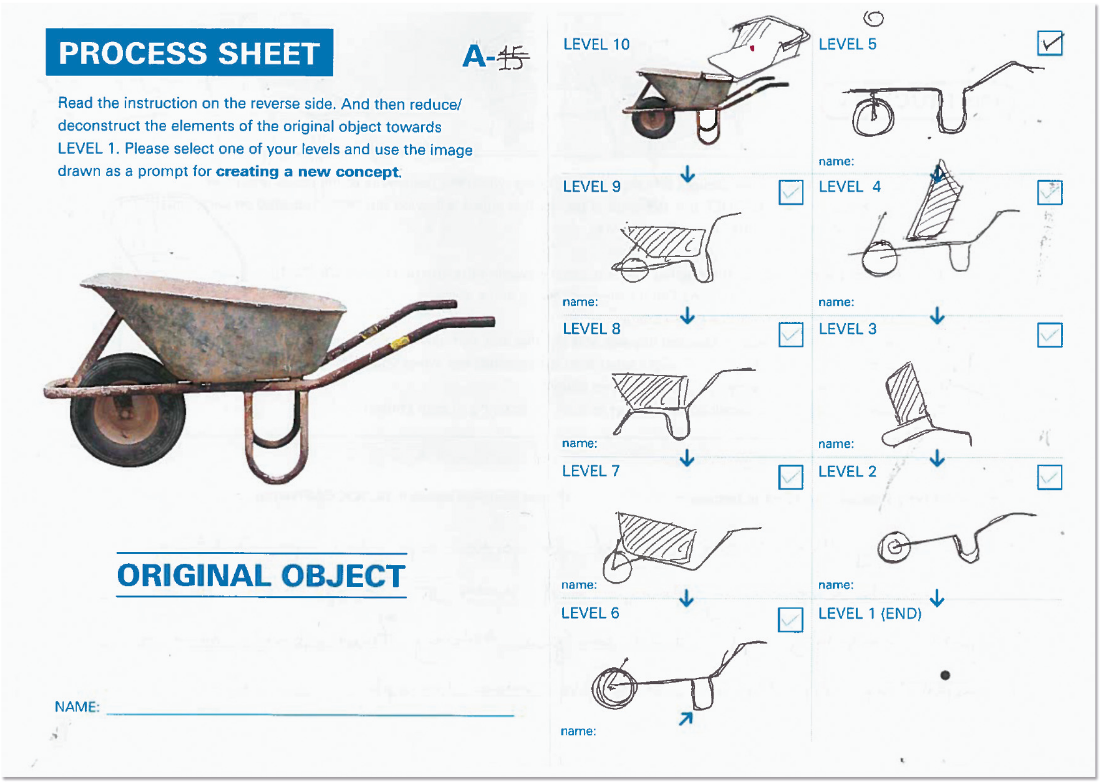



*Figure 74. GA's Process Sheet.*

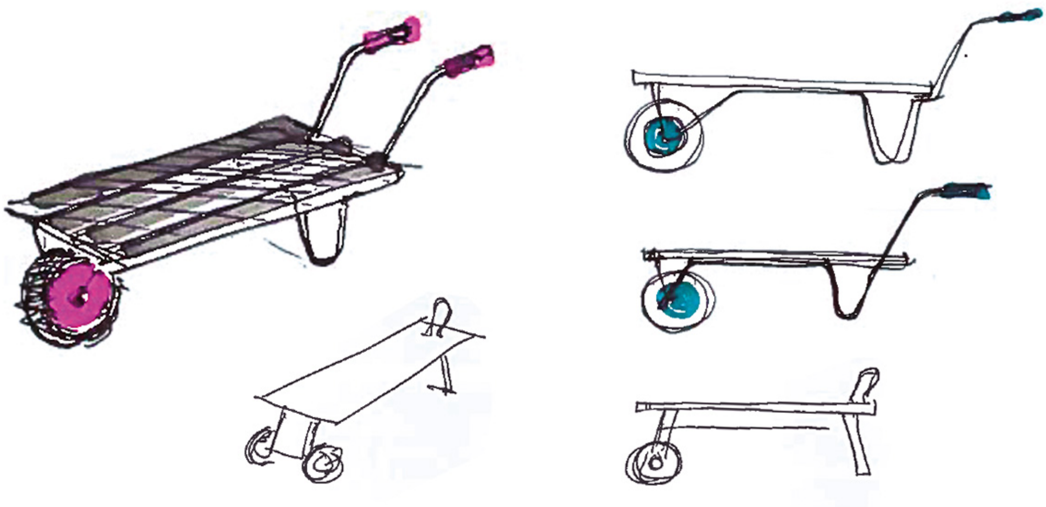


*Figure 75. GA's final idea depicted on the Idea Sheet.*

## 4.6.1 Critical Review

What GA pointed out in the first place was the discomfort about sequentially reducing the elements of the original object. GA could not find the relevance between the original object and the black dot. It appeared that GA struggled with finding out any rationales for reducing the elements step by step from one end to the other:

> *"I personally found it's restrictive in a sense that I had to take elements away. I found it's quite containing because I wanted to take elements from it (the original wheelbarrow), but I didn't necessarily want to do it in a sequential way that I was reducing it down less and less because I can't really see that (the original wheelbarrow) and that (the black dot) anyway in any relationship so I was really struggled at what point you take it away (GA, 00:00:10)."*

GA also stressed the importance of developing the reductive process, being apart from the restrictive rule instructed on the *Process Sheet*. GA described that it was important to have a freedom of trying and exploring various directions of the thinking process, playing with the elements GA focused on, rather than sticking to one single reductive approach:

> *"I was more interested in taking elements and perhaps playing with them. Taking elements away and seeing what I could do with them. (...) if I'm honest, prefer to see this (the original wheelbarrow) (...). It's just like always remind myself of it (the original wheelbarrow) and then not look at it again. (...) when I got into this (the Idea Sheet) (...) I felt I had more freedom to work with because I didn't have to follow the geometry of that exact object. I could just try and capture something of the idea of it and it doesn't quite work out straight away that's why you should play with it a little bit (...) (GA, 00:00:22)."*

Additionally, when GA reconstructed the reduced and deconstructed elements in order for exploring ideas, the process needs to be flexible and free (GA, 00:05:22). In this respect, reducing the elements in a sequential manner obstructs the development of the process. Therefore, the linearity of the process was not ideal for the reasoning process of the person who engages.

GA also pointed out the problem in the selection of the original prompt. GA stressed the difficulty of engaging with the reductive process, working with such a simple and elemental object. The wheelbarrow as the prompt object was too simple for reduction. Accordingly, GA seemed to struggle with reducing the elements of the object:

> *"(...) because it's quite reduced object anyway… you know there isn't any extra decorations. There is nothing excessive on it. I can reduce it but it's no longer functional or I'm perhaps more inclined just… instead of taking things away, I'm more inclined to tweak it and to extend and exaggerate a bit (GA,00:01:11)."*

What is most important for GA during the reductive process was how to interact with the attribute information of the prompt object such as the typology, the materiality, what it is for or where it is for (GA, 00:05:24). Due to the plain nature of the wheelbarrow, GA struggled with finding out meaningful clues for reduction and, consequently, forced himself to unnecessarily engage reductive modification of the elements. GA described that just reducing the elements from the original prompt without certain understandings or rationales did not effectively provide meaningful insights about the object:

> *"I can't see how I can keep removing bits from it and actually producing something meaningful. I could remove stuff from it but then it won't say anything. It's fairly random. It's just almost be mathematical anatomy. I cut it out away and cut it out away and what is left isn't meaningful."*

Thus, the simplicity of the original wheelbarrow forced GA to work with it in a more awkward manner and did not effectively prompt GA's thinking process for reduction. This appeared to suggest that the original object as a prompt ought to have multiple layers of attributes beyond its functionality in order to encourage more effective reductive experiences.

### 4.6.3 Conclusion of the Preliminary Study 4

In conclusion, the researcher learned from this short evaluation that the following two issues emerged: 1) the importance of the spatial freedom on the *Process Sheet* and 2) the selection of the original prompt that includes rich attributes information. The sequential manner of the reductive process fundamentally restricts the development of various reasoning processes. Accordingly, the proposed rule where the designer reduces the elements following the levels on the Process Sheet cannot effectively prompt their imagination. Instead, providing the designer more spatial freedom on the *Process Sheet* arguably allows him/her to develop more meaningful reasoning processes without constraints. Also, the prompt object should involve multiple layers of sociocultural attributes beyond functional factors. The complexity of information as to the prompt allows the designer to read, interpret or assume the object in a variety of ways. Accordingly, the selection of the object that includes rich attributes potentially provides an insightful conversation with the prompt during the reductive process and it can be subsequently reflected upon the outcomes. This short review gave the researcher the critical suggestions for the subsequent improvement of the proposed reductive technique. The technique was then revised based on these insights derived from GA’s review.

# 4.7 MAIN STUDY 1: AUTONOMOUS REDUCTION VERSION 2.0

## 4.7.1 Introduction

The technique of *autonomous reduction* aforementioned in the section 4.5 was modified from the critical review of the earlier study. The results of the third and fourth preliminary studies suggested that the current state of the reductionist technique had the limitations: (i) the participants seemed to struggle when they reduce the elements of a simple object such as a wheelbarrow as it had not enough attributes to be reduced, and (ii) the rigid structure of the reductive method in which the participants were required to reduce the elements of an object in a sequential manner following the indicated levels from 10 to 1 seemed to make an awkward restriction in the process of imagination. Accordingly, in this study, a different artefact was carefully chosen for the original object used the prompt for reduction. Also, the design of the *Process Sheet* was revised, based on the limitations identified. The study was conducted with industrial design students in their final year. In this study, the researcher observed the behaviours of the participants focusing on how the designer reduces attributes of the original object, and how they explore different design concepts within the reductive transition when they were given a more ornate prompt. *Process sheets* were provided to the participants and they were asked to explore ideas as much as they could and select one of the ideas they created for the final design proposal. After the completion of the session, the participants were interviewed in the format of a semi-structured interview.

## 4.7.2 Methodology—Main Study 1

The aim of this study was understanding the impact on the participants' reasoning processes, where the designers are tasked to reduce/deconstruct the elements of an existing object. Accordingly, the researcher felt the need to thoroughly observe the entire process of each participant wherein they challenge to reduce the attributes of the prompt object provided and explore new design concepts simultaneously. The study was conducted by giving an individual task to each participant and during this time all the exercise was video recorded. The participants were also asked to think aloud throughout the process and all the verbal data was transcribed and used for the subsequent analysis. As well as verbal data derived from the observation, the participants were interviewed after completion of the task and the findings were also used for the analysis as a supportive data.

In this study, the image of French classical clock was used as visual prompt and a set of work sheets, called the *Process Sheet* and the *Idea Sheet* were created. These sheets were used by all the participants as they carried out reduction, idea exploration and finalisation of their design proposals. The participants were asked to complete the task by sketching using these work sheets.

Additionally, the researcher varied the amount of information that the prompt conveyed to the participants by changing the level of the clock's visual fidelity. One represented the clock as a full-colour photographic image and the other was expressed by simple dotted lines. Accordingly, the participants were split into two groups and each group was provided with one of the different visual prompts created. Except for this difference of the visual prompt provided, both groups were given exactly the same task.

#### 4.7.2.1 Selection of Original Object as Prompt

The wheelbarrow used for the previous studies as a prompt for imagination was considered too elemental in so much as that it did not represent rich attributes within the object. Each component or element of the wheelbarrow embodied its pure functionality and rationality. In this respect, the object used as prompt for imagination needs to represent certain varieties of attributes that have elements and a capacity for reduction. The choice of the original object has been made following the selection outlined below:

- *The prompt should be identifiable and still familiar with as a product at the present day*
- *The prompt should be an object that the participants can readily understand its functionality*
- *The prompt should have a form that represents cultural contexts beyond its functionality*

In accordance with these criteria, a classical French bracket clock designed in circa1746 was selected (Figure 76). This is a small ormolu bracket clock whose height is less than 30 cm and its movement was designed by Stollewerck (Nicholls, 1975). A cherub playing the pipes on top of the clock part. The bracket clock is the classical timepiece that was made to stand on a decorative, matching bracket fixed to the wall (Smith, 1979). This type of bracket clock was produced following the fashion for the carrying of watches on the person increased in the seventeenth century in France (Nicholls, 1975).

***Figure 76. A small ormolu bracket clock by Stollewerck (c. 1746).***
***© Victoria and Albert Museum, London.***

This bracket clock is in the style of the rococo style. Rococo style involves ornamental motifs which make of this style a combination of the artificial and natural, of culture and nature (Minor, 1999). According to the Nicholls (1975), the design of rococo clocks are characterised in the following description:

> *Rococo designs combine abstract curves and scrolls with shell- and coral-like shapes, as well as flowers and leaves and, later, Chinese and Gothic motifs. (…) One of the most popular types of clock was the waisted bracket clock. At first it was veneered with tortoiseshell and brass inlay with gilt mounts. Later examples are sometimes veneered in brightly coloured horn, and sometimes inlaid with flowers in constructing colours. Others were lacquered and painted*

*with flowers while some of the most superb are of bronze. (Nicholls, 1975 p.56).*

Accordingly, this clock is highly ornamental and is a cultural object that represents a particular period of time in the art history. The excessive ornament given on the surface of the object gives the viewer more than what the essential function or utility as a product, but more about its cultural contexts. The richness of the attributes that the clock represents, e.g. the decorative form, the colour or the materiality, can offer more opportunities for the participants to read, interpret and imagine the attributes of the object compared to the wheelbarrow used previously. On the other hand, the object as a timepiece is still common at the present day. The participants can readily identify what the object is because of the visual elements e.g. clock face even if they have never seen the image of the object before. Therefore, this bracket clock was regarded as the appropriate object as prompt for the study as it met the selection criteria.

#### 4.7.2.2 Prompt Provided in the Study

The purpose of the study was to investigate the impact of the autonomous reductive approach of the design practitioners on their imagination and behaviours during the idea exploration process. In this study, two different levels of visual fidelity utilising an object as prompt were prepared (Figure 77). The intention of this exploration was to compare how varying amount of attributes the visual prompt has, affects the participants' reasoning processes. This comparison allows the researcher to identify what types of aspects the participants focus on by being given different levels of image quality.

The first image (A) was the photographic image of the bracket clock, without background, printed in full colour. This image contains multiple attribute information of the object e.g. colour, materiality, surface texture, ornamental details, graphical elements and so on. Accordingly, the image A was considered as the prompt that involves richer information and offers more visual elements to reduce.

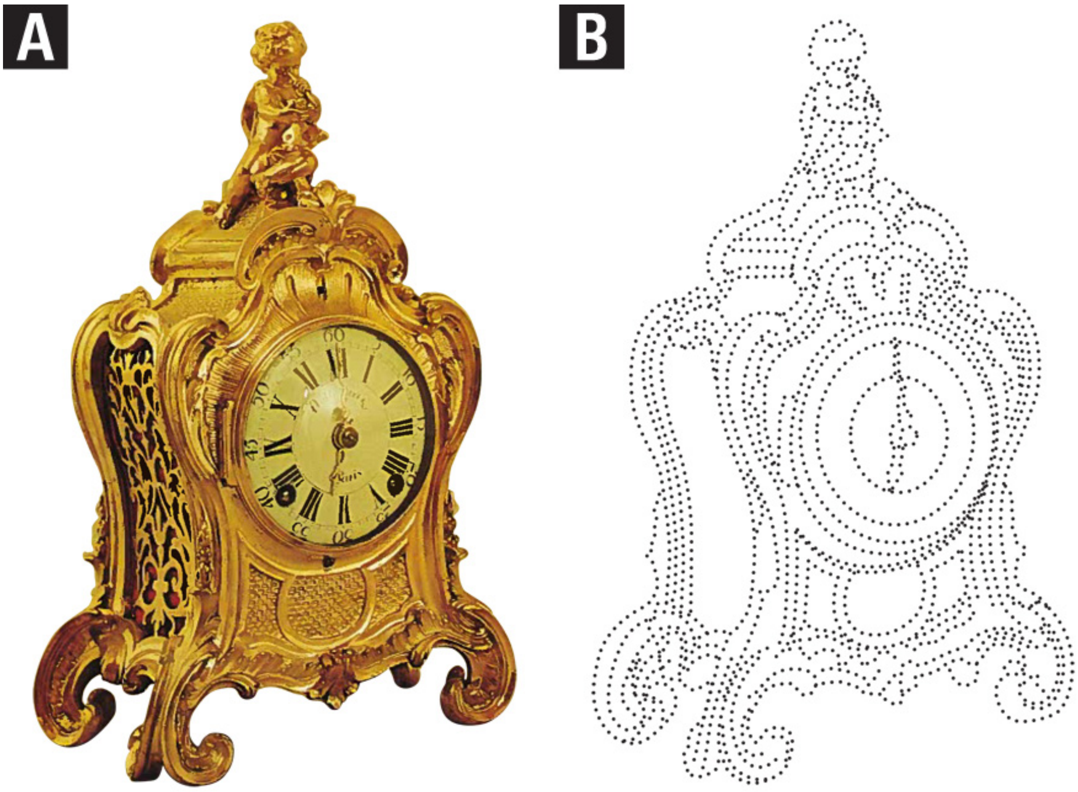



*Figure 77. Two different fidelity levels provided to each group.*

The other image (B) was the image of the same bracket clock depicted as a visual of black dotted-lines. The dotted image was digitally made tracing the contour lines of the photographic image of the clock (used with group A). The image represented by the dotted-lines provides a more limited set of attributes and information for the participants. The sets of simple black dots contain neither colour nor material information per se. Also, the decorative details and the surface textures are eliminated. Accordingly, this image B was considered as an alternative visual prompt that involves poorer information and offers less visual elements. Both visual prompts were physically printed and provided during the study (Figure 78).

*Figure 78. Printed visual prompts formatted in A4.*


### 4.7.2.3 Process Sheet and Idea Sheet

Two types of work sheets were designed and provided to the participants in order to visually capture the process of the participants' idea-exploration as well as the final outcome at the conclusion of their design ideation (Figure 79).


*Figure 79. Process Sheets for both groups (left: Group A & right: Group B).*

The first sheet provided to the participants was called *Process Sheet*. In this *Process Sheet*, the participants were asked to reduce the elements of the original object as a prompt, and evolve new design concepts within the reductive process. The scaled-down image of the original object is placed at the centre of the sheet with a small arrow next to it. The participants were asked to reduce the elements of the original object step by step using arrows that show the trace of the processes of idea development (Figure 80). Additionally, on the *Process Sheet*, the following instruction texts were printed:

*Reduce/deconstruct the elements of the original object. Please select one of your ideas and use it as a prompt for creating a new concept.*

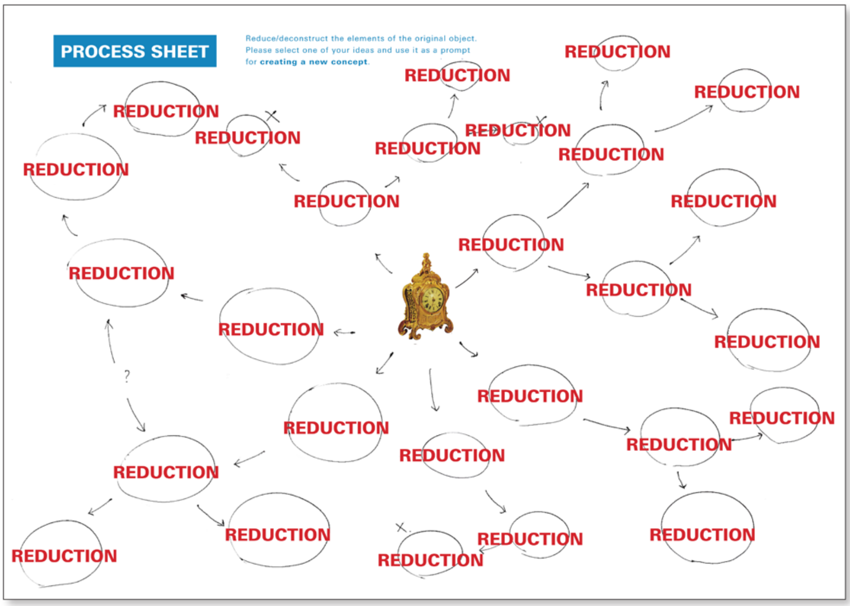
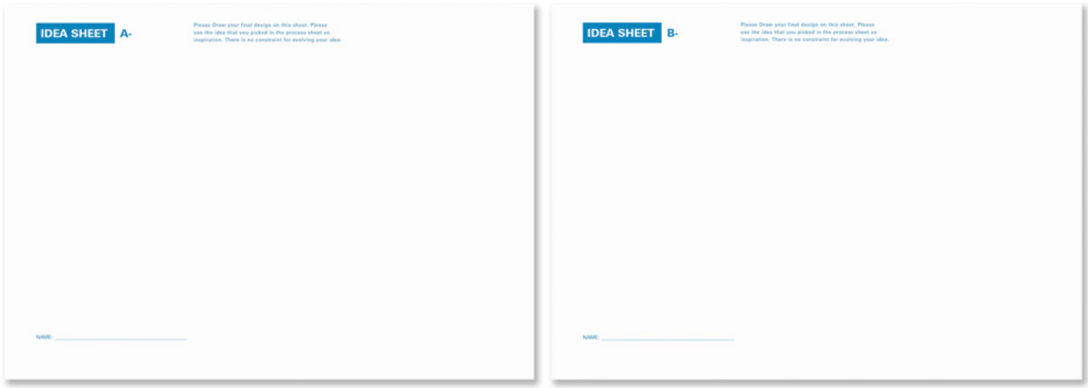



***Figure 80. Example of the use of the Process Sheet.***

There were no fixed rules or methods of engagement, except for the use of arrows, in terms of the way in which the participants reduce/deconstruct the elements. Accordingly, the participants were allowed to interpret the notion of "reduction/deconstruction" in their own ways.

The second sheet provided with the *Process Sheet* was called the *Idea Sheet* (Figure 81). In the *Idea Sheet*, the participants were asked to conclude their ideas developed into the final design proposal through sketching. The participants were instructed, at the beginning of the task, to select one of the ideas evolved on the *Process Sheet* and use it for the final design proposal. In so doing, the participants were required to complete the *Process Sheet* first and then move on to the *Idea Sheet*. In the same manner as the *Process Sheet* instruction, there were no rules or regulations required. The participants were allowed to tailor the way they use the sheet on their own arrangement.

*Figure 81. Idea Sheets for both groups (left: Group A & right: Group B).*




### 4.7.2.4 Participants

In this study, 8 voluntary participants from Northumbria University were involved. All the participants were industrial design students in their final year of study. The study was carried just before their graduation. Accordingly, they can be regarded as matured industrial design students who have an advanced level of design expertise and are equipped with the skills for designing products. They were split into two groups, each one comprises four participants in the study.

### 4.7.2.5 Instruction

Printed instructions were provided to each participant before commencing the task. The participants were given time to read the instruction that was on the desk throughout the task. The contents of the instruction were the following:

> *Your task is to explore different concepts of an object within the transitions of the visual reductive processes. Please visually REDUCE the elements of the original object as much as you want. The reduction of the "elements" is totally up to you.*

1. *Look at the image of the original object.*
2. *Reduce the elements of the original object gradually by drawing on the process sheet. Please speak aloud while you are drawing as much as you could.*
3. *Pick one of the ideas which you are inspired the most.*

4. *Move to the Idea Sheet (provided separately) and finalise your design by drawing. There is no constraint at this stage. You may add other elements on your design if you wish.*

#### 4.7.2.6 Study Environment

The study was individually conducted in a quiet, closed and familiar space within the university premises (Figure 82). The video camera was set next to the participant as well as the sound recording device. The researcher sat on an adjacent seat to the participant and acted as the instructor and the observer.

***Figure 82. Study environment of the main study 1.***

As well as observing the participants' behaviour, the researcher was also note taking on how the reductive process and the idea exploration are carried out during the task. The purpose was to thoroughly track and record the participants' behaviour and thinking processes noting down comments, diagrams, sketches and annotations (Figure 83). The prominent characteristics captured were subsequently used as a supplemental data for the analysis.

***Figure 83. Examples of the notes taken by the researcher during the task.***

#### 4.7.2.7 Procedure of the Study

The overall procedure of the study is described here. Fundamentally, there was no time limitation to complete the task so that the participants were allowed to spend as much time as they wanted. The study was carried out in accordance with the following procedure:

1. *The instructor explained the instruction of the task to the participant.*
2. *The participant was asked to explore new design concepts reducing/ deconstructing the elements of the original object on the process sheet. They were also required to think throughout the reductive/deconstructive process.*
3. *The participant was asked to select one of the ideas they evolved for the final proposal.*
4. *The participant was asked to move to the idea sheet to finalise the selected idea as a conclusion.*
5. *The participants were interviewed after the completion of the task.*

#### 4.7.2.8 Post-production Interview

After the completion of the task, the participants were interviewed by the researcher. The purposes of conducting a post-production interview was to understand the participants' design and the processes that they explored their ideas. The information that both the *Process Sheet* and the *Idea Sheet* can capture is limited due to its special constraints. In fact, many participants did not sufficiently specify the detail information of their designs such as the design intention, the material choices, the intended scale of the object or the way it is used. Accordingly, asking the participants specific questions focused on the detail of the outcomes was helpful in fully understanding what the design outcomes are. Additionally, asking their opinions, reflecting their experiences regarding the reductive task allowed the researcher to compensate for what the participants missed in their verbal description during the task. The participants' reflective hindsight allowed them to objectively describe what their experience was and also to grasp the whole reductive process consistently. Consequently, conducting a reflective interview proved to be crucial, the content of these interviews were transcribed and used as supplemental data for the analysis. The questions asked during the interview were the following:

- *Please describe the artefact you created.*
- *Please describe how your design would be used.*
- *Please describe the materials used in your object and the reason(s) why you chose these materials.*
- *Please describe the colour and the texture used in your object.*
- *Please explain your reductive processes ...And please explain the reason(s) why you selected the particular reductive process for the final idea.*
- *What kind of elements of the original object did you eliminate or leave?*
- *At what point did you come up with the key idea for the final design? ... And what were the key factors that inspired the idea?*
- *Have you referred to the image of an existing object as a reference during the imagination?*
- *What would you highlight in the exploration of the reductive process?*
- *What did you find most difficult during the reductive process?*

#### 4.7.2.9 Data Analysis

All the data was collected during the study and the main data sources were from the following four media: 1) verbal data collected during the task, 2) visual data derived from the *Process Sheet*, 3) visual data derived from the *Idea Sheet* and 4) verbal data derived from the post-production interview. Along with these, the behaviours of participants captured in the video recordings were also used for the analysis as supplemental data. The think-aloud processes were developed in accordance with the progress of sketching activities on the provided sheets. The drawings depicted on the *Process Sheet* and the video recorded data visually show how the participant moved within the space on the sheet and how the ideas developed were interrelated amongst the thinking avenues. This process allowed the researcher to observe how the reductive/ideation processes were exactly developed in detail. Thus, the analysis was conducted within the mixed data sources.

Data analysis was conducted following the protocol analysis method (Ericsson and Simon, 1984). In particular, the process of analysis was conducted through the verbal analysis method (Chi, 1997). The verbal data captured during the reductive process was transcribed and the contents of the entire corpus were segmented. Then, each segment was coded independently and the patterns were identified and interpreted. Based on the patterns identified, the diagrams that represent the overall characteristics of each group during the process were developed (see section 4.7.4). Additionally, the mapping that visually and thoroughly describes the detailed reductive/ideation process of each participant was also developed based on the protocols identified and used for the analysis. The detailed characteristics of both groups were described along with these mappings and the tables where summarised the themes identified.

As part of the analytical process, the outcomes were visually recreated with CAD software by the researcher under the consent of the participants (Figure 84). The 3D rendered images that represent the outcomes were reproduced as accurately as possible based on the drawings and the annotations depicted on the *Idea Sheet*. The contents of the post-production interviews were also used for the analysis as well as the supplemental comments obtained after the completion of the study. The purpose of this reproduction is to allow the researcher to better understand and compare all the results with the same visual quality. Each participant illustrated their final ideas in different styles and some of the drawings were limited in some details in visually describing the outcomes. Therefore, the resolved digital images for the outcomes explicitly represent the final design ideas, allowing the researcher to better understand their conception, it afforded a level platform to understand how the artefacts are constructed and how they would look if made into physical outcomes.

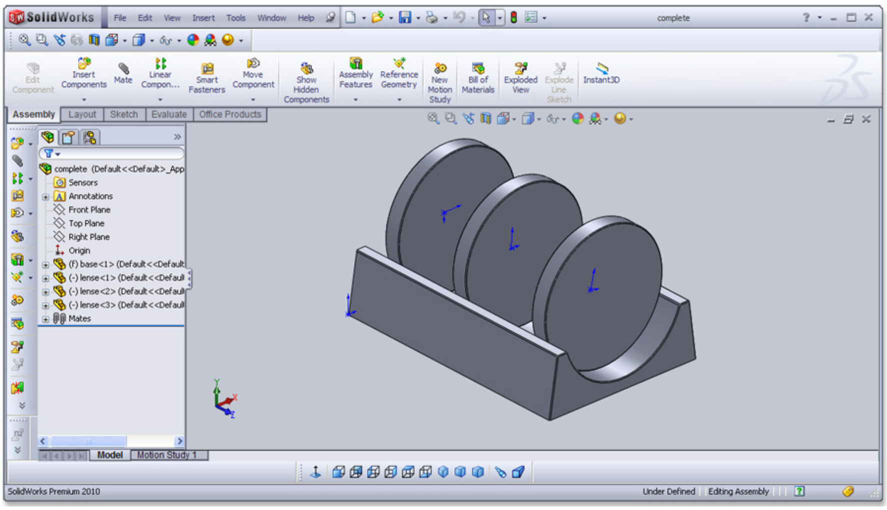



*Figure 84. Reproduction process of the outcome.*

## 4.7.3 RESULTS

This section describes the results of each participant. All the data shown derived from the following sources: the contents of the *Process Sheet*, the *Idea Sheet*, the verbal data captured during the task and the post-production interview. The aim of this section is to unveil all the outcomes of the participants' design and their reductive processes in working towards the final conclusion. Accordingly, the data shown in this section are thoroughly captured and investigated, focusing on the aspects of both the attributes of the outcomes as the final design proposal and their idea exploration processes during the reductive task.

### 4.7.3.1 The Outcome of Group A (high-fidelity Prompt)

The outcomes of the group A that was given the high-fidelity visual prompt (full-colour photographic image) are presented here. Three out of four participants designed a timepiece and one participant created a speaker set. Each of the participants developed their process in a unique way and their reductive/explorative processes were neither consistent nor straightforward. All the participants, however, conceived creative ideas to a high level, going through complex processes. Therefore, the researcher considered that it is critical to thoroughly capture and document the complexity of their dynamic thinking processes as they occurred during the autonomous reduction. In this section, the process of each participant was exhaustively described from their start to finish of the task, showing the development of their *Process Sheets*.

#### 4.7.3.1.1 The Participant A1

The participant A1 designed a desk clock composed of the three separate disks and a base (Figure 85). Each disk has a different display function of the clock. The main mechanical clock including its hands are mounted in one single disk, and the second display is tinted with a colour. The third disk is also coloured and displays a clock dial with lines at one-hour intervals. Each disk represents the three key concepts that A1 discovered during the process: "technical", "cultural" and "graphical". The composition of these discs can be shuffled on the clock base depending on the user's discretion or desired purposes. The key idea of the separation of display elements was derived from A1's close observation of the clock face of the original object. A1 discovered that the original clock face involves two different display styles that are roman and Arabic numerals, and conceived it as a discrepancy. Following this, A1 took over this feature and integrated it with the key concepts that A1 identified from the original object to foster the final design idea. The clock base is proposed to be made of beech wood, and borosilicate glass is used in the layered lightly tinted disks.

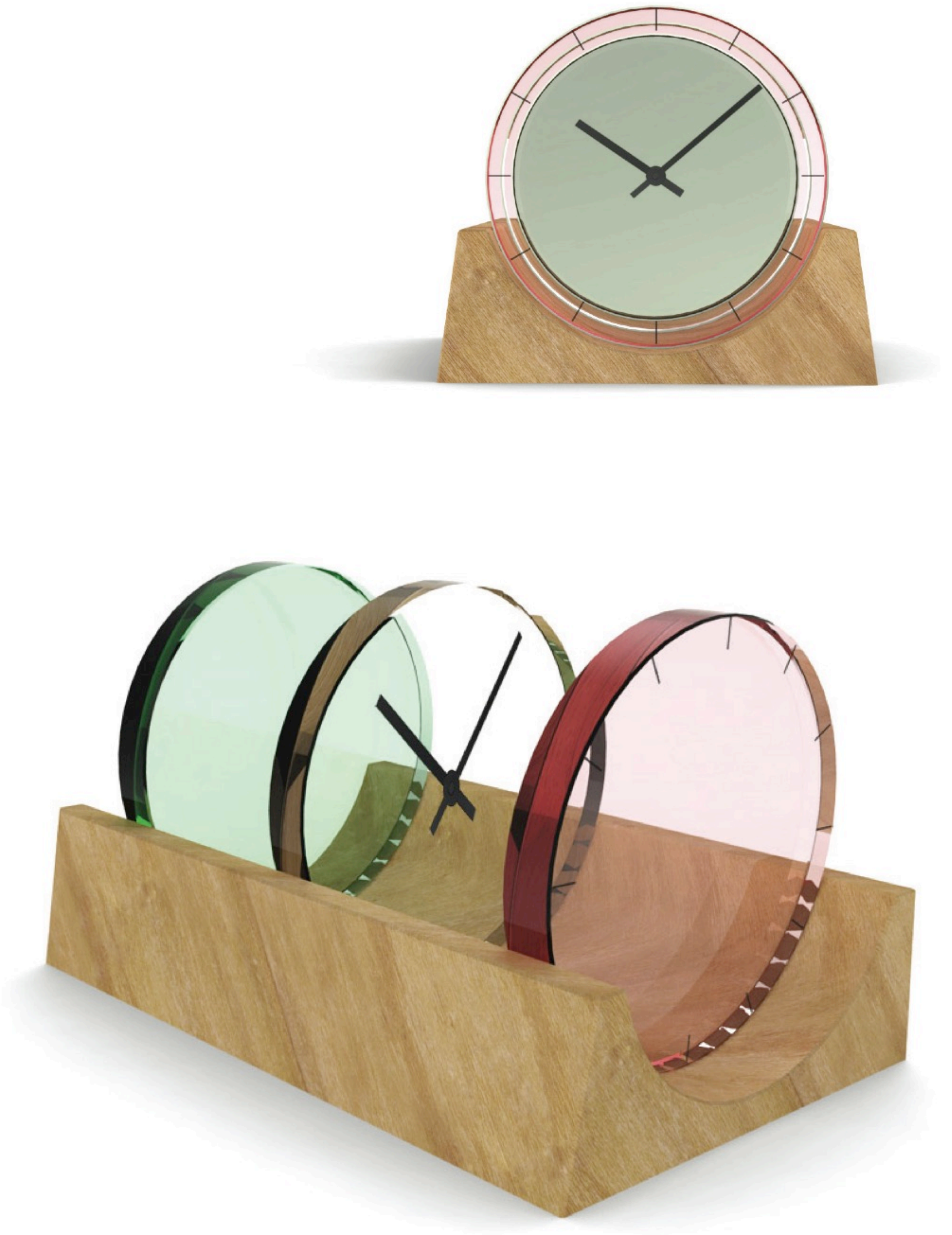


*Figure 85. The reproduced image of the outcome of the participant A1.*

The thinking process of A1 was initiated by observing the original object. A1 focused on the structure of which the main body of the clock is supported by legs and conceived whether this structural separation can be used an opportunity for reduction (A1, 00:02:06). Based on this structural understanding of the object, A1 evolved the idea of replacing the material of the leg part with transparent materials (A1, 00:05:35). Next, A1's attention shifted to the side structure of the original object. A1 has discovered that there is a cavity inside of the main body of the main clock and reinterpreted that the body is composed of folded one single sheet (A1, 00:07:45). A1 conceived the structural principle of the original object by simplifying the components. A1 continued the further reductive process from the previous idea. A1 conceived the idea that the clock face is placed inside of the cavity and it can be seen through the circular hollow cut out from the surface (Figure 86). A1 then attempted to explore different variations based on the same principle. According to A1, this reductive treatment can create an abstract impression to the viewer (A1, 00:10:26).

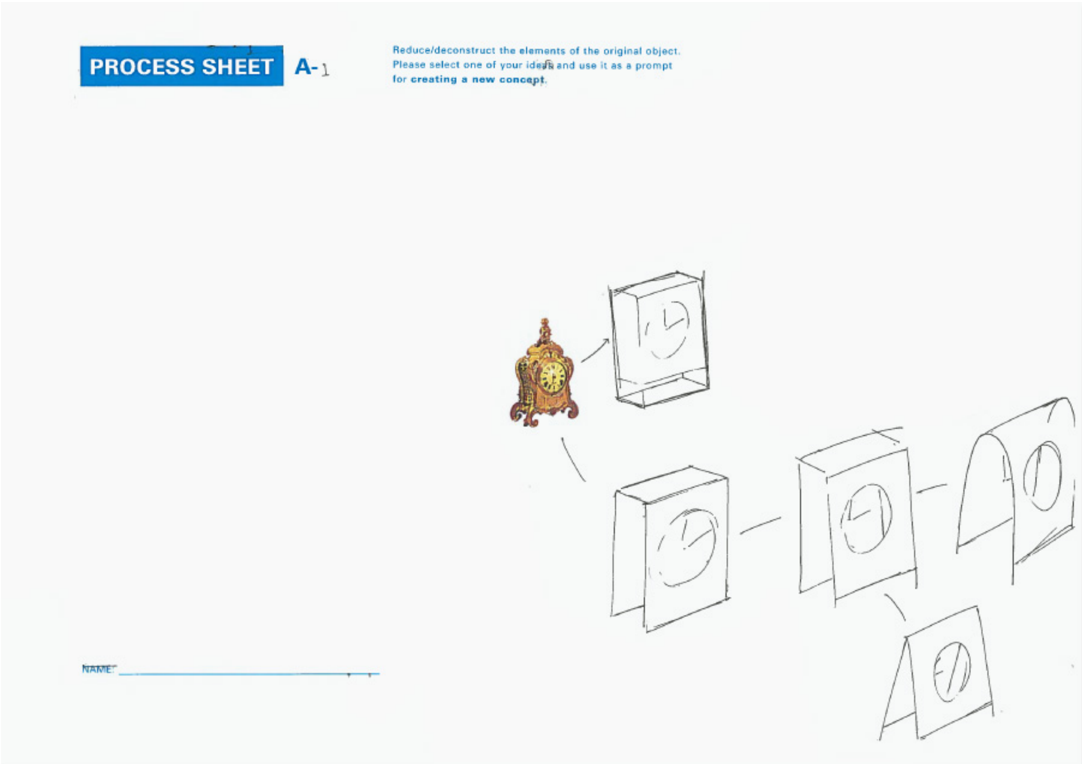
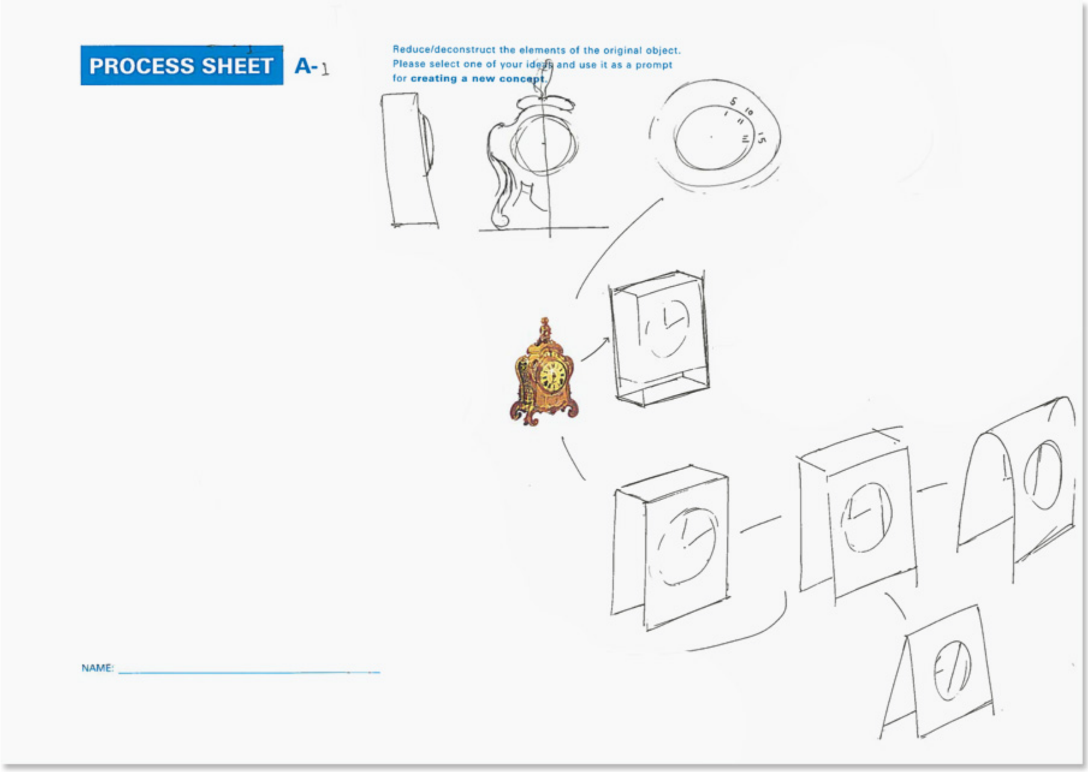



*Figure 86. The process of A1 at 00:12:46.*

A1 then moved to a new thinking avenue and started drawing the half front-view of the original object. It seemed A1 attempted to trace the ornamental aspect of the original object by this drawing. A1 continued drawing and depicted a clock face look part (Figure 87). These drawings led A1 to the understanding of which the most primal essence of a clock is the face as A1 described: *"As a clock, (...) once you look at the ornamentation and the things* *everything would be the first is the face as a clock as its function so you can kind of see (…) the face is a flash with the rest of it (…)" (A1, 00:23:54).*

***Figure 87. The process of A1 at 00:22:31.***




A1 then drew a simplified side view of the clock whose face part is extruded from the surface, and interpreted the design intention of this particular feature: *"This (the face part on the side view) is like a sense of motion. This is just rad on here stressing, kind of pushing out of there almost." (A1, 00:22:46).*

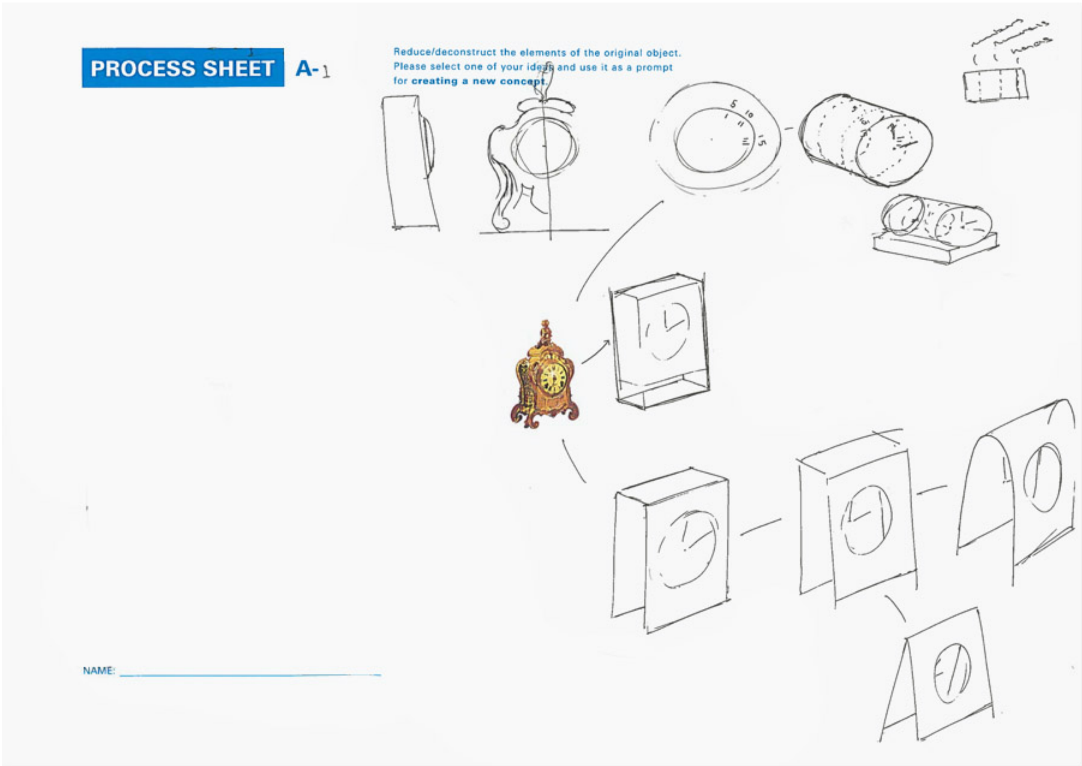
At this phase, A1 realised the clock face involves two different display styles that subsequently became the core idea of the final idea: *"I guess what's quite funny about the clock is it has Roman numeral and (Arabic) Numbers." (A1, 00: 25:07)*. A1 further discovered that the clock face involves three visual elements: the Roman numerals, the Arabic numbers, and the clock hands. For people of today, a clock face has no need to have multiple display styles to tell time. A1 focused on this discrepant feature of the clock face and regarded it as "hierarchy of information" (A1, 00:25:45). A1 classified the elements identified depending on the levels of significance and reduced the less important features. A1 stressed the importance of this hierarchisation of information:

> *"I guess a hierarchy to me is the key to reduction. It's highlighted the most important and reduced everything of dull images. You may remove*

*unnecessary information or place enough form where you can really understand what is more significant" (A1 00:25:48).*

As A1 carried out this reductive process, A1 discovered the idea of a transparent cylindrical clock face made of glass (Figure 88). Within this idea, the perception of the user is altered by spatial distance. A1 described that the clock hands are displayed at the surface at one end of the cylinder, and another layer of Roman numerals comes after, and the Arabic numerals is finally set at the other end (A1, 00:26:44).

***Figure 88. The process of A1 at 00:32:24.***




A1 described that the reason why A1 focused on the spatial aspect within A1's reductive process was that A1 deliberately focused on reducing the information in a three dimensional way:

*"I guess clock is a very graphical object normally. It's often flat and it's about a single face to it (...) you can keep on reducing it graphically, but I guess it's graphic design (...) And then when you design a graphic, it no longer reduces it. (...) it's not for like the materiality as an object that has this physical dimension or spatial dimension. If just reduce it graphically, it gets flatter and flatter and it's just the numbers on the circle. You can display that on a screen,*

*for example, and that has no reasons to have a physical object anymore" (A1, 00:27:39).*

A1 found the limitation in the approach of two-dimensional reduction as it dismisses physical aspects of the object such as materiality. Therefore, for A1, it was important to reduce information conceiving physical properties of the object in order to explore ideas.

A1 mentioned, at this phase, that A1 attempted to consider the reductive approach in different angles (A1, 00:53:40). A1 then went back to the previous thinking avenue where A1 discovered in the first place, and continued further reduction from it (Figure 89). A1 integrated the idea of material transparency inspired from the previous cylindrical idea with this first idea. The purpose of this application was to reduce the "visual weight" in the appearance of the objects conceived (A1, 00:53:74).

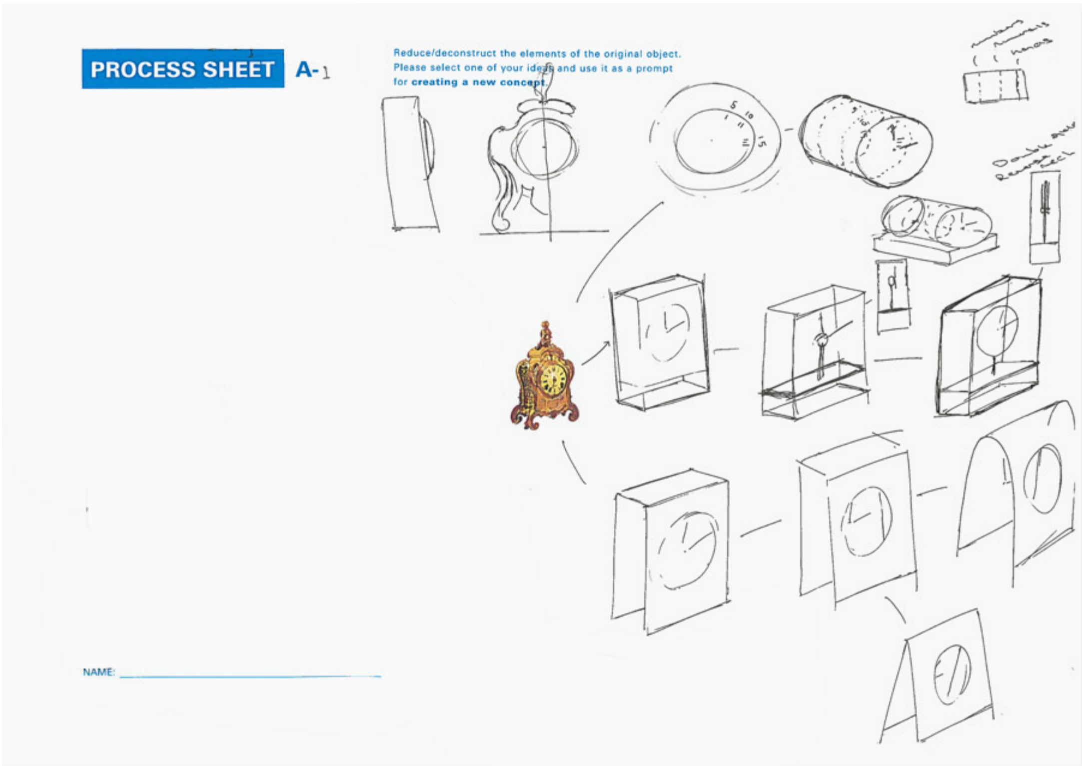



***Figure 89. The process of A1 at 00:43:20.***

A1 again stressed the importance of the approach of three-dimensional reduction rather than pursuing it in two-dimensional ways. A1 described that the ideas conceived need to have a reason for being as a physical object and this thinking approach led A1 to further discovery of an idea:

*"(…) if it is an object, it has to have a reason for being as a physical thing rather than digital thing or graphics. So, it only has double-side clock faces so that you'd have two mechanisms (…) so you can read it from either side. And then, there is a divider (in between the two clock faces), like really thin sheet, aluminium or something as a face (…) (A1, 00:54:40)."*

After exploring the previous thinking avenue, A1 returned back to the original object and discovered different aspects that A1 has not identified yet. A1 looked at the original object from different angles, and divided the identified factors into the following typological classifications:

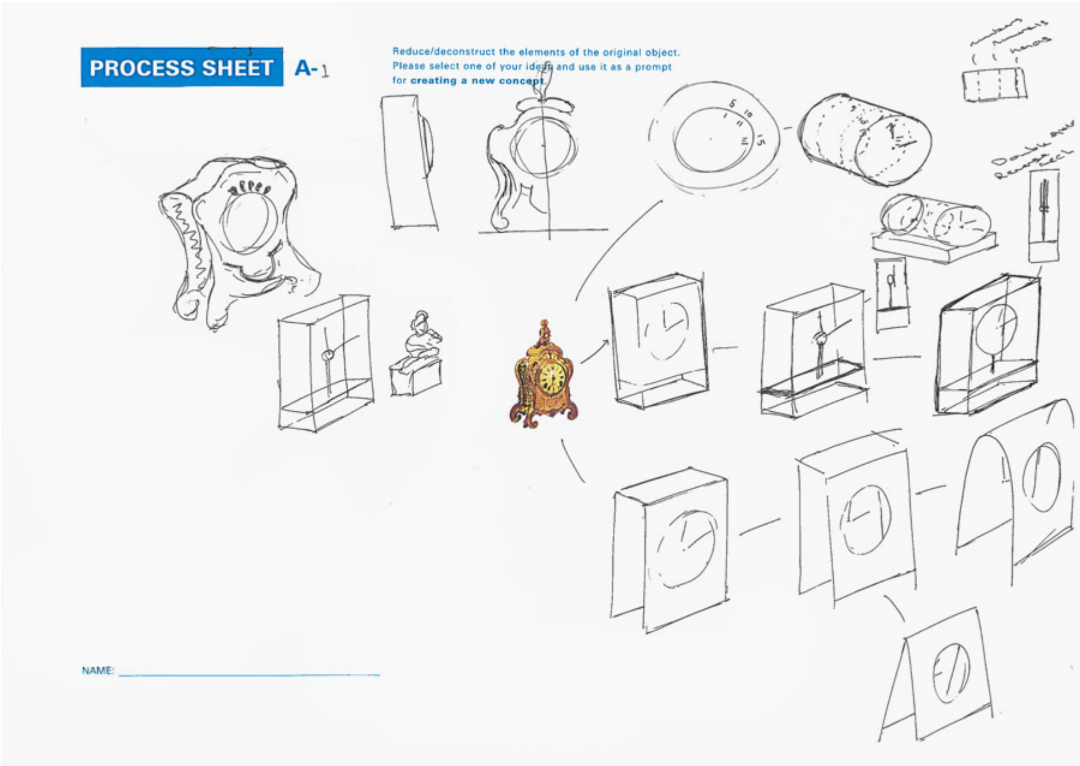
- a clock as functional device,
- a clock as cultural object and
- a clock as technical object (A1, 00:56:50).

A1 described that the object can be seen as a functional device that communicates the passing of time. It also can be seen as a cultural object represented with the ornaments attached on the surface of the object. These ornaments express more than its utility functions. Finally, it can be regarded as a technical object. In A1's description, the term "technical" here means that a clock as an object is defined with a specific technical role, and involves the aspects of precision or engineered functionality (A1, 00:56:58) as well as its technical progression and development in the history. Although A1 founds these three key aspects within the original object, A1 felt that these were not well connected. A1 explained that the ornaments are just added on a structure, and the technical elements were just concealed inside of the body (A1, 00:57:46). Based on this discovery, A1 depicted those three elements separately on the Proc*ess Sheet* (Figure 90). A1's intention was to re-integrate them back into a single object in some ways later.

A1 then again looked at the original object as a whole and attempted to take up the distinct graphical parts. The selected graphical elements were reinterpreted in a more integrated way. A1 stressed that it is the reduction of superfluous elements rather than just removing things, and also the remained elements are re-integrated (A1, 00:59:24). It appeared that A1 always attempted to find out particular aspects as a clue in the original object in order to rationalise A1's decisions for reduction: *"(…) (integrate) into something more than just ornaments. So that has functions or… may be not so much functions but like structural or purpose or… when you see it, it feels reasons and justify it… like more resolved" (A1, 00:59:40).* In the process of discovering particular features of the original object, actually sketching them out helped A1 to understand and interpret the contexts behind them: *"By sketching it, that helps me to define what is graphic, what is technical, what is cultural (…)"*

*(A1, 01:00:38)*. A1's reductive approach was on the basis of understanding the contextual attributes of the original object based on close observation of elements by sketching.

*Figure 90. The process of A1 at 00:59:00.*




A1 then returned back to the previous thinking avenue where A1 identified the three typological classifications. A1, again, deconstructed the original object into the three components but in a more abstract way and those were sketched out (Figure 91). Each sketch of the component represents the three concepts:

- The box with a clock mechanism as "the clock mechanism",
- The figurine as "the ornament" and
- The box shape with a circular hollow as "the graphic elements of the clock face".

A1 then stated that each information-set listed above corresponds to the key concepts previously mentioned respectively: "technical", "ornamental" and "cultural" (01:18:54).

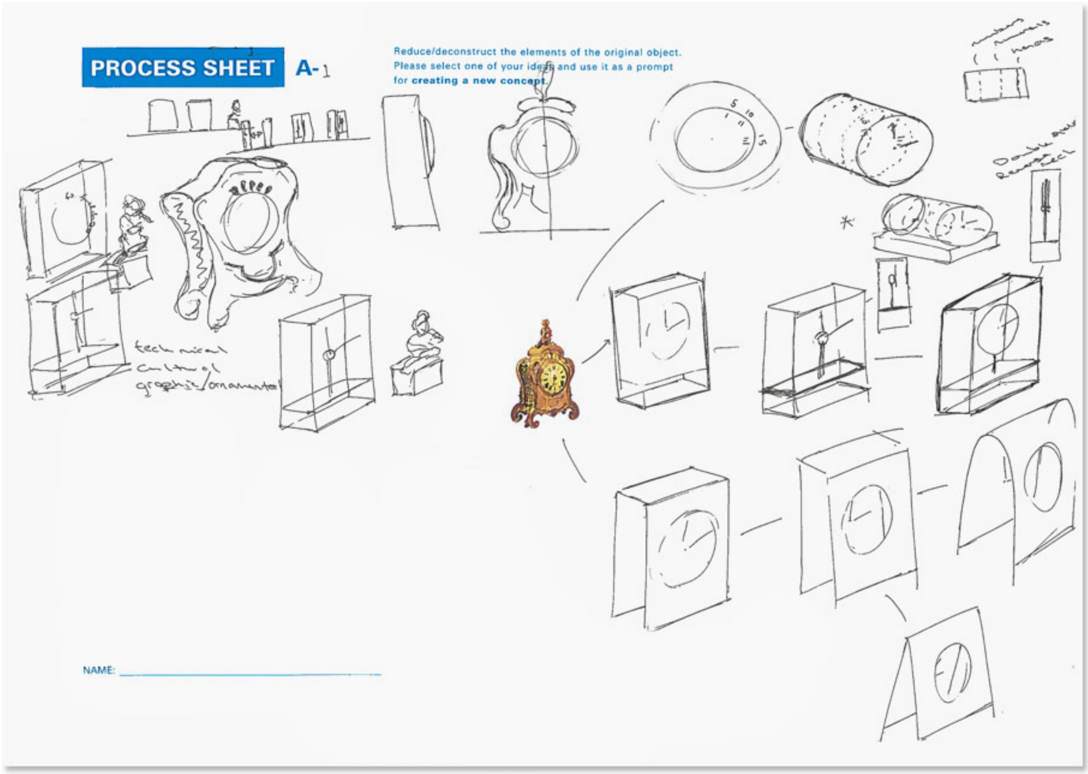



*Figure 91. The process of A1 at 01:18:54.*

A1 also emphasised the ornamental details around the clock face on the previous drawing. A1 then returned back to the previous thinking avenue of the clock idea formed by one folded surface with a hole and continued reductive process focusing on the ornamental elements around the clock face (Figure 92). It appeared that A1 continued to evolve the previous idea integrating with the focus of the ornamental detail. This development process of ideas was continued as well as reduction, and multiple ideas evolved incrementally based on the same focus. A1 retrospectively described that A1 was thinking of how the object is manufactured. A1 particularly focused on how the extruded feature around the clock face can be replicated with a flat steel or aluminium sheet (A1, 01:21:28). In these sketches, A1 also attempted to apply the feature of cut out details around the original clock face to A1's idea as a clock dial.

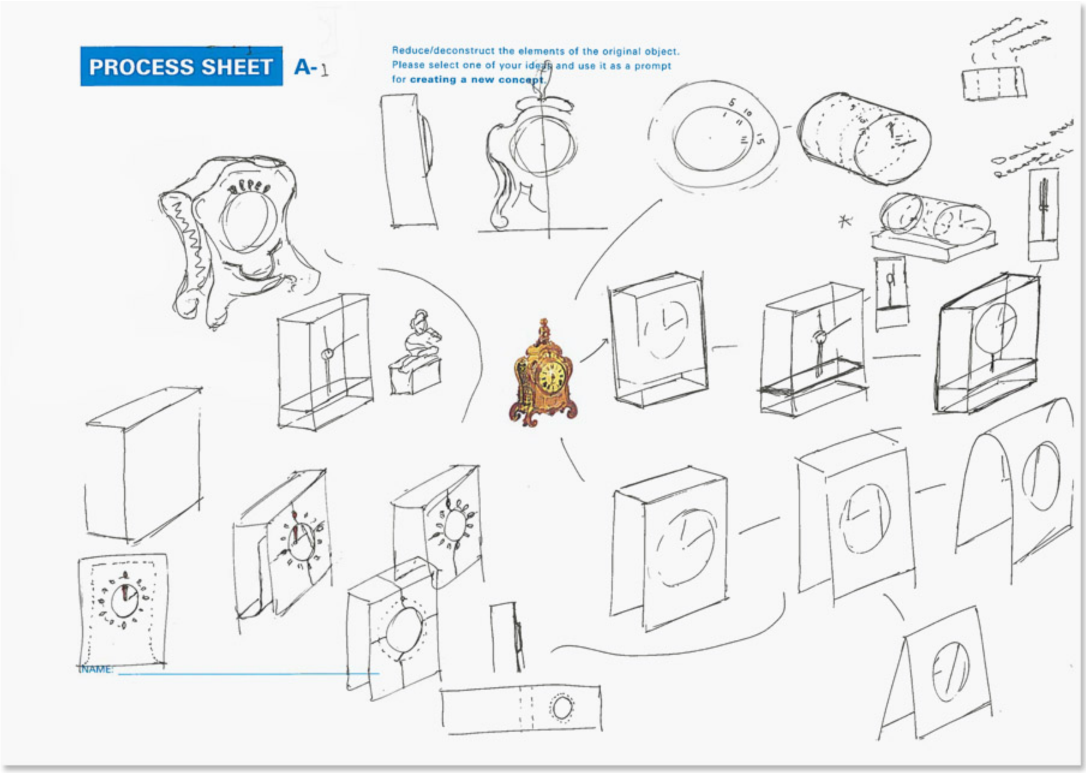



***Figure 92. The process of A1 at 01:20:00.***

During this phase, A1 remembered the book titled “Analogue and Digital” written by the famous German graphic designer, *Otl Aicher*. According to A1, the book was arguing about the way we interpret clock faces digitally or in an analogue fashion. A1 then considered that we, in general, spatially read the clock hands rather than through the precise numerical information placed on the clock face of the original object. The analogue clock face can be replaced with a digital display if we prefer to know the time in more precise and exact ways. Based on this thought, A1 conceived the idea of abstracting information of the clock face by decomposing its visual elements spatially and this idea will subsequently be the core concept of A1’s final design:

> *“If you abstract them (the elements of the clock face) then you have the faces as separate parts, so then you can place them in your own hierarchy to it. So maybe you place the face in front the hands as it is more significant, or behind it. Or, maybe they are not together but those have kind of spatial range between them so you can define them depending on the relevant to you or something” (A1, 01:20:29).*

A1 asserted that although A1 explored different ideas reducing the elements, A1’s attention was still caught by the idea of the cylinder-shaped transparent clock composed of multiple layers of graphic elements. After all, A1 selected this idea and decided to polish it towards the final conclusion. A1 then moved to the second *Process Sheet*.

On the second *Process Sheet*, to begin with, A1 started drawing the section view of the idea. As a next step, A1 suddenly trace the front view of the original object emphasising the ornamental part underneath the clock face. Then, A1 evolved the form of the base for the based on the shape of the ornamental part where A1 focused on (Figure 93). It appears that the form of the clock base was derived from this particular ornament of the original object.

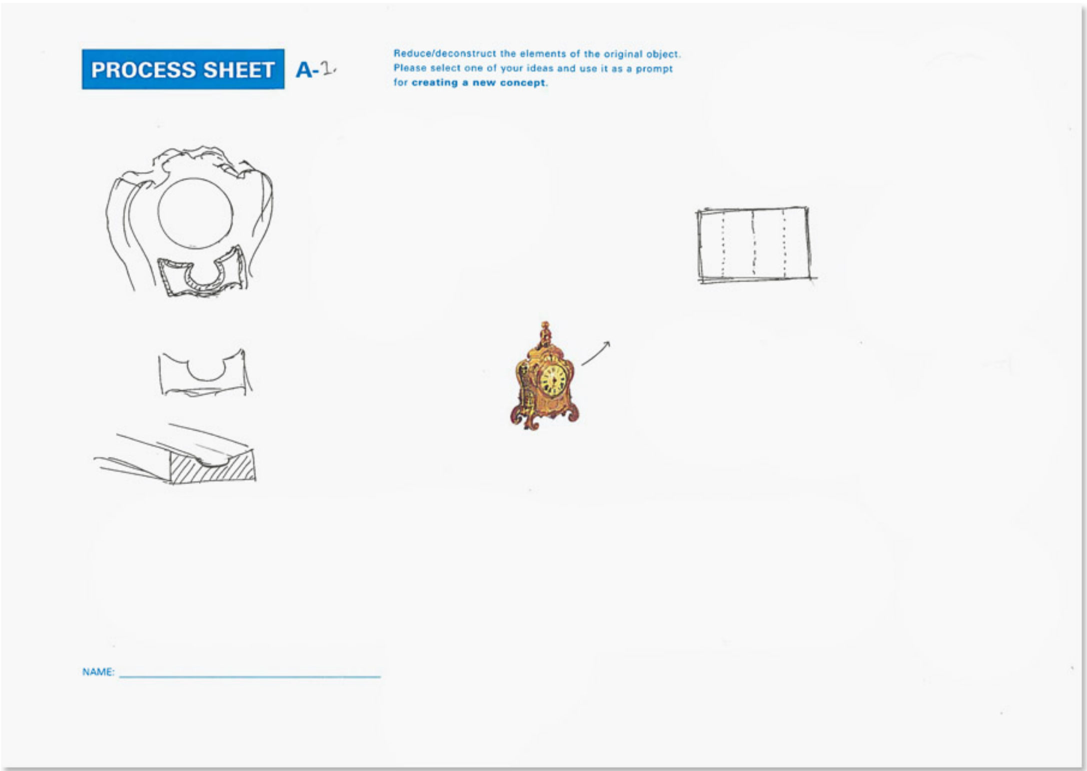
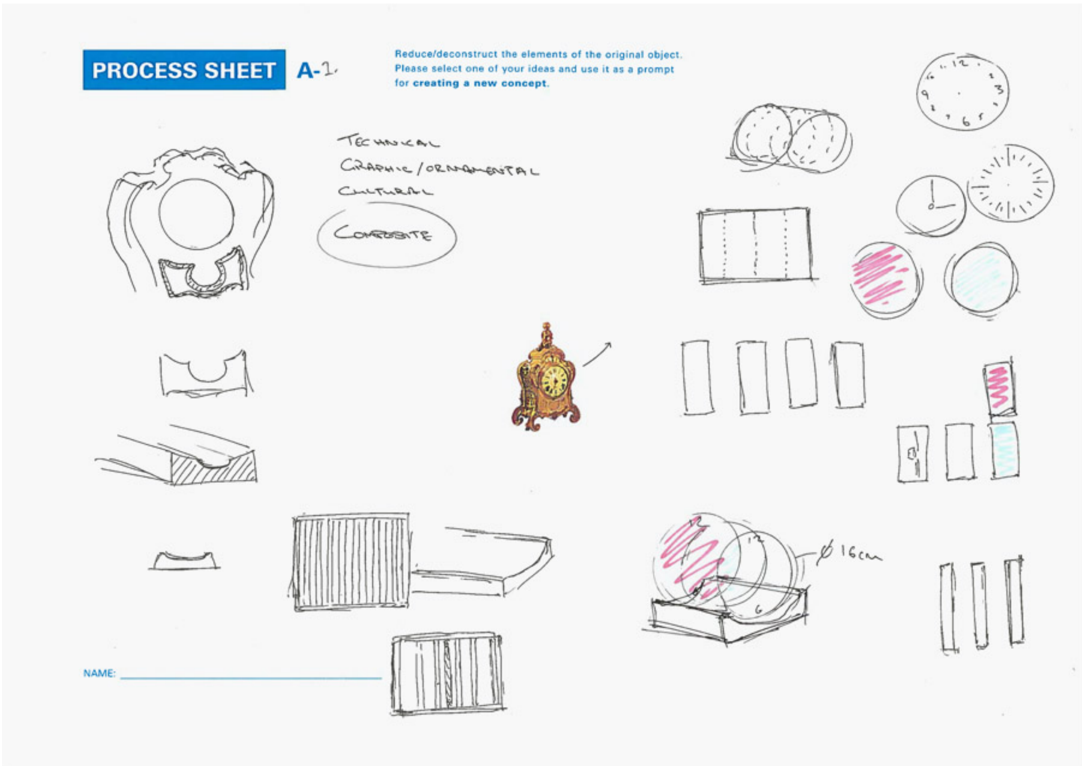



*Figure 93. The process of A1 at 01:30:00.*

A1 then continued drawing the main body of the clock. A1 was considering how the object can actually be composed with multiple layers of graphical elements by drawing. At one point, A1 suddenly went back to the previous *Process Sheet* and added the keywords that A1 previously identified: “technical”, “cultural” and “graphic/ornamental” (A1, 01:31:06). The object as the final idea was formed little by little clarifying the details such as the colours to be added for the clock face, the composition between the faces and the base or the spatial arrangement among the layers. In this process, A1 described that A1 continued the further integration of the elements discovered in the first *Process Sheet* (A1, 01:46:49). A1 focused on the discovery of the hierarchical structure of visual elements as a three-dimensional object, in the idea of the cylinder-shaped clock aforementioned. As well as this discovery, A1 also considered the understanding of the contextual attributes of the original object identified such as ornamental, graphical, technical and cultural. A1 was interested in the way in which those multiple elements are physically arranged depending on the context where A1's object is placed. The combination of these two thoughts led A1 to the idea of which the components as part of clock display of the object should be separated in order to allow the user to configure the graphical elements in their desired way (Figure 94):

> *"(...) these three components (disks), and you can set and define the structure to yourself. Each has a self-contained vessel. The clock is in the only one part with a moving part (clock mechanism) and the others are very simple. It's just kind of disks" (A1, 01:47:57).*

***Figure 94. The process of A1 at 01:47:57.***




A1 also re-interpreted the meaning of ornamental aspects that the original object involves in the contemporary context in A1's design. A1 considered that the decorative elements can be represented with multiple colours in the modern design context where monochromatic shades such as black, white and silver are predominant (A1, 01:48:34). In A1's notion of modern design, it lacks the feeling of "lightness" so that the clarity gained from the transparency of glasses was important for A1's design. Additionally, the colours given to the transparent glass disks adds ornamental value to A1's design:

*"(...) just a coloured glass or something like that so this (a disk) would be lightly tinted. The colours provide ornaments (to A1's design). It could either be used as the front face and then you see through that everything is filtered as a coloured... red or pink or green or whatever. Or, if you put it at the back, you see the different colour. (...) So, the idea is that there is a base and you slot them into and you can shuffle them around. (...) because it's a 3D object, you never really view it straight on. It's always slightly from an angle which means the amount of the colours intersects. Maybe you chose to use two colour paints and if you don't want to use numbered face at all. In that case, you can get an interesting composition here by overlapped colours" (A1, 01:49:05).*

A1 concluded A1's final design after trying a few different arrangements of the disks placed on the clock base by drawing (Figure 95). At the end of the process, A1 also mentioned about the intended scale of A1's design that the object cannot be too small as it needs a certain amount of light shining through the tinted translucent glasses.

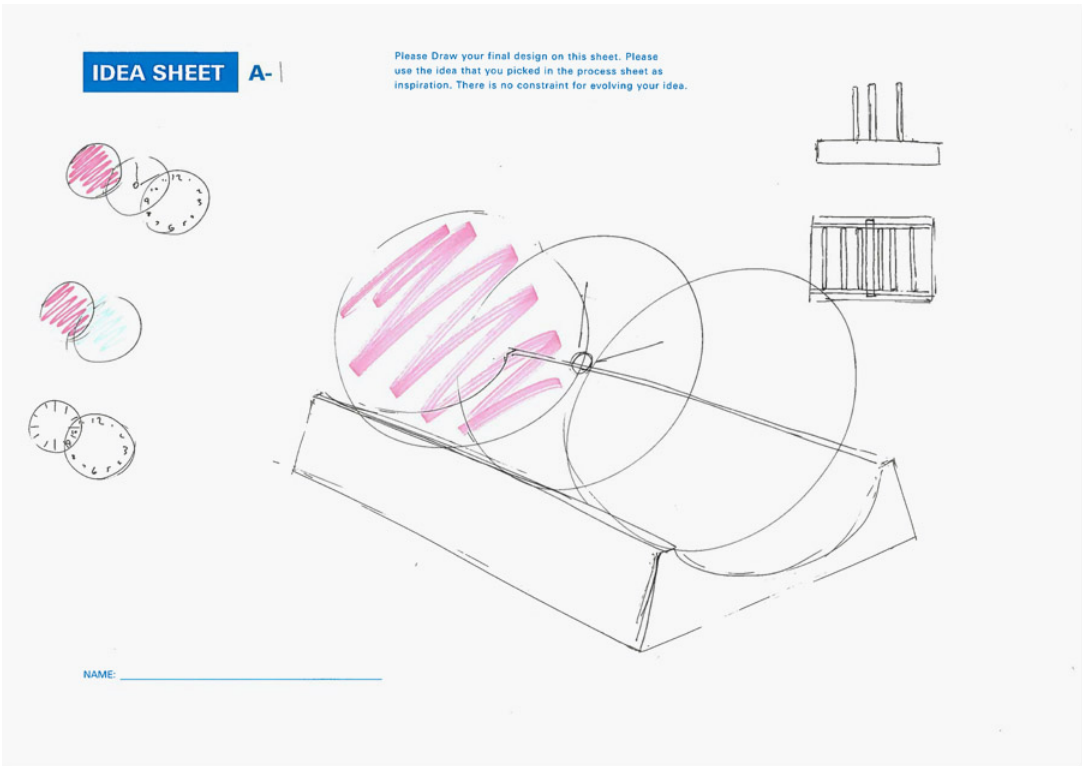



*Figure 95. The final conclusion depicted on the Idea Sheet.*

#### 4.7.3.1.2 The Participant A1: Summary

The previous chapter described the entire process of reduction and idea exploration of the participant A1. In this chapter, the summary of the processes is described along with a diagram that illustrates the actions A1 took during the task (Figure 96).

The approach A1 took was not completely linear. During the process, the multiple thinking avenues evolved, and A1 frequently returned back to the image of the original object and/or previous thinking avenues that A1 had developed before. A1 evolved a thinking avenue and then either went back to the original object to look anew at it and develop another approach or back to one of the previous ideas explored and add or combine different thoughts. At the end of the idea exploration process, A1 selected one of the key ideas A1 had previously discovered for the final idea. Although several thinking avenues were explored after the finding of the key idea, the elements discovered during the process were integrated into the final outcome based on the notion of "hierarchy of information".

The prominent characteristic of this participant was that the reductive process always started with observing a particular feature of the original object. The ideas always evolved based on the understandings, the interpretations, the identified key concepts, or the awareness derived from the scrutiny of the original object. A certain level of understanding led to another interpretation one after the other, and these were subsequently integrated and used to foster ideas as a clue. In the post-production interview, A1 asserted the importance of focusing on a particular aspect of the object, breaking the factors discovered down into separate elements and re-integrating them into a different arrangement of composition. This process allowed A1 to discover a "new balance" of the elements as a clue for exploring ideas:

> *"I found that you can't start with everything because it's too hard to understand so you have to understand the object itself. So, primarily by breaking it down I just understood the way the volume is constructed as a mass of it, as a structure conceptually or culturally (...) whatever different aspects that make up of this object and how they balance and when you look at it where, as an object, (...) the balance already has its own harmony. But then you consider things you have to work out… a new balance of the object or a new harmony, because obviously as you change factors it loses its balance so that you are trying to reassemble it and refine the balance so it may be a different balance" (A1 Interview, 00:23:05).*

In conclusion, the process of reduction provided A1 with the opportunities of learning about the original object from multiple angles. After the learning process, the extracted key concepts were re-interpreted/re-integrated into the thoughts that fit in the modern context, and the ideas were discovered and fostered maintaining the same functionality as an object.

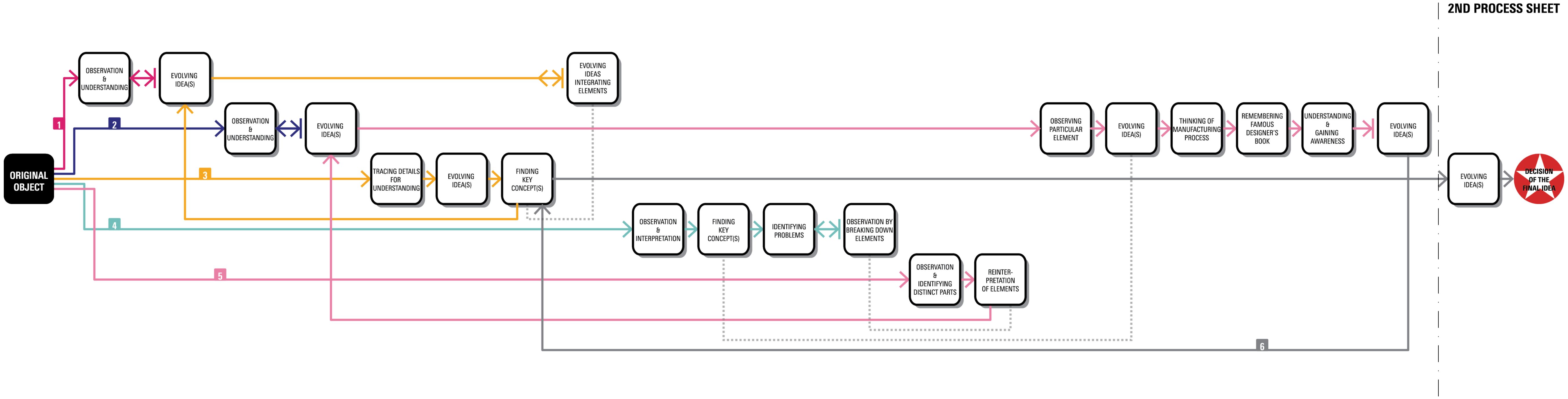



*Figure 96. The diagram that shows A1's reductive process (This diagram will be shown in a separate spread in the thesis).*

#### 4.7.3.1.3 The Participant A2

The participant A2 designed a stand clock whose elements are ultimately simplified, and it has a concave detail around the circle shaped clock face (Figure 97). The design intention of this plain clock is to show its simplicity without excessive features and the user appreciates the subtle shadows the distances amongst the clock hands, the concave detail and the plain clock face make. Also, the use of two contradictory materials that are artificial plastic and natural wood gives an impression of contrast. The scale of this standing clock is portable size. The materials assumed to be used in the object are matt-surface plastic for the main body and beech wood for the stand.

The reductive process of A2 was started with focusing on the most prominent details of the original object for A2: the face and the hair of top figuring, the legs and the surface texture of the ornamentation at the side (A2, 00:01:08). A2 was also sketching those features on the sheet (Figure 98). After looking at those details, A2 understood the structure of the main body that the part is composed of multiple layers and has a hollow in it. Then, the focus of A2 shifted to the decorative curves on the profile view of the object and traced them by sketching on the sheet. It seemed that A2 attempted to figure out how the ornamental curves are formed by sketching: *"The overall profile is something like this. That shape is very ornate. It's really eccentric. Many many things are happening. I guess there are many faces and roundness" (A2, 00:03:14)*. A2 also focused on the detail of the clock face and depicted one of the roman numerals enlarging its size. The focus of A2 shifted quickly to different features of the original object. A2 then returned back to the thinking avenues regarding the profile view and continued the thinking avenue adding some details by sketching. Based on this sketch that represents the profile view, A2 continued to develop a couple of simplified images of it replacing the curve details with simple straight lines. Within this process of simplification, A2 discovered that the certain impression of the object cannot be altered even if its prominent characteristic of the form is removed:

> *"That profile curve. (...) this such a big shoulder is very sort of strong, broad shoulder. It's quite masculine sort of shape. So, if you take away the curves, it doesn't reduce masculinity. It's just a very strong block piece." (A2, 00:06:19).*

*Figure 97. The reproduced image of the outcome of the participant A2.*

A2's attention moved to another detail of the object. A2 focused on the ornamental detail around the side corner of the main body and sketched it out. Then, A2 transformed this detail into simplified geometric form. After the quick sketch of the corner detail, A2 moved back to the previous thinking avenue focused on the leg part and continued further reduction of its form. It appeared that A2 attempted to capture as many different aspects as possible in order to find clues for ideas and to avoid A2's thinking stagnant during the reductive process. A2 acknowledged that focusing on a wide variety of details and abstracting the elements were the first step of reduction for A2 (A2, 00:09:53).

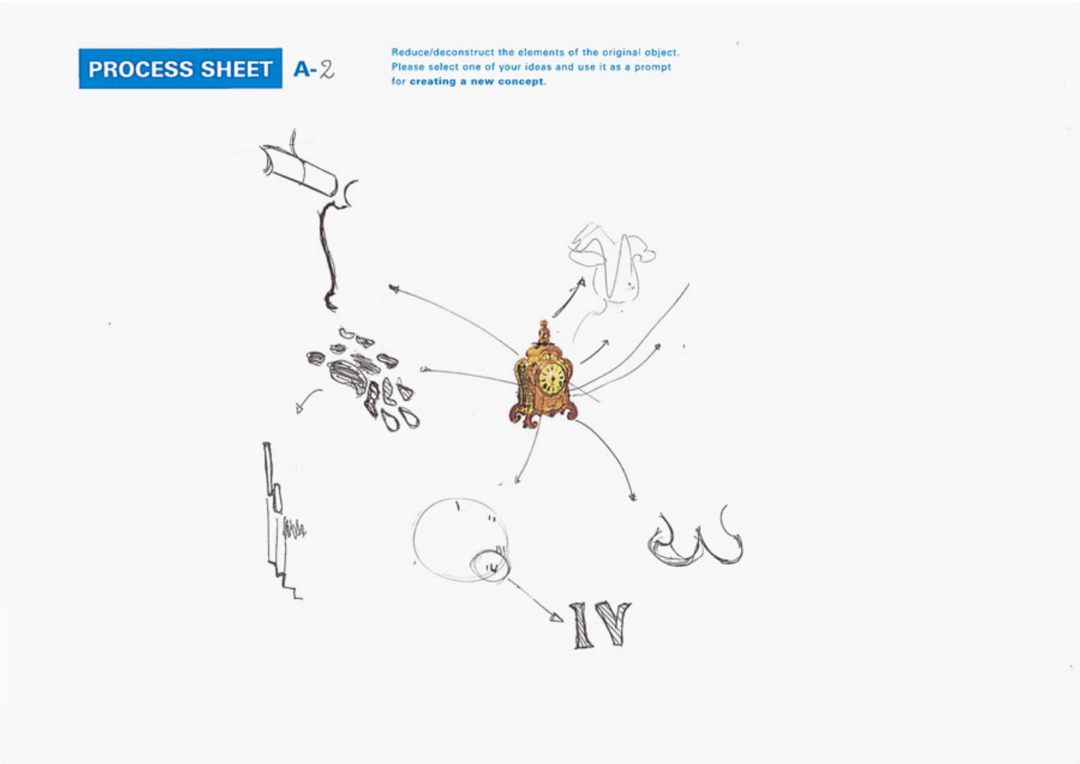



*Figure 98. The process of A2's idea development at 00:01:10.*

At this stage of the process, A2 evolved a new thinking avenue by simplifying a particular detail of the decorative part under the clock face of the original object. Then, extra elements were added to the extracted form. A2 just attempted to combine these different elements to see what comes out from its consequence (A2, 00:10:18). A2 continued to evolve ideas based on the same focus by iterative simplification of forms (Figure 99). A2 also combined an original element with the form A2 developed. Later, A2 reflected and explained about this process that A2 attempted to sketch out a detail and look at it as a whole profile of an object:

> *"That's (pointed with A2's finger the decoration part underneath the clock face) what I am trying to pick up. The small detail. These (the ideas of the*

*evolved and simplified form) become, to me, feels like full profile now. Just taking inspirations from that detail" (A2, 00:18:35).*

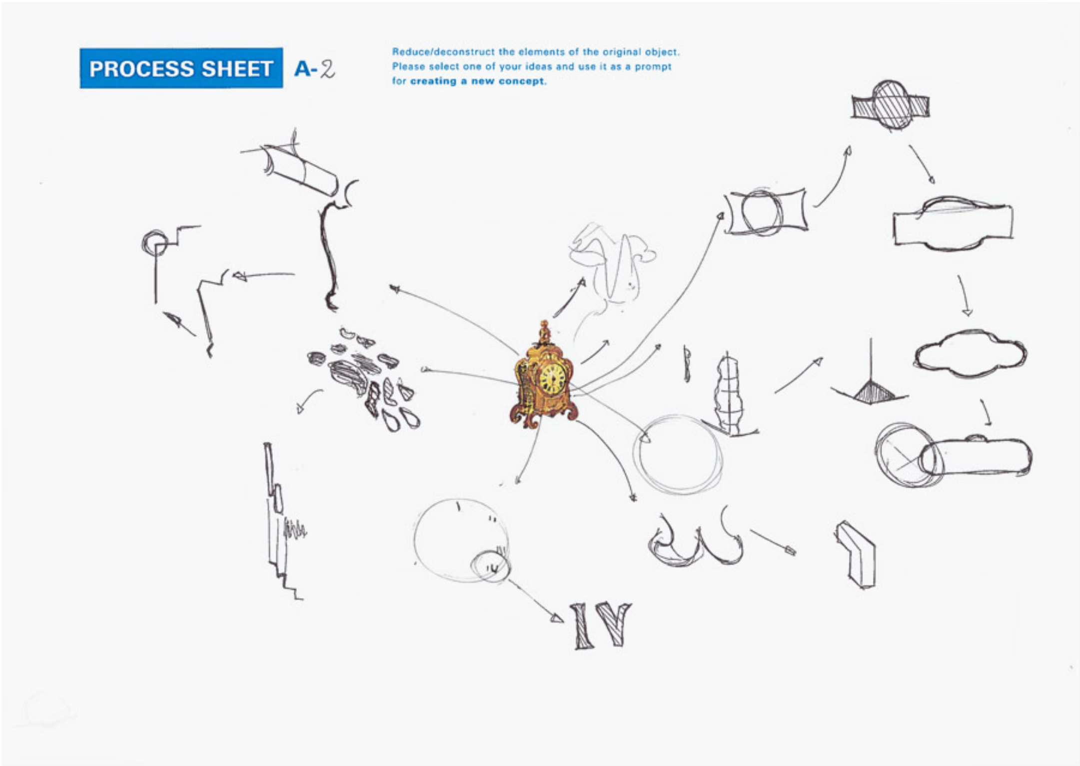



***Figure 99. The process of A2's idea development at 00:10:20.***

A2 returned back to the previous thinking avenue that focused on the side decoration pattern with hollow. A2 assumed how the part is structured and what that characteristic offers to the viewer of the object (A2, 00:13:10). Based on this focus, A2 drew a section viewed from the top that represents the layered structure of the original object. A2 evolved a couple of ideas regarding the surface detail of object referring to the previous sketch. It appeared that A2 attempted to evolve ideas of a detail following the understanding derived from observation. A2 then returned back to the previous drawing that represents the pattern of side decoration and transformed the organic form of the elements into an arranged geometric pattern (Figure 100).

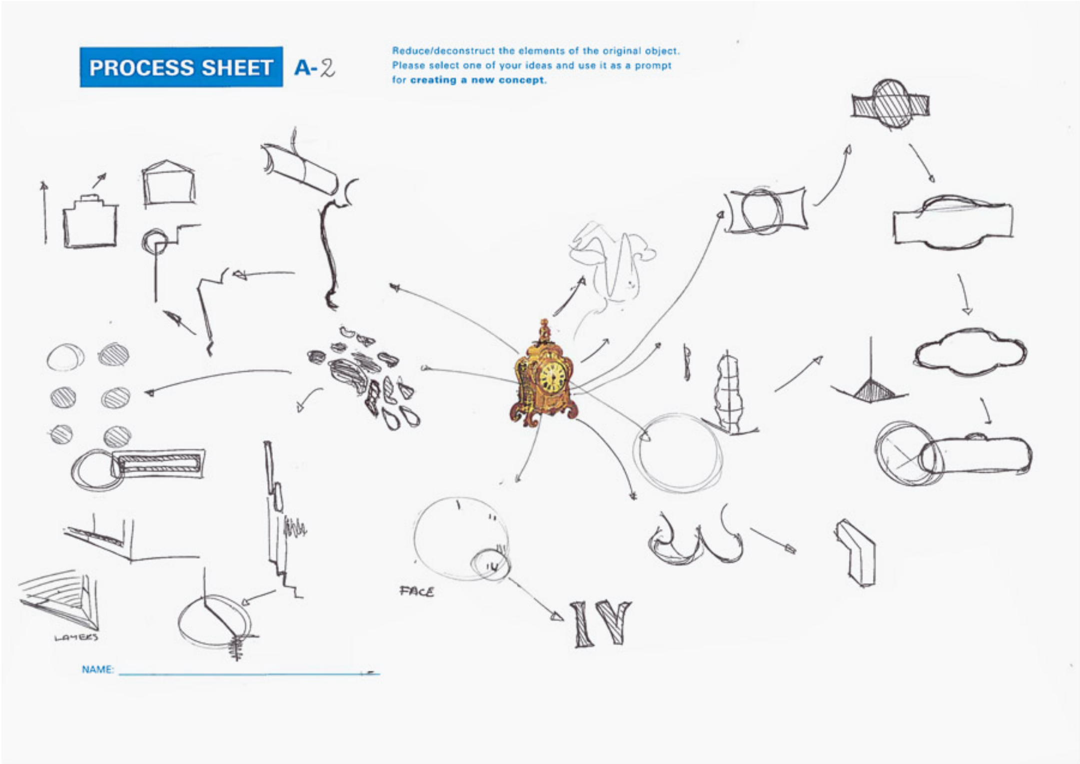



*Figure 100. The process of A2's idea development at 00:15:00.*

A2 quickly jumped to the previous thinking avenue that focused on the profile view of the object and evolved a few ideas. At this phase, A2 described about what A2 is doing that A2 was focusing on small details of the object and enlarge each element in order to understand them better (A2, 00:17:56). A2 also mentioned that, once A2 start focusing on a specific detail of the object, A2 evolved ideas dismissing the original object (A2, 00:19:21).

A2 returned back to the previous thinking avenue that focused on the leg part and continued further reduction evolving a few ideas shaped tube. At this phase, A2 described that after focusing on several small elements A2 now looked back at the original object in order to find the aspects that A2 had not considered yet (A2 00:21:16).

A2 went back to another previous thinking avenue regarding the aspect of the clock face. A2 considered whether the numerical information can be replaced with an abstract shape. It appeared that A2 evolved ideas by abstracting the literal information into geometrical graphics. In this process, A2 replaced the elements of the numerical display with circles first, and then A2 conceived the idea of which the clock dial represented with the dots is reduced to the concave ditch (Figure 101):

*"If it replaces the number with just circles it doesn't need to be coloured. I'm thinking how the things are going to be taken away. Can these circles become, instead of solid surface, just lines? Even then taking away the painted outline it's just making that into a surface detail. You see it as… scooped out" (A2, 00:23:16).*

During this reductive process, A2 also asserted that taking elements away is actually bringing more results (A2, 00:24:25).

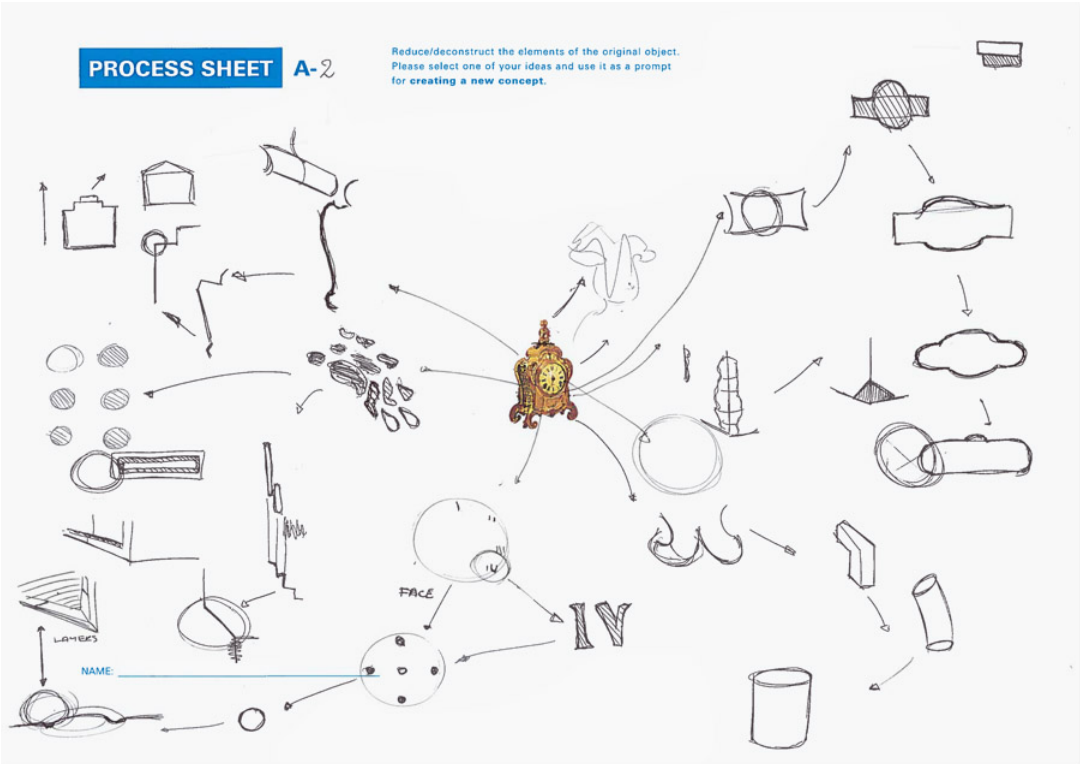



***Figure 101. The process of A2's idea development at 00:23:16.***

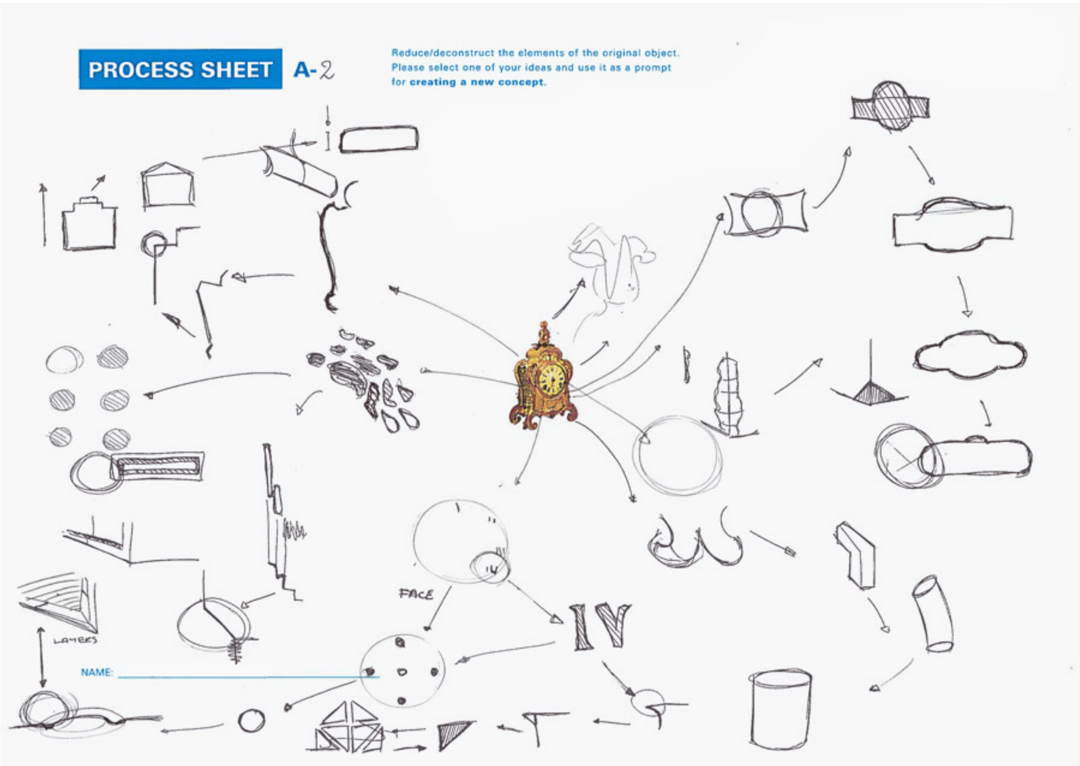
A2 again went back to the previous thinking avenue focused on the profile view of the original object and continued further reduction. A2 altered the form of the simplified profile view of the object in even simpler form shaped rectangle. A2's intention was making the form less dominant (A2, 00:26:10).

At this phase of the process, A2 described that A2 was seeking the elements that can be integrated (A2, 00:26:50). It appeared that A2 was trying to reflect the thinking avenues developed and relate some similar elements to each other:

*"(...) it's sort of reduced but some elements are merged... not merged but similar so now I'm trying to combine two three things." (A2, 00:28:05)*

A2 then focused on the graphical elements on the clock face again, and evolved ideas focusing on its details. A2 conceived a geometric pattern composed of triangles, and stated that the triangular shape was derived from the characteristic of serif of the typography used for the original clock display (Figure 102). A2 attempted to pick up a part of the elements and transformed into another idea. At this phase of the process, however, A2 considered that A2 was actually adding elements rather than reducing so that A2 decided to stop this approach.

***Figure 102. The process of A2's idea development at 00:30:10.***




At this phase of the process, A2 was seeking a possibility of combining different elements that has been discovered already (A2, 00:34:23). A2 also stated that A2 decided not to keep the decorative elements of the original object but rather to use the simplified and abstracted figures for A2's ideas (A2, 00:34:40). It appeared that A2 attempted to exploit the decorative elements that are translated into geometric forms as the inheritance from the original object.

A2 reflected the entire reductive processes and added the circle marks on some depicted elements on the *Process Sheet*. While doing so, A2 also stated as follows: *"I'm* *just trying to… what feels the most interesting… you know, what to keep and what to take away" (A2, 00:35:25)*.

A2 started classifying what elements are essential or subordinate identifying the meaning of a part. The aim was to quickly confirm and identify less important factors to be removed: *"(…) this figurine to me is just an addition. Not essential. I'm just quickly getting rid of things." (A2, 00:36:45)*.

A2 then looked over the instruction on the *Process Sheet* again and attempted to define the words of "new concepts" written. This action led A2 to realise that the ideas evolved were not forming a concept but shaping forms focusing on the decoration details of the original object:

> *"I guess the "new concepts" mean a new form and non-literal objects really. (…) that's how I'm looking at it. This (the thinking avenues A2 has evolved so far) is not trying to find what it could be. It's just like a shape deconstructing elements (…) it's just like a physical form (…) with detail elements" (A2, 00:35:35)*.

A2 moved back to the idea of simplified profile view that A2 has developed again and continued further reduction of form into a square. Then, A2 drew a cube with a detail shaped like a picture frame that is very similar to the form A2 discovered before (Figure 103). It appeared that A2 combined the two different elements previously discovered together. In fact, A2 described that A2 picked out some elements and reintegrate them: *"I sort of picked out a few elements that were drawn to. It's not essentially the one thing. (…) then I'm thinking how I can combine them back. Disassembling and reassembling" (A2, 00:43:10)*.

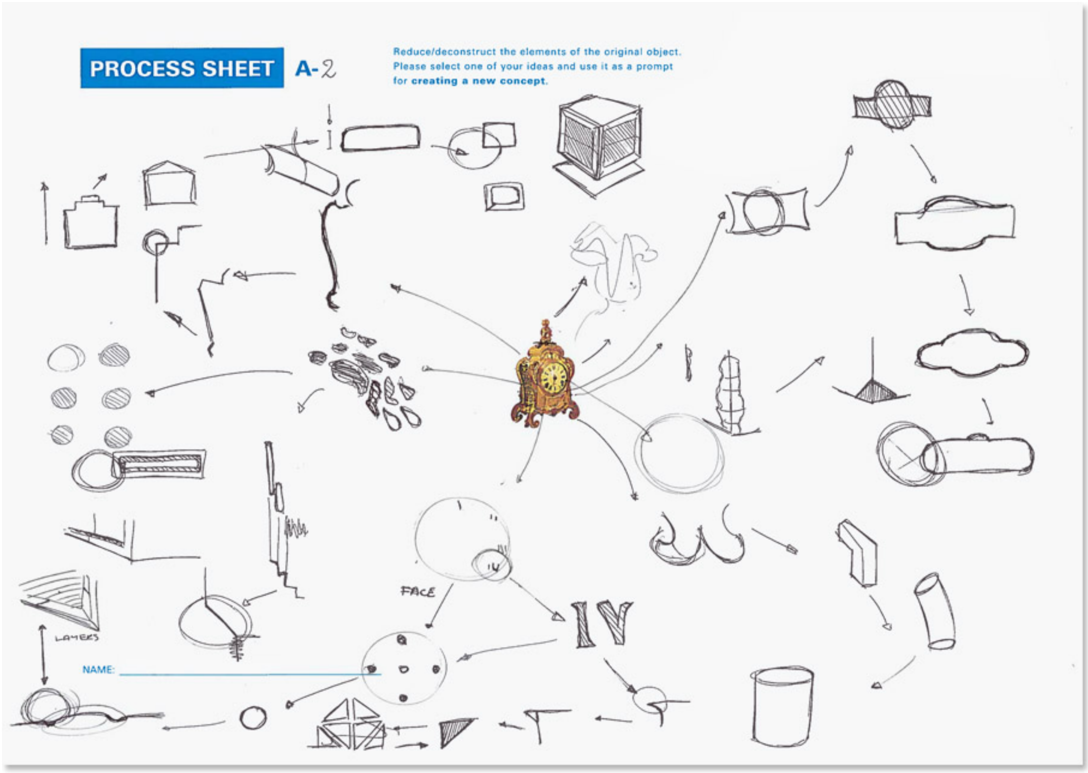



*Figure 103. The process of A2's idea development at 00:40:00.*

At this point, A2 asserted that A2 got lost so that returned back to the original object. Although it seemed that A2 attempted to start over the thinking process from the original object, A2 went back to the previous thinking avenue and continued further reduction. A2 then evolved an idea from the drawing shaped cube, and connected the new idea with another idea placed next to it with an arrow (Figure 104). It seemed that A2 was evolving ideas by combining different elements. A2 continued the idea development iteratively.

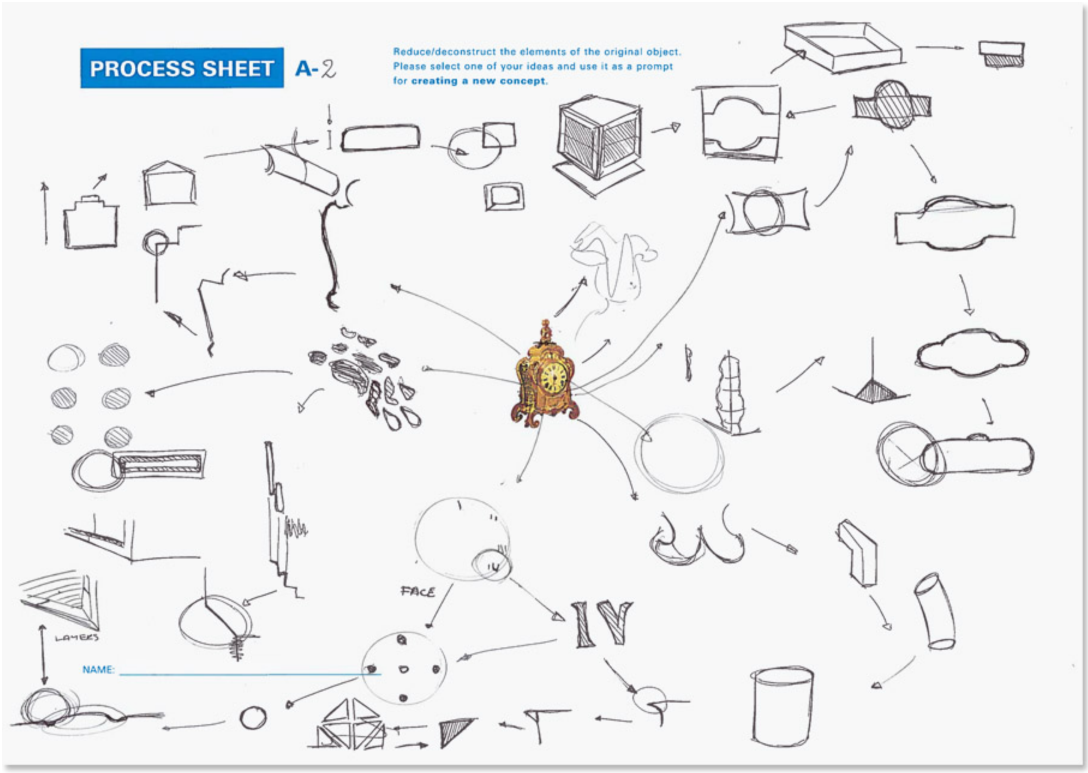



*Figure 104. The process of A2's idea development at 00:45:00.*

At this phase of the process, A2 asserted that A2 found the key element for the final conclusion (A2, 00:47:39). A2 described that A2 focused on the entire profile of the original object and evolved the previous cube-look idea by integrating multiple micro-elements discovered. Then, now the focus returned back to the thinking avenue that focused on the aspect of the clock face and decided to continue this perspective towards the final conclusion:

> *"I think it's quite interesting looking at the face itself. Even simplifying the numbers (the original Arabic numerals on the face) into (geometric figures)… and (…) again by removing them (clock dials) from its surface… so taking material away from the surface… which is again the reductive detail. Also, layering thing (the layered structure of the original object that A2 focused before) is quite interesting because it shows the depth of an object so I'm working with the multiple elements" (A2, 00:48:29).*

Although A2 selected a particular thinking avenue for the conclusion the multiple ideas were integrated in it. In relation to focusing on the aspect of the clock face, A2 reinterpreted that the entire object can be regarded as a picture frame that accentuates the clock face (A2, 00:49:56). Based on this thought, A2 evolved the idea of which a simplified clock whose face shaped circular depression is placed in the centre (Figure 105):

*"What I'm seeing is a linear simplified profile which is housing this circular thing (clock face). I think the circle is still the main feature… pushing that in a very simple and minimal thing (the case of the clock face shaped square) which is still highlighting… (the clock face)" (A2, 00:50:27).*

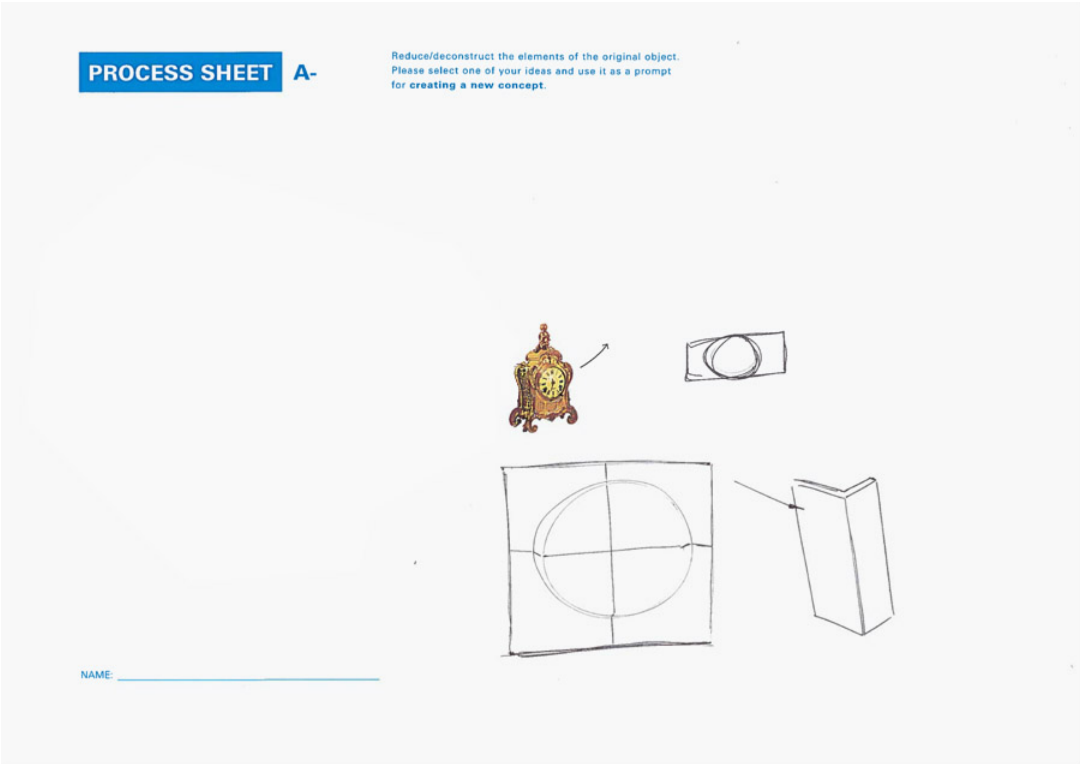



*Figure 105. The 2nd process sheet of A2's idea development at 00:50:27.*

The intention, according to A2, of this idea was designing the subtle detail of the clock face that only be found when the user look at it closely (A2, 00:51:28).

At this point, A2 asserted that A2 starts designing the final idea (A2, 00:55:05). Before going into designing, A2 started describing the summary of the process in which A2 reached the key concept. As A2 went through the reductive processes, the focus of A2 became stronger on the aspect of the clock face and dismissed the ornamental elements. A2 kept on conceiving of objects as a timepiece throughout the process as the essential functionality of the original is a clock. A2 did not change this assumption within the reductive process since the functionality that the original object involves was the most important element when A2 envisaged ideas (A2, 00:55:45).

Another thinking avenue focused on the side structure of the original object evolved. This aspect of the object was reviewed by A2 previously. A2 asserted, however, that A2 attempted to look at the particular aspect again with a fresh eye and double-checked what A2 was thinking by drawing (A2, 01:00:03). A2 also described that even though A2 attempted to look at the same aspect of the object differently, what caught A2's attention was the same after all. A2 confirmed that A2 was truly interested in this particular aspect of the object (A2, 01:00:53).

After sketching out a simplified leg part, A2 discovered the concept of the profile of the final design. A2 finally adopted the simplified profile form that A2 conceived before, and merged it with the circular shape of the clock face of the original object. A2 described the reason why the circular form of the clock face was kept for the final design was that it is the simplest feature in the original object (A2, 01:02:40). The ornamental aspects of the original object were completely dismissed at this phase of the process.

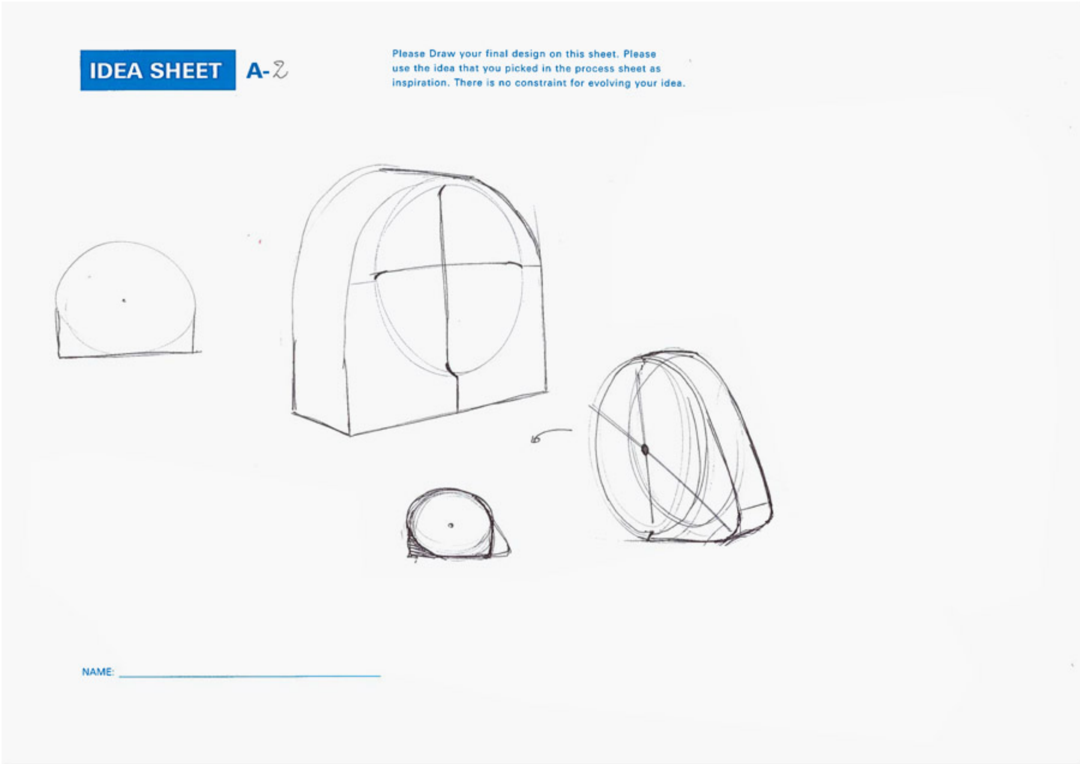
A2 moved to the *Idea Sheet* and continued the reductive process to finalise the conclusion. A2 had not depicted the concrete image of the final design yet at this stage. A2 started drawing with a simple circular form. Based on the circle, A2 added an extra volume to it to make it stand on the ground. Then, A2 started reducing the volume of the depicted object to make it simpler (Figure 106).

At this phase, A2 stated that A2 had a clear idea about the final conclusion. In the visualisation process of the idea, A2 attempted to design the object reflecting the discoveries in the previous thinking avenues (A2, 01:10:36). A2 also stated that A2 had been evolving ideas without thinking about designing a clock:

> *"At this stage, I'm not thinking of it as a clock. I'm just trying to accentuate the circle in the middle but looking at it as a static object. But that profile is evolved from the circle and… those two things (circle and square) so it's not going to be rolling" (A2, 01:12:48).*

It appeared that A2 was just focusing on the minimal forms rather than other attributes of an object such as functionality. This thinking process led A2 to discover the combination of the two elemental forms of both circle and square that were subsequently reflected in the final design.

*Figure 106. The 1st Idea Sheet at 01:04:14.*




A2 then integrated the idea of a ring-shaped concaved ditch that was discovered before into the current simple form. The part of clock dial was highlighted by placing the ring-shaped ditch around the face (A2, 01:14:49). The front and the side view images were depicted based on the idea (Figure 107). A2 attempted to actualise and understand the details of the idea by drawing (A2, 01:16:19). A2 also asserted that the side structure of the idea was derived from the previous discovery about the construction of the original object (A2, 01:17:05).

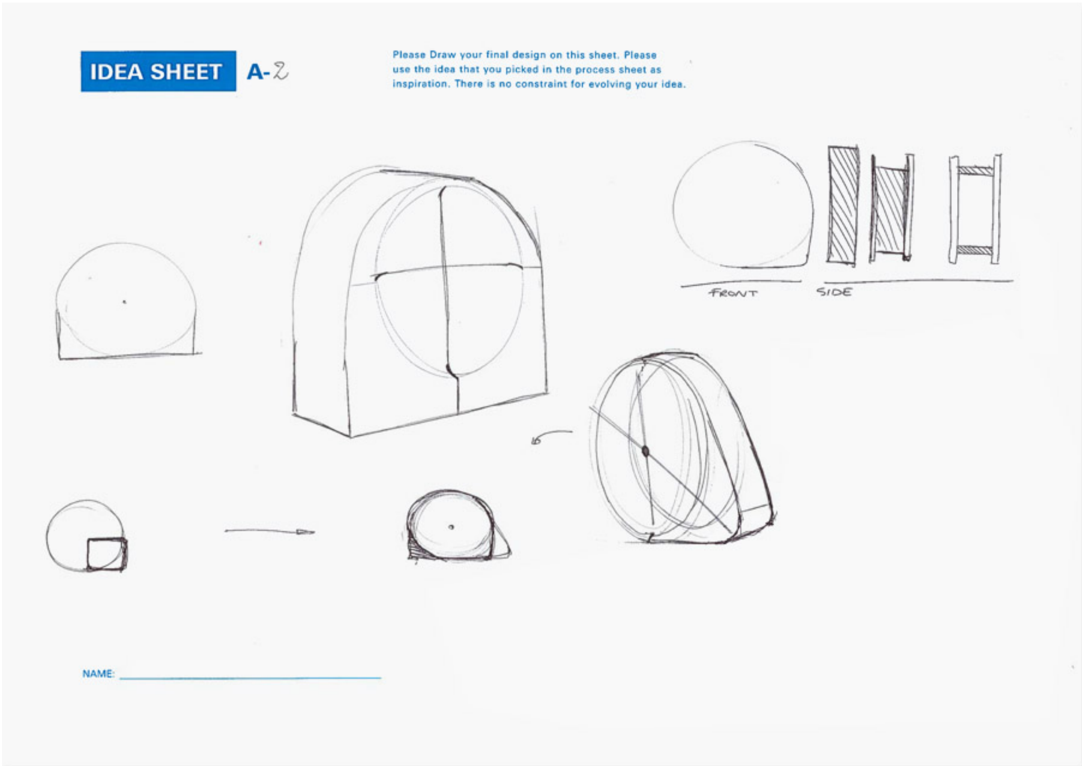



*Figure 107. The 1st Idea Sheet at 01:16:00.*

A2 has discovered that the original object contains a void inside and it can be seen through the pattern attached to the side. A2 attempted to exploit this feature into the side structure of the idea. It appeared that A2 attempted to integrate the elements that were discovered in the previous thinking avenues into the final design. A2 also continued reducing the volume of the idea step by step until the inside of the object is a void being sandwiched between the two flat sheets. During the reductive process, A2 realised that one of the flat surfaces is not necessary as the object only needs one flat surface for the clock face. This reduction led A2 to the idea of the clock consisted of a thin clock face and a small stand that became the final outcome (Figure 108).

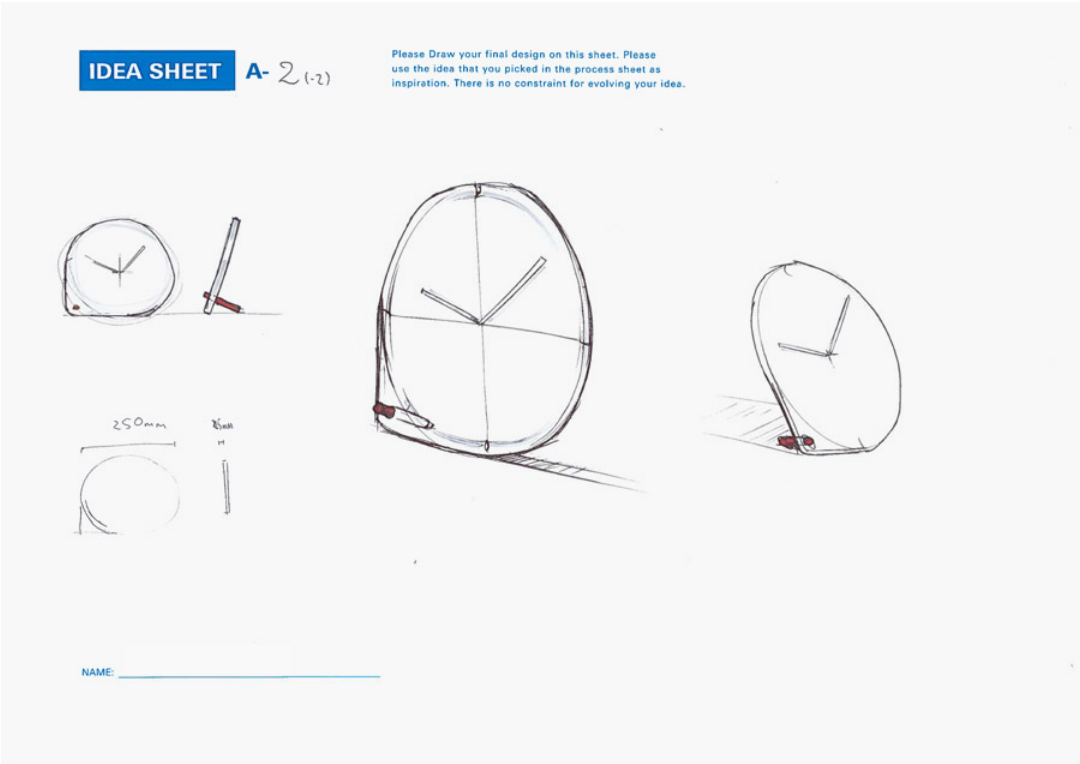



*Figure 108. The conclusion depicted on the 2nd Idea Sheet of A2.*

#### 4.7.3.1.4 The Participant A2: Summary

As is the case with the A1's process, the approach of A2 was not linear but rather cyclical (Figure 109). At the beginning of the reductive process, A2 started with observing individual details of the original object through sketching them out. At this phase of the reductive process, A2 repeatedly went back to the original object focusing on several details respectively. A2 then developed thinking avenues and evolved ideas based on the understanding derived from the observation. A2 retrospectively described that A2 was focusing on the complex elements of the original object and attempted to reduce them into the simplest forms. Also, A2 conceived how those simplified elements become design details (A2, Interview, 00:05:55). Halfway through the process, A2 frequently returned back to the thinking avenues that were previously explored and fostered ideas combining or correlating the identified elements of each other.

A2's thought was sticking with the same functionality of the original object throughout the reductive processes. The ideas evolved within the reductive process were always based on the idea of a clock. For A2, conceiving different objects is "adding" rather than reduction:

> *"Because I was quite happy for it to be a clock. I didn't mind starting the clock to begin with. I just didn't like all the other details (of the original object) (...) I liked the circle (the original clock face shaped circle) to work*

> *to begin with (...). If I wanted to make it into other objects, that would probably mean adding more to the circle" (A2, Interview, 00:09:25).*

The essential functionality as a clock was always kept and never targeted for reduction. In turn, the additional elements e.g. ornamentation attached to the main function were the primal target for reduction. The reduced and simplified elements were then re-integrated with the essential functionality as a clock for the final idea (A2, Interview, 00:07:04).

Another characteristic identified by this participant was that the main focus of A2 was on the physical details of form of the original object such as its profile, the volume, the layered structure at the side, the form of the legs or the clock display, seen through close observation. The understandings derived from the observation led A2's thought to another interpretation or ideas generation. It appeared that the rich visual information of the high-fidelity image of the object encouraged A2 to take a form driven approach.

In conclusion, the reductive process encouraged A2 to investigate the physical details of the original object by sketching the elements out to enable understanding. The ideas were then evolved based on the discoveries derived from the investigation. The process, however, was not straightforward and A2 frequently returned back to the previous thinking avenues integrating or correlating the elements discovered. The ideas were cultivated within this cyclical process towards the final conclusion.

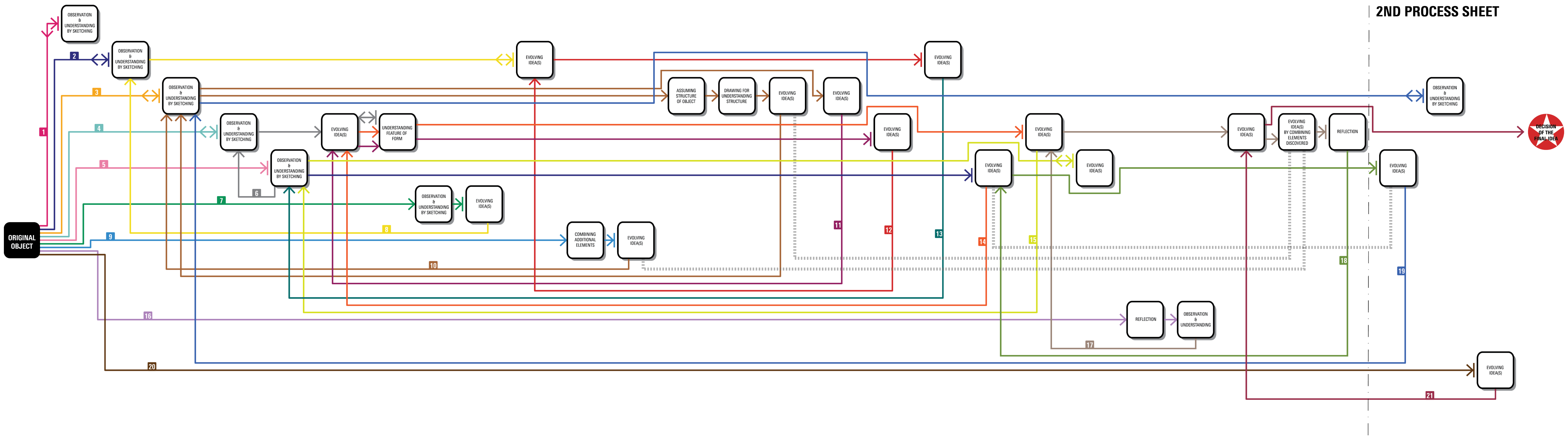



*Figure 109. The diagram that represents A2's reductive process.*

#### 4.7.3.1.5 The Participant A3

The participant A3 designed a square shaped modular speaker (Figure 110). The design shows two portable Bluetooth speakers set on top of a main speaker and the battery of the mobile set is charged while they are in place. These portable speakers were easily detached from the main body. The speaker sits on sturdy legs and this allows the user to clean the floor underneath the object easily. As well as its utility, the appearance of its mass is lifted by the legs aesthetically suggests a piece of furniture rather than electric products. The height of the main speaker conceived is approximately 300cm which is almost the same height as generic side tables. The main speaker produces loud and powerful sounds and the portable speakers are taken around by the users for their desired purposes. The felt fabric material is given to the surface around the speakers with the punched speaker-mesh and the sturdy legs that both are made of anodized steel. One of the highlights of the design lies in the material contrast between the warm felt fabric and the cold metal. Additionally, the felt fabric gives soft, warm and comfortable tactile experiences to the user. Although there is a difference in its function between the rococo clock and the modular speaker, several features of the original object such as feet, square in shape and proportion were kept but translated into a modern form.

To begin with, A3 started the process identifying the original object as an "old-fashioned" clock (A3, 00:00:59). A3 then asserted that the ornaments need to be "cleaned" and drew a box shaped clock with legs whose decorative elements are eliminated. A3 described A3 drew such a sketch as a starting point of the process (A3, 00:02:13). Based on this drawing, A3 associated its form with a washing machine and drew an object that has a circle and buttons without legs on the sheet (Figure 111). A3 also stated that all the features of the original object are removed in this drawing.

*Figure 110. The reproduced image of the outcome of the participant A3.*

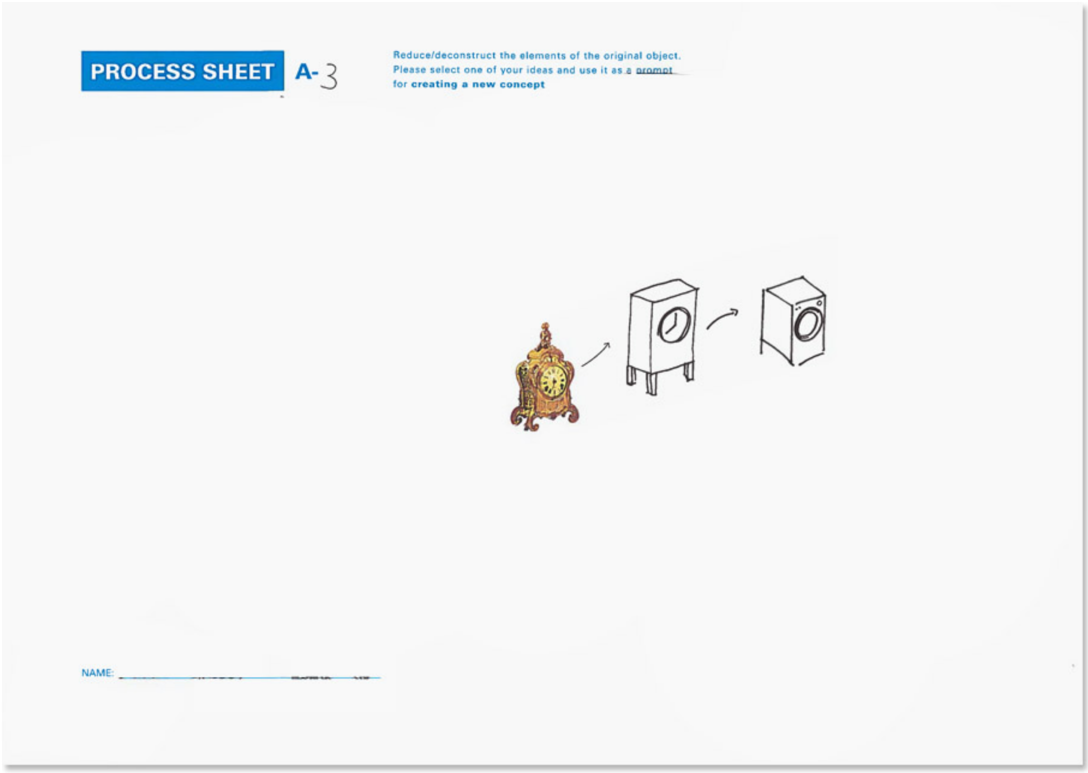



*Figure 111. The A3's Process Sheet at 00:03:02.*

A3 moved to another thinking avenue. At this phase, A3 asserted that A3 gave up the idea of a clock and decided to create a tray (A3, 00:03:40). A3 chopped off the upper part of the original object and kept the bottom including legs. A3 then focused on the top figurine of the original object and evolved the idea of a coin storage integrating it with the idea of a tray. A3 described that the ideas evolved crossing over the different presence of each object (A3, 00:05:29). In this process, A3 also stated that some decorative elements of the original object are used in the drawing (A3, 00:06:33). It appears that A3 attempted to evolve ideas considering its relevance to the original object. A3 further continued to evolve another idea of a stick with the figurine of the original object (Figure 112). This object was meant to be a toy as a gift for a child. In this ideation process, A3 was remembering the A3's recent project and integrated it with the previous idea envisaged:

> *"My mind is, for some reasons, suggesting putting the figure on a stick. This might be because I'm doing a project with a lot of dowels at the moment and it's in my mind. It's like a rod that's why that's in my mind" (A3, 00:07:03).*

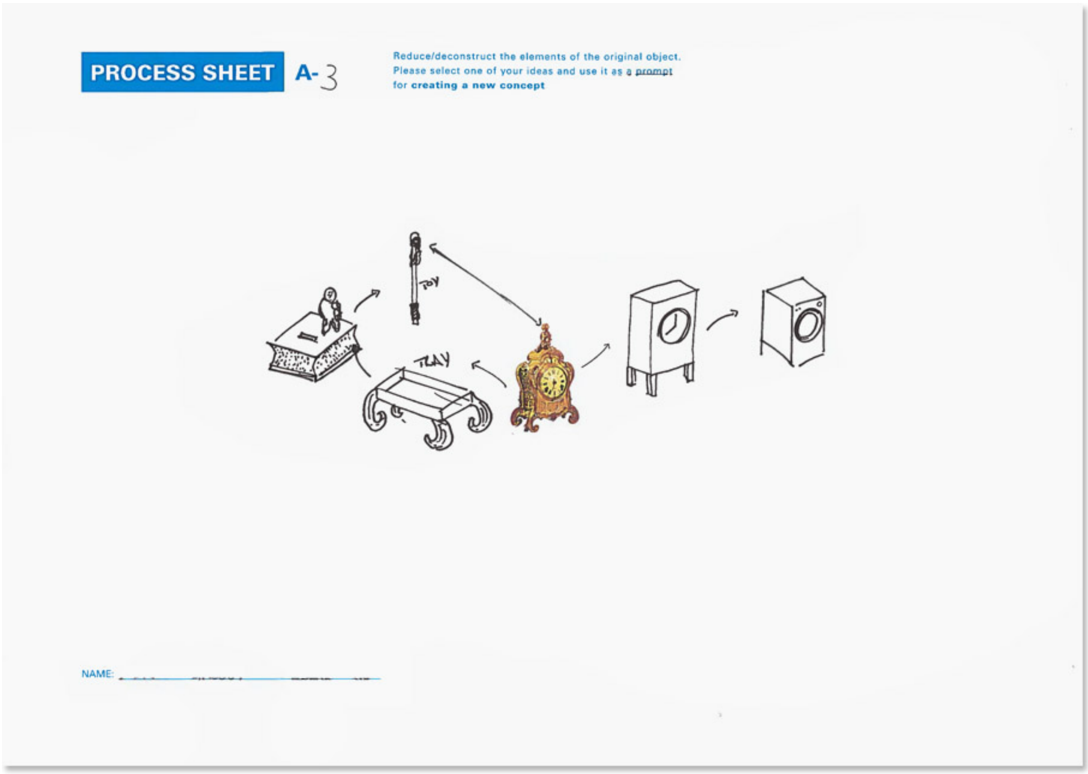



*Figure 112. The A3's Process Sheet at 00:07:50.*

A3 then returned to the original object and started the process from it. At this phase, A3 asserted that A3 attempts to evolve ideas sticking with clock (A3, 00:08:17). Following this idea, A3 conceived the idea of an archetypical alarm clock that has a circular clock-face with bells and little feet. After eliminating some elements of the alarm clock, A3 evolved several ideas iteratively by changing the form, the radius of its edge or the clock mechanism. A3 then started drawing a pebble-look object, and associated with a speaker from its form and the assumed size within the process of a form exercise:

> *"These shapes are a bit boring so I'm going to go to more pebbly sort of shape. I think I'm creating a really smaller scale… the size as I am drawing but it's more of like a speaker" (A3, 00:12:37).*

The category of the designed object was switched from a clock to a speaker at this point of the process. A3 also described that the form reminded A3 of existing speakers (A3, 00:13:05). This association encouraged A3 to go for the idea of a speaker, and evolved the further idea of a speaker-stand changing its scale (Figure 113.).

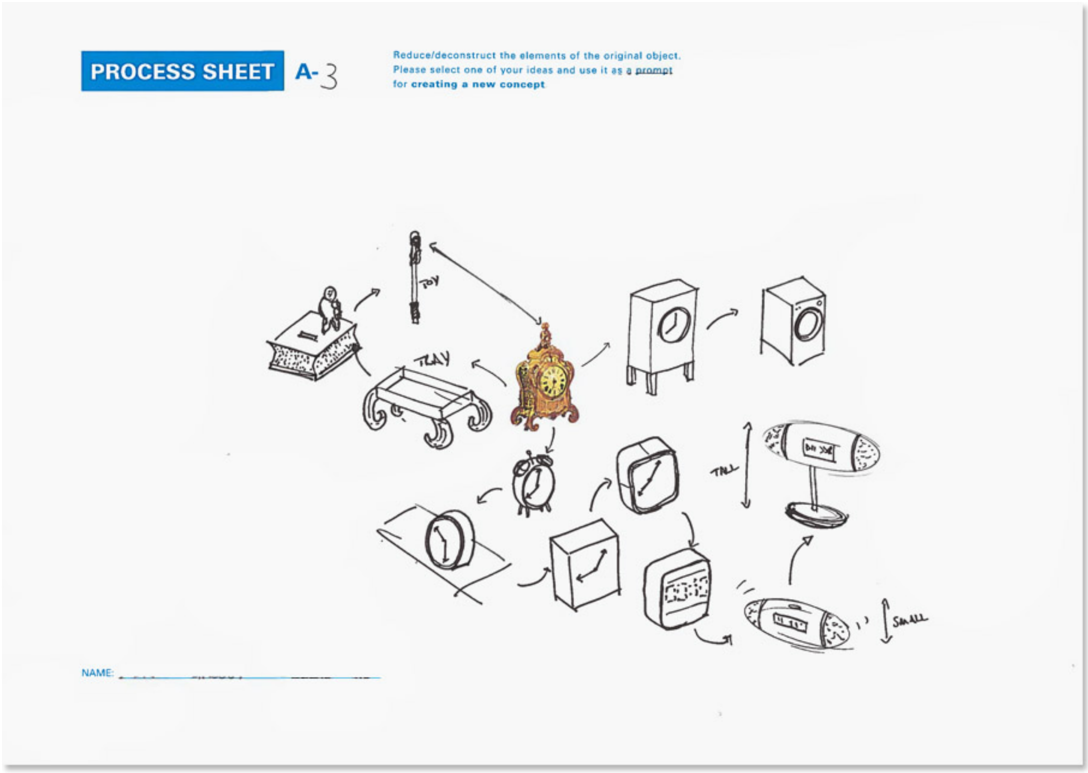



*Figure 113. The A3's Process Sheet at 00:15:35.*

At this point, A3 stated that A3 returns back to the previous thinking avenue in which the idea of a washing machine was developed (A3, 00:15:37) and conceived the idea of a stackable modular fridge. A3 also added a logotype of the existing fridge maker, SMEG on the sketch. At this point, the notion of "modular" was discovered and it will eventually become the core concept for A3's final design:

> *"(...) I am going to draw the two stacked each other. It's like a modular fridge. (...) this is going to be a simple fridge but the idea can be modular so you can buy more. You can move on top. Something like that. Appliances. Assembled in a different way" (A3, 00:06:05).*

A3 evolved the idea of modular kitchen system based on this identified concept. Following this, A3 combined the concept of "modular" with the idea of the speaker that A3 previously developed. A3 then envisaged the details of this idea referring to an existing speaker product and A3's past experience of sharing objects:

> *"(...) this one is more of a room speaker. This is speaker mesh and these two are smaller modular speakers so you can actually move these. So this is basically the hub for the speakers (...). Each one might have different*

*patterns. It's almost like the Jawbone Jamboxes (existing speaker product) do…* may be circular pattern… almost like circular mesh… *and the power button, play/pose… keep it simple. (…)* This is maybe something for group household or something for a school or something (…) *I'm thinking that I realized when I was at a uni, the school used to get borrowed school laptops. So they are a bit covered and there would be lots of spaces for the laptops you take and use them… just like a library. So I'm going to do it for the speakers" (A3, 00:19:41)*

The detail of form and the notion of sharing within this idea were developed combining the image of object A3 had seen before and the memory derived from daily-life experiences. The development of the idea of modular speaker further continued and A3 evolved the sphere-shaped speaker sets (Figure 114).

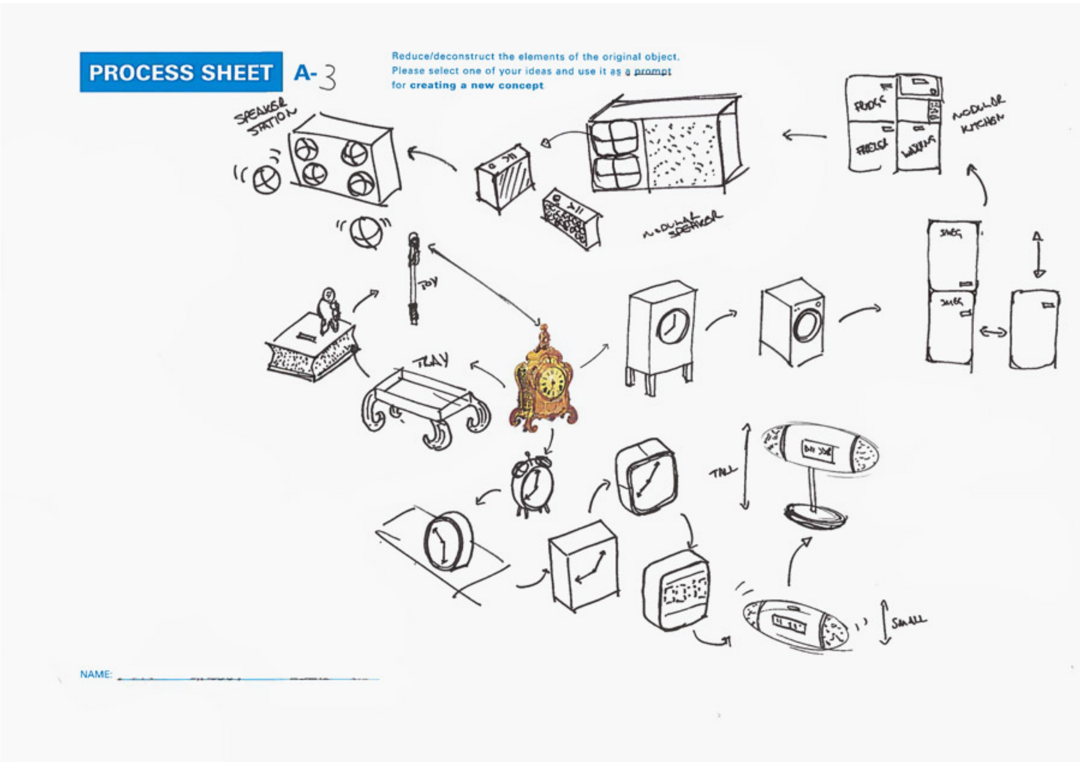



*Figure 114. The A3's Process Sheet at 00:23:06.*

At this phase of the process, A3 returned back to the original object. A3 stated that A3 attempts to see the original object as a speaker. It appears that A3 was trying to switch the way of looking at the original object using the idea that had been developed previously:

> *"I wonder if I'm looking back to the image of the (original) object which I haven't done in a while but I'm doing it now. So, I'm going to try to lend the form of this as a speaker to see what happens now" (A3, 00:23:14).*

After drawing the image of a speaker whose shape is similar to the original, A3 regarded the top figurine as an interactive switch for its functionality. Following this, A3 reduced all the ornaments attached on the surface of the object and drew a simplified desktop speaker. The aspect of the switch inspired by the top figurine, however, was kept but its shape was transformed into a simple joystick. Within the process of idea development, A3 discovered the key idea regarding the interaction, and this discovery led A3 to another idea:

> *"I quite like the idea of interacting with something other than buttons with the speaker. So, the idea of playing and interacting with this figure. Now it made me think I wonder if it is··· because of pulling it back to the basic shapes I'm just going to draw a circle on a… it's almost like a joystick" (A3 00:26:42).*

A3 also drew a similar type of speaker but with no feet and a different interaction. A3 described that the top surface of the object having dimples where the balls became a switch for controlling the speaker (e.g. changes of songs or volumes) are placed. At this point in the process, A3 changed the way the object evolved from speaker to radio. It appears that the idea of interaction evolved allowed A3 to conceive the different type of object:

> *"You put the ball and creates music or volume… It's (the ball and the speaker) separate. This thing is you are going to have it over here (…). Putting the ball in the different areas. (…) maybe it (pointed out the original object) becomes a radio. It's no longer be a speaker. (…) So this is no longer be the speaker. It's a radio. What I may think that is because these could be different channels… radio 1, radio 2 whatever, so it's the different stations" (A3, 00:30:44).*

The focus on the interactive aspect of the object also encouraged A3 to evolve further ideas. First, A3 evolved a radio with a tray attached to its main body. A variety of different shapes of pieces, such as triangle, square, and circle is stored in the side tray, and each represents a various genre of music. The user changes channels of the radio station by placing these tangible pieces on the top surface of the object. A3 also associated with an ordinary radiator cover because of the similarity between the texture of a speaker mesh and a radiator grill (Figure 115).

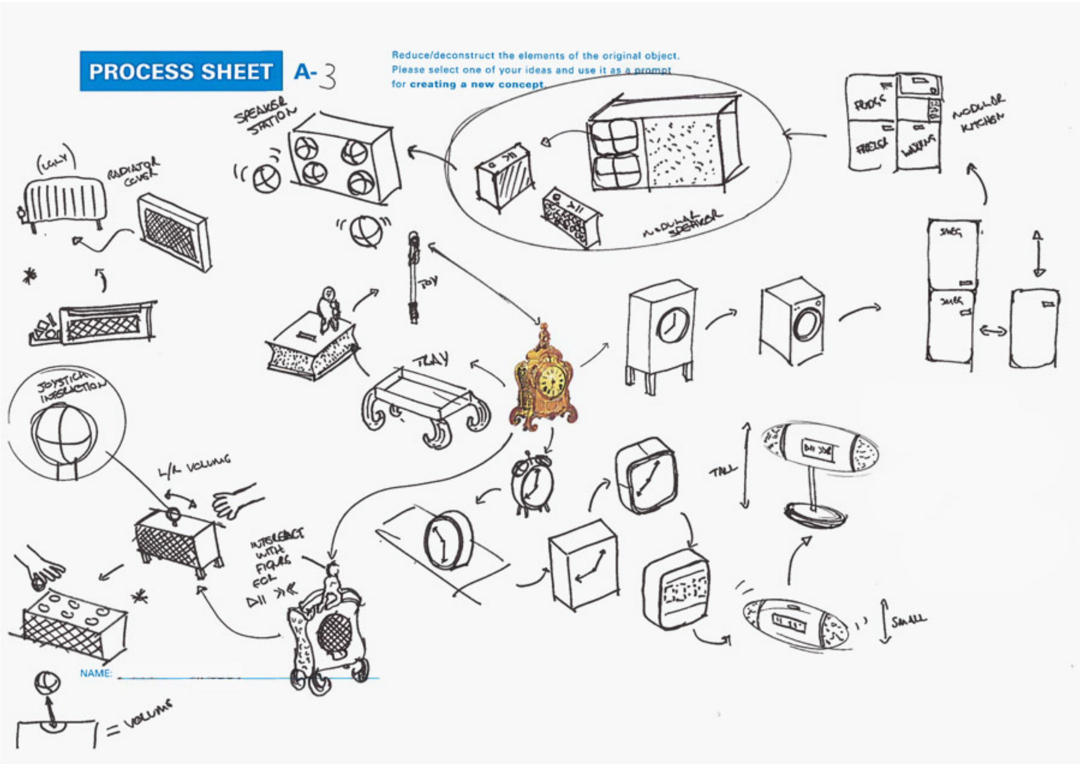



*Figure 115. The A3's Process Sheet at 00:36:15.*

At this phase, A3 reflected the entire process and described that A3 felt lost (A3, 00:36:18). Then, A3 returned back to the previous thinking process in which A3 had envisaged the idea of a speaker with a stand, and combined it with the key concept of "modular". After evolving a couple of ideas, A3 looked over the entire process again and made a decision for the final idea: the modular speaker. It appeared that multiple different ideas had been developed but the idea of modular speaker was, nevertheless, selected:

> *"I started looking over what I have done. It's a big mess of stuffs where I just did washing machine or radiator. There are so many different products here. But I think I like the speaker route. The modular speaker specifically... I really like this idea" (A3, 00:37:20).*

A3, however, again reflected where the thinking avenue of this modular speaker had stemmed from referring to the idea of the speaker with a stand. Then, A3 developed the idea of detachable speaker integrating the previous idea within the key concept of "modular".

At this point, A3 asserted that A3 made a decision about the direction of the final conclusion. A3 also mentioned that the final object will be a modular speaker and it shares some similarities with the original clock in the composition of forms:

*“I’m thinking of going for the modular, the modular speaker. (…) It’s going to be more similar to this (the original object). I think it’s going to be a speaker but a piece in a room, so it’s going to be 3–4 height. It’s going to be on the legs. On small little feet. It’s basically a boom box but then on the top, it’s going to be a tray which I’m kind of taking from over here (the idea of a radio with a tray)” (A3, 00:39:41).*

Within the process of decision making for the final conclusion, A3 integrated multiple ideas that had previously evolved: the modular speaker and the radio with a tray. A3 moved to the *Idea Sheet* in order to finalise the idea and designed the modular speaker unit (Figure 116).

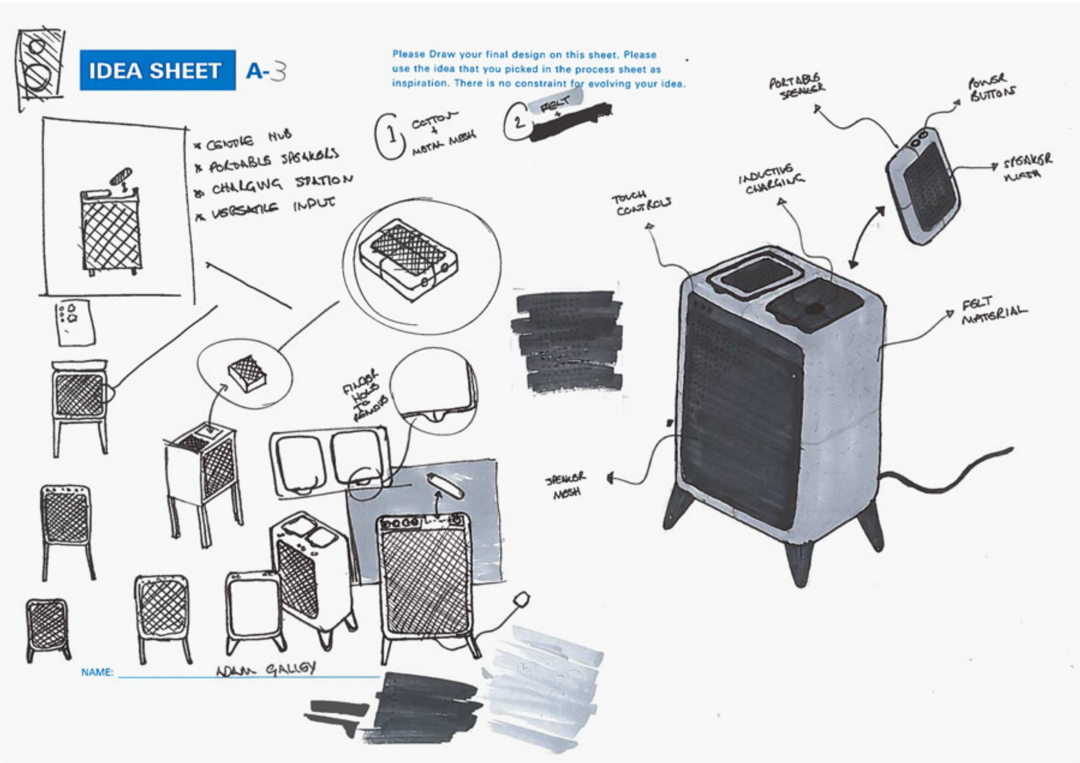



***Figure 116. A3’s final design depicted on the Idea Sheet.***

#### 4.7.3.1.6 The Participant A3: Summary

A3 was unique, as the only participant who designed a different type of outcome other than a timepiece. The reductive process of A3 was somewhat different from other three participants in Group A (Figure 117). A3 conceived ideas at the very early phase of the reductive process and evolved ideas one after another, focusing on the aspect of form. A3 reduced the ornamental details into basic and minimal forms at the beginning. Following this, several ideas were explored, by making associations with existing objects (e.g. a washing machine or a fridge) as well as recalling A3's recent design projects. Despite starting a thinking avenue, by considering an idea of a clock at the beginning, A3 developed different types of objects, transforming their forms. This suggested that A3 gained inspiration for ideas from form transformation. Also, A3 often focused on specific details of the original artefact such as the top figurine or the entire proportion and reduced other elements keeping the features identified. A3 then discovered a key concept *"modular"* within the process, and this was integrated with another notion *"speaker"* that was previously conceived. This integration of two different concepts became the core concept for the final artefact.

A3 developed several thinking avenues on the *Idea Sheet*. A3 stressed that although A3 could have developed just one thinking avenue, A3 deliberately evolved multiple paths in order to keep possibilities of different approaches and to reflect on them at later stage for the final conclusion (A3, interview, 00:12:43). The multiple perspectives derived from different thinking avenues allowed A3 to find valuable elements, such as a key concept, sense of scale, ideas regarding interaction or a system that configures multiple components, and they were subsequently used to foster the final conclusion.

In conclusion, the reductive process encouraged A3 to conceive different perspectives regarding objects and ideas through form exercises. Also, multiple elements and key concepts discovered within the avenues were integrated for the pursuit of discovering final conclusion.

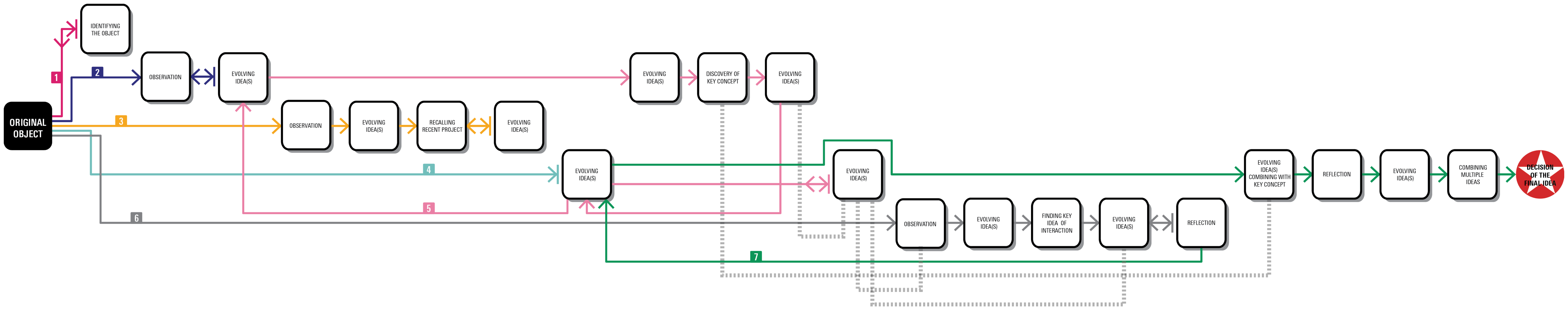



*Figure 117. The diagram that represents A3's reductive process.*

#### 4.7.3.1.7 The Participant A4

The participant A4 designed a clock that includes two contrasting styles into a single object (Figure 118). The design intention was to create an object where both the reduced form and the ornamental detail of the original clock coexist. The exterior of the object represents a reduced simple form of the original clock. The interior, however, of the object that the user can see at the back still suggests the detail of the original clock within the line of the cut-out form. Accordingly, this object requires the users' extra attention to communicating this concept. The simplicity of design as a clock fits the modern lifestyle environment, but the object also playfully encourages the user to discover the hidden characteristic of the reference to the original rococo clock. According to A4, since it is a very conceptual object, this clock is suitable particularly for art lovers. The object is made of beech wood. However, the surface texture of the exterior part is polished and painted and the interior is just bare and natural wood finish that represents the contrasting elements of both modernity and classicality.

The reductive process of A4 started with abstracting forms focusing on several aspects of the original object. First, A4 evolved an idea of abstract clock form dismissing the ornamental details of the original object and wrote the keyword "minimal" next to the drawing. A4 then moved to a new thinking avenue and explored the idea that the particular parts i.e. the feet and the top figurine of the original object are exaggerated. Also, A4 wrote the keywords of "dominant features" next to the drawing. Within this process, A4 did not merely emphasise the features but was also trying to explore new forms by combining the elements identified: *"I'm thinking (...) pronouncing the very strong forms so the feet of the clock here or this sort of (...) a figurine (...) on the top so I'm just focusing on those and trying to blend that out to create a new form from that" (A4, 00:05:19)*. Then, A4 observed the composition of the original object and disassembled the prominent features/shapes into geometric forms as separate components, and reassembled them into an object. Again, the keyword of "abstracted" was written next to the image. Following this, A4 again focused on the profile of the original object and developed the idea of which keeps the same form without ornamental details. A4 also wrote the keywords of "no surface texture detailing" next to it. At the early phase of the process, A4 quickly explored several thinking avenues focusing on different aspects of the original object and extracted keywords within the reductive processes (Figure 119).

*Figure 118. The reproduced image of the outcome of the participant A4.*

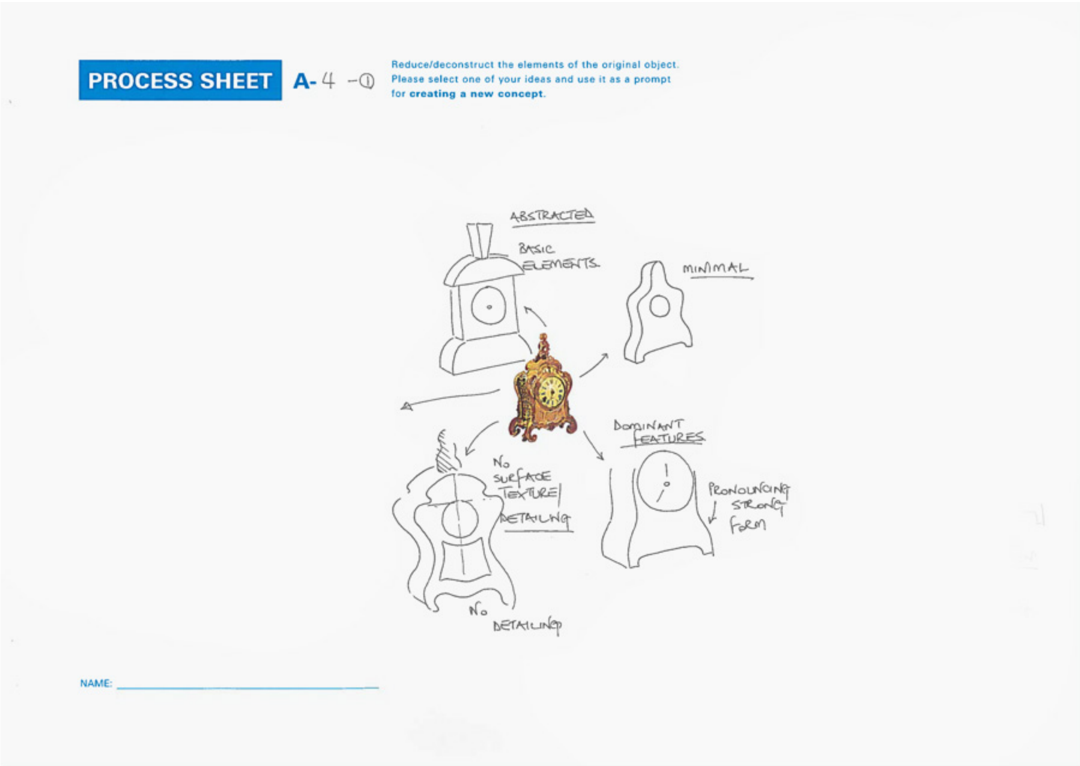



*Figure 119. The A4's Process Sheet at 00:07:05.*

A4 then returned back to the previous thinking avenues entitled "prominent features", and continued further simplification. Based on the simplified form, A4 spontaneously associated with a mosquito net and subsequently saw the image as the object whose surface is covered with stretch textile. This spontaneous idea provided A4 with the insight about the visual effect of covering up an object with membrane:

> *"(...) almost like a mosquito net being stretched around. It'll obviously contact these prominent points and you will suddenly start to see the surfaces and it almost simplifies it. It's just sort of getting the essence of the overall form without actually understanding the details" (A4, 00:08:57).*

Along with enabling A4 to develop the unique abstracted appearance, A4 realised that this covering method is helpful for A4 to quickly understand the prominent features of the original object as it covers up all the other smaller details. In other words, obscuring less dominant details of the original object suggested A4 a hint to re-recognise what the prompt is: *"I'm not concentrating on any more details but it's the overall form again. (...) so you're starting to just understand the form on a very very basic level" (A4, 00:10:11).* A4 also described that this discovery derived from the drawing where A4 attempted to emphasise the prominent features, and this experimental visual transformation brought an idea to A4 (A4, 00:10:00). A4 again returned back to the previous drawing entitled “dominant feature” and conceived similar idea to the previous covering idea. In this idea, the membrane is loosely draped over the object (Figure 120). According to A4, the fluid form brought from covering communicates its overall presence of the object to the viewer (A4, 00:13:12).

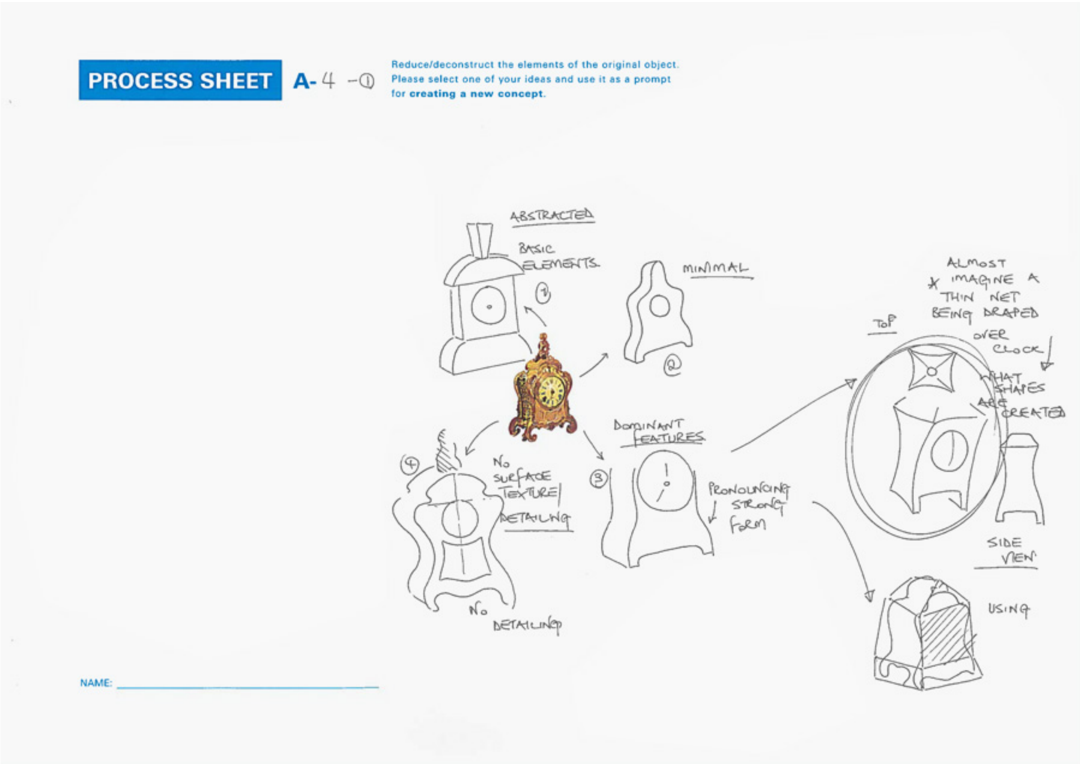



*Figure 120. The A4’s Process Sheet at 00:13:12.*

A4 then returned back to the previous thinking avenue entitled “abstracted”, and continued the further reductive process. At the beginning of the process, A4 started describing the definition of the idea of reduction. A4 found that reduction is generating questions about the object to understand and capture the essence of the object without additional attributes such as ornamentation:

> *“(...) reduction… for me, I’m just trying to avoid all of the kind of the confusion of the object so when you look at it obviously a lot is happening. It’s very ornate. It’s very natural, organic object. Just trying to avoid that and keep away from that. Just understanding the object as… (...) just get the sense of what it is without all these complexities. What is it by itself or… It’s very prominent features here. What are they? What are they serving? If you forget about all those texture and details, then what is the object and then what is it becoming?” (A4, 00:14:22).*

Based on this attitude, A4 evolved the idea of an object whose profile is simple but the part of a clock face is visually pronounced and wrote the title of “reverse”. The size and thickness of the clock body were reduced but the clock face was emphasised and expanded within the process of reduction. Following this, A4 continued reducing the volume and the prominent characteristic of form into more neutralised shape (Figure 121). By this reductive simplification of form, the part of clock face was naturally enhanced as there are less visual details around it. A4 stated that simplifying the ornamentations by tightening up the entire form enabled A4 to control the surface of the object in A4’s idea development process (A4, 00:19:01).

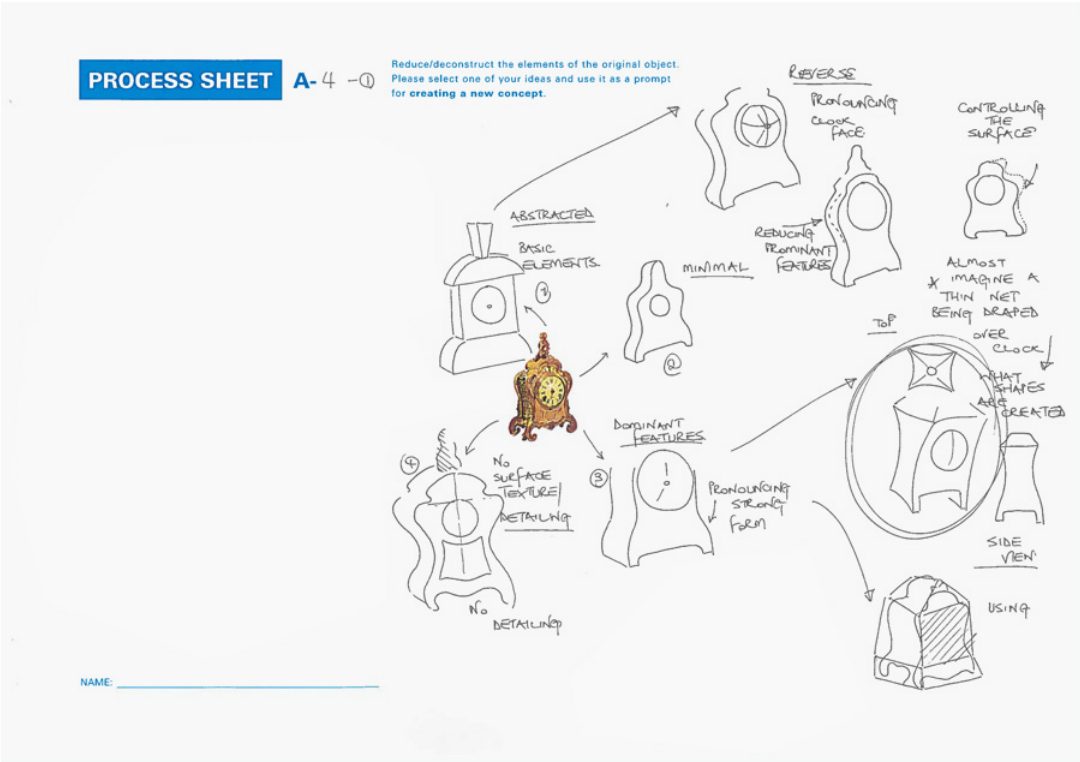



*Figure 121. The A4’s Process Sheet at 00:19:02.*

After staring at the original image for a while, A4 moved back to the previous thinking avenue entitled “no surface texture detailing”, and stated that A4 focuses on the aspect of surface texture. A4 then evolved the idea of an object in which its entire form is simplified but the complexity of surface texture of ornamentation is kept. Also, A4 wrote the keywords of “simple form, complex patterns”. This is opposing the approach that A4 previously took: keeping the form without surface texture detailing.

At this point, A4 returned back to the previous idea entitled “abstracted” in which A4 had broken the simplified basic components of the object and reassembled them. A4 decided to carry out the similar reductive process but in more extreme way. A4 reduced the component forms into very basic geometric shapes e.g. a cube or cylinder and then exploded each element instead of reassembling them. The idea of doing this was to understand and learn the roles of components of the original object by form simplification and drawing them in the manner of exploded view: *"I'm (...) just thinking about the constituent parts and exploding those so you really understand where does shapes come from or… just again, trying and bringing back to the very very basic form to the initial intention" (A4, 00:25:37)*. A4 also wrote the key words "exploding design, basic form" next to the drawing.

A4 then started thinking of taking components away as a reduction (Figure 122). A4 presumed that the perception of the object can change if the essential part of the original clock such as the legs is removed: *"(...) if you remove the legs, it almost becomes a different object. You perceive it differently (...). The profile looks almost like a bread once you do the feet away" (A4, 00:26:30)*. The drawing was entitled "reduce by removal".

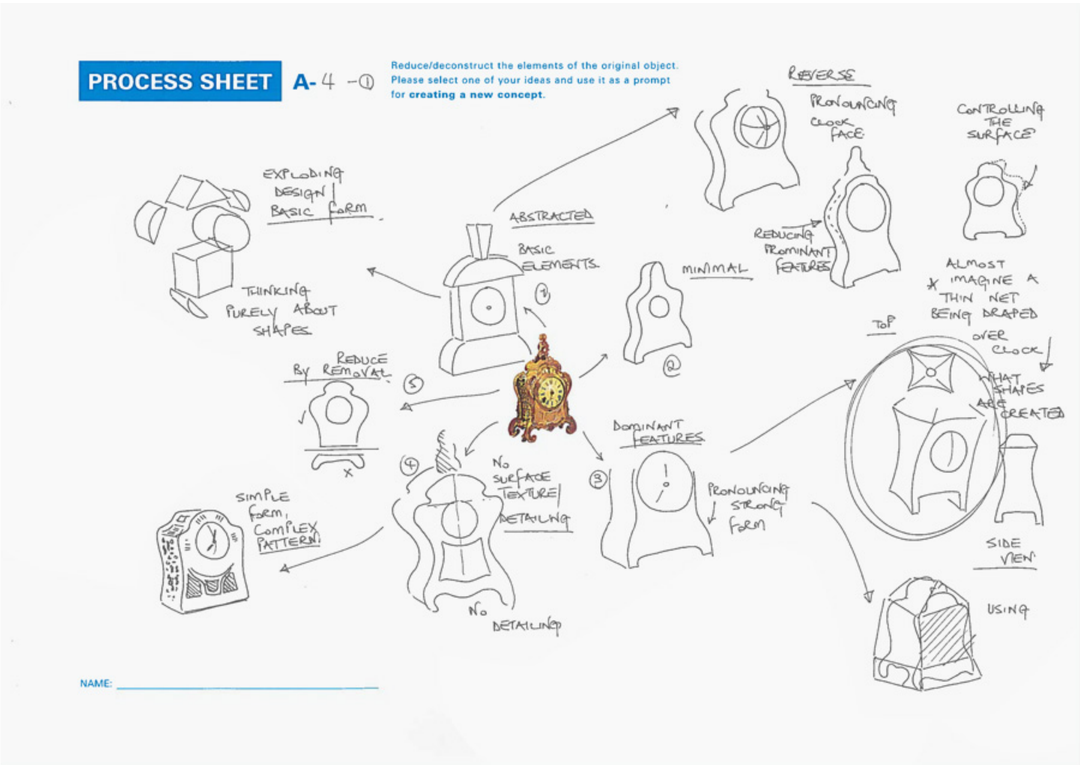



*Figure 122. The A4's Process Sheet at 00:26:30.*

At this point, A4 assigned numbers on the ideas developed primarily from the original prompt in order to reflect the thinking processes. After the short reflection, A4 returned back and continued to develop the last thinking avenue, and visualised the idea of a clock without legs. A4 discovered how much the legs as part of the clock plays significant a role for A4's object recognition within the process:

> *"How does that affect the rest of the body really? Because it's almost just the end if you just take the legs away. (…) The legs are so much emphasis really. It almost lifts the object and it has such a big effect on it. Once you removed that, it almost becomes something else" (A4, 00:28:35).*

Meanwhile, A4 also assumed the way the object is produced seeing the depicted image of the solid body with no legs. The image of a solid body suggested to A4 to think of a way to create a form by taking materials away from the block just like sculpture (A4, 00:29:15). A4 depicted its idea and titled as "starting with a block + removing". A4 paused this thinking avenue at this point.

A4 moved to the previous idea titled "dominant features" and continued a further reductive process. In this avenue, the focus was on emphasising the features of the original prompt, and A4 attempted to conduct the same process focusing on the top figurine in a more extreme way. A4 identified that, in the original prompt, the viewer's attention to the top figurine is less since every other part is also very intricate and ornate. Accordingly, A4 decided to focus more on the top figurine, and emphasise the part by simplifying other parts around in order to control the attention of the viewer (A4, 00:31:06) (Figure 123). This attempt of controlling viewer's attention provided A4 the idea of "revealing object through reduction" that will eventually be the key concept for the final proposal:

> *"So, maybe playing with the idea of 'revealing object through reduction'. (…) you're reducing the form and then I suppose I'm making it a bit simpler but you're still keeping it as interesting or giving it a character because you're still leaving some elements for you to appreciate its ornate patterns (…). May be it's really simple in the front. It's quite contemporarily piece but then from the side it start to reveal different characters, originality (of the prompt)" (A4, 00:33:25).*

At this point, A4 moved to the second *Process Sheet* and continued the process. To begin with, the key word of "revealing" was written. At this phase of the process, it was important for A4 to consider how to reduce and keep the meanings of the original prompt at the same time. Based on the key perspective in which the elements are reduced and revealed at the same time to control the viewer's attention, A4 evolved another idea. In this idea, all the ornamentations except for the side decoration are simplified and it enables the viewer to appreciate the ornamental details of the object that has not been highlighted. The description of "focus our attention on some detailing to truly appreciate it" was annotated next to the drawing. A4 also described this discovery of idea came from A4's own experience:

> *"(...) I wouldn't really notice that after the first glance because so much happening and I was looking at all over the place. My eyes drown everywhere. Where we are looking at... one of the aspects of the project or sort of a product we find for an attention and maybe it's trying to appreciate... I mean, this is really nice pattern here (...)" (A4, 00:36:55).*

The reductive process allowed A4 to discover the valuable aspect of the object that A4 has never paid attention to. A4 paused this thinking avenue.

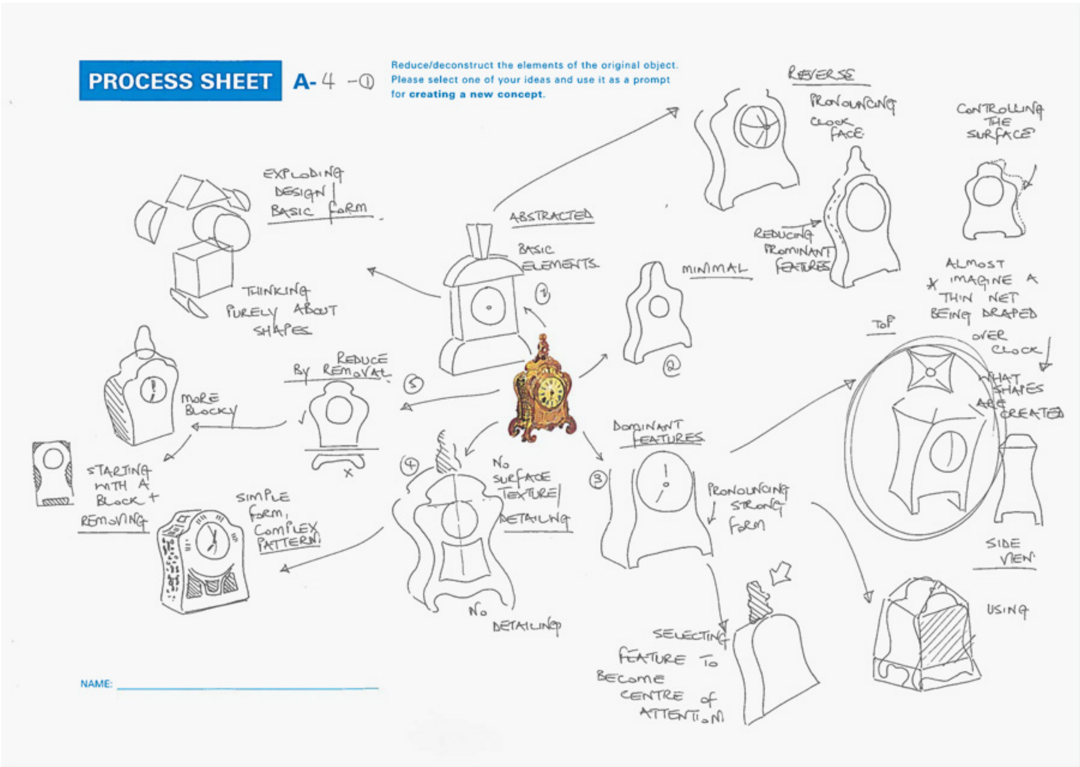



*Figure 123. The A4's Process Sheet at 00:32:50.*

At this point, A4 returned back to the image of the original prompt and the keywords of "changing material/reducing presence" were written. In this avenue, the focus was on reducing not the volume of the object but its visual presence by replacing the materials. A4 regarded that the materials and the colours used in the original prompt give an excessive impression so that A4 tried to reduce the sense of the presence of the object by replacing the material of the clock's outer case by transparent medium e.g. clear acrylic or glass. The intention of the idea was also controlling the viewer's attention. The visual transparency derived from the materials naturally encourages the viewer to pay attention to the inside clock mechanism even if they perceive the complexity of form of the outer case. A4 realised that the perception of an object can easily be reduced just by manipulating material transparency without reducing actual substances (A4, 00:38:50). At this point, A4 paused the thinking avenue.

After staring at the image of the original prompt, A4 wrote the key descriptions "reduce to add more aesthetic appeal" and "less material". The focus in this thinking avenue was on how the heaviness of the object can be reduced. A4 conceived the idea of a clock that is similar to the original prompt but the decorative part underneath the clock face is removed (Figure 124). The point of this approach was to visually reduce the heaviness and to increase aesthetic values simultaneously:

> *"I suppose, by reducing it, you're trying to make it even more desirable or ornate or delicate. By reducing giving it something else. (...) you are improving the object aesthetically by reducing so it's counteractive. By removing the parts, making it look less weighty either making it more decorative... maybe more delicate so it's more appealing" (A4, 00:41:50).*

At this point, A4 paused this thinking avenue and left for a new one.

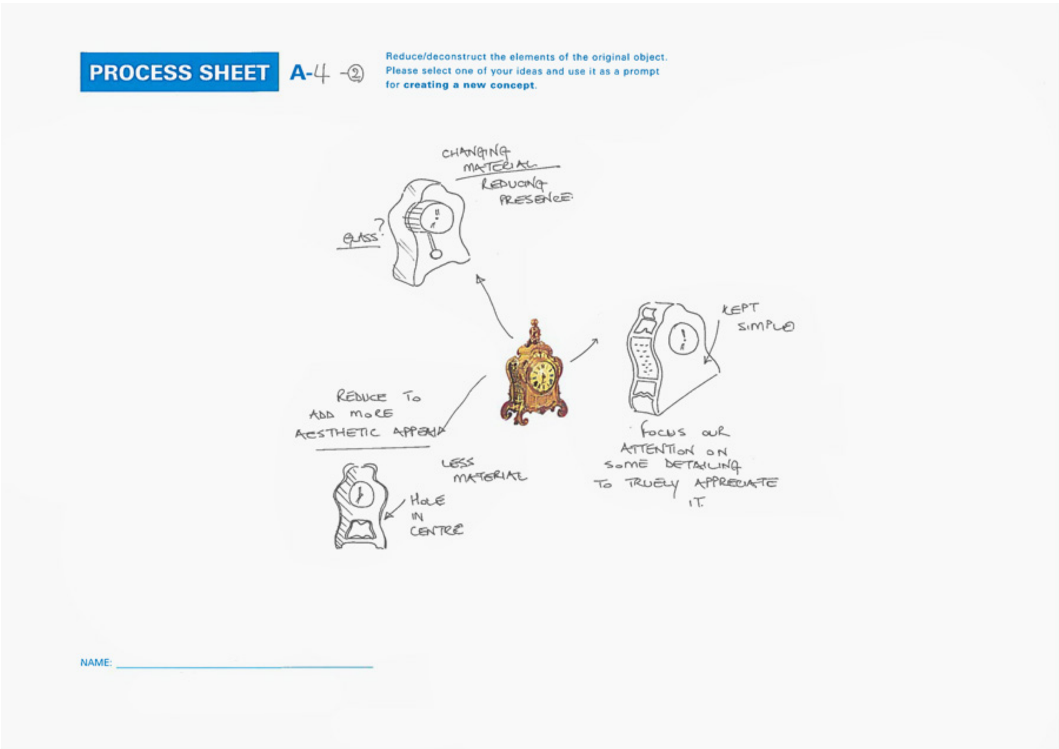



***Figure 124. The A4's Process Sheet at 00:44:54.***

A4 then staring at the image of the original prompt again, and wrote the keywords "subtle aesthetics". A4 then started describing the idea in which all the intricate details attached to the surface of the original prompt are filled with "Spackle Paste". A4 described that the attention of the viewer can be focused on the profile of the object by making its surface smooth (A4, 00:45:25). Even if the intricate decorations are flattened, the essential ornamentations of the original object e.g. the profile, the proportion, or the extruded clock face can be kept, and the viewer's attention can still catch the characteristics as such. This idea is derived from observing and interpreting the design intention of the original prompt:

> *"There is a nice curvature here (the decoration around the clock face). That's almost pronouncing the clock face. (…) maybe it will catch the light or… you still have the sense of where are the relations (between the clock face including its decoration around and the profile) each other but the detailing (other ornamentations) are removed so it's the question of where your attention will then go (…)" (A4, 00:46:29).*

This fact shows that this idea was not randomly hit on but rather conceived through the observation of the details of the original prompt. This thinking avenue was paused here, and A4 moved to explore a new path.

After staring at the image of the original prompt, A4 wrote the keywords "manufacturing constraints", and the key question "what has to be reduced?". A4 then started thinking of the possible ways to produce the original clock by primitive manufacturing (A4, 00:49:35). The idea was to regard the limitations derived from the unsophisticated manufacturing or techniques as a mean of reduction. A4 described that if the original clock is manufactured by unsophisticated techniques, many ornamentations are inevitably dismissed as it is technically difficult to replicate the intricate details precisely. Based on this perspective, A4 imagined how the object possibly looks like if it is produced within such a constraint. A4 drew the top part of the object where the idea was represented (Figure 125). A4 paused this thinking avenue here and moved to explore a new one.

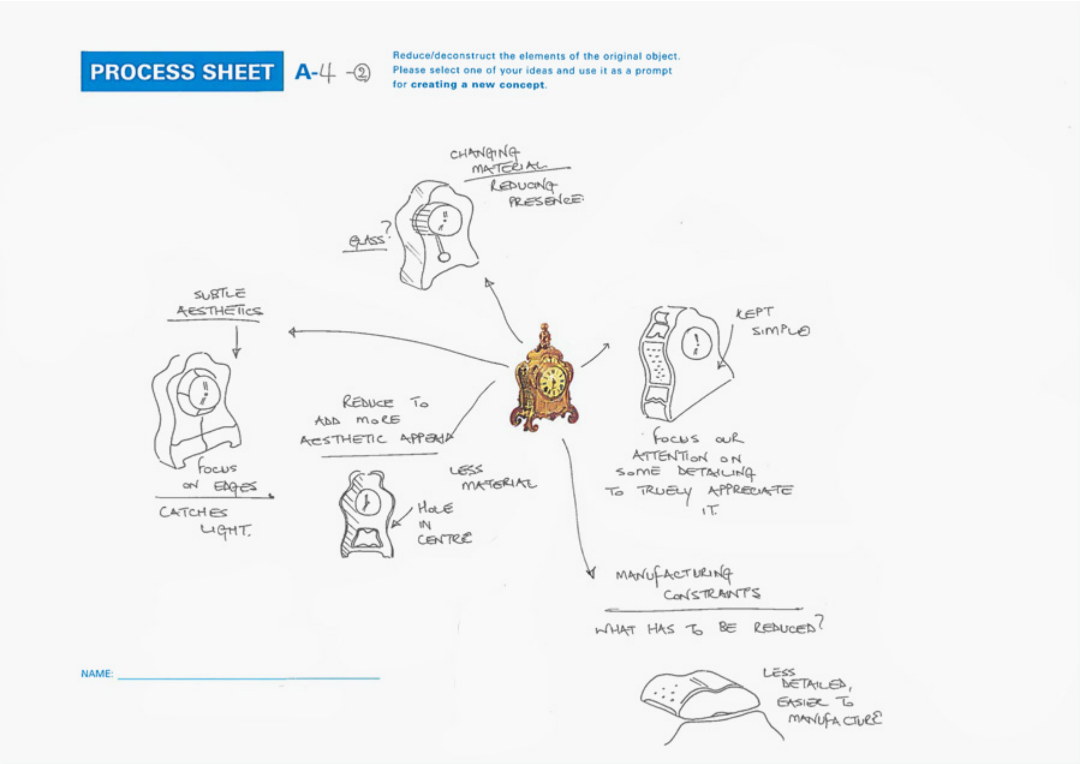



*Figure 125. The A4's Process Sheet at 00:52:26.*

A4 returned back to the image of the original prompt and stared at it. A4 then evolved the approach of which is seeing the original clock as a flatten stencil drawing (A4, 00:53:41). A4 described about the idea that the form as a physical object is simple, but the face of the clock represented with a stencil drawing on the surface visually describes the characteristic of the original prompt. In other words, the elements of both simplicity and the decorative elements of the original clock coexist within the same object. A4 also described about this idea referring to the way we perceive "retro" objects:

> *"(...) when you are thinking about retro objects, they take something quite modern and add features which hint like a retro so a lot of forms produced now, they hint retro forms now but they are still contemporary and you accept them because you are pleasing the styles in this age. (...) you are sort of reducing the complexity of this object (original clock) and you are reducing its presence by putting it into another object with a lot less form" (A4, 00:55:14).*

According to A4, A4 took a cue from the characteristic of coexistence of modernity and classicality within a "retro" object. Based on this insight, A4 conceived the idea of reducing and keeping the elements of the original prompt within the same object. A4 then wrote the key description “reducing complexity of object by making it a detail on a simpler form”, and paused this thinking avenue at this point.

As A4 had done several times before, A4 stared at the image of the original prompt and wrote the keywords “reduce aging”. In this thinking avenue, A4 attempted to reduce the sense of “out-of-date” style (as in, rococo) that the original clock includes by incorporating more contemporary elements (A4, 00:57:43). Based on this perspective, A4 conceived the idea of a clock whose profile is abstracted and its legs are replaced by simple pegs (Figure 126). A4 described that the particular style the original clock represents does not fit the contemporary living environment. Accordingly, replacing some elements of the original clock with components in the modern style possibly becomes a more contemporary object that includes both classical style and modernity, and people living in the present day appreciate. Essentially, altering the elements of the original object into a contemporary style allows it to be a timeless piece like other design masterpieces (A4, 00:59:20). This thinking avenue was paused here.

A4 stared at the original image for a while and developed a new thinking avenue. The focus was on reducing the visual impact of the object by altering the colours and the texture appearances on the surface of the clock (A4, 01:03:48). A4 described that if some surface decorations are covered with black spray, the way to perceive the object can possibly change. In this sense, the viewer’s perception of the object can be affected just by controlling the visual visibility of the surface textures with different colours. A4 regarded this as the “reduction of visual impact” of the object. The keywords, “reduce visual weight” were added next to the image and this thinking avenue was paused at this point.

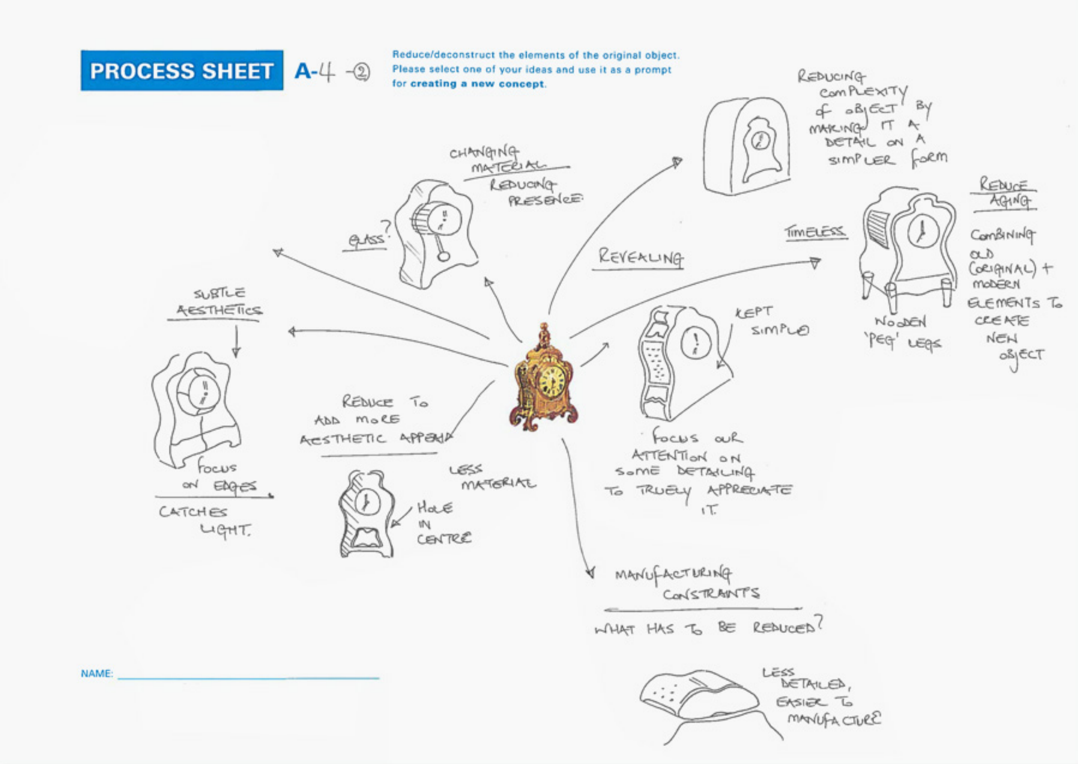



*Figure 126. The A4's Process Sheet at 01:01:51.*

A4 moved to a new thinking avenue and stared at the image of the prompt, and wrote the keyword "inside-out" and the description "reduce visual weight but keeping detailing". A4 described that the key concept suddenly came to A4's mind and that will eventually play an important role in the final design proposal. As A4 wrote, the key concept of "inside-out" was conceived and used it as a hint for designing the idea of interaction between the viewer and the object:

> *"I don't know why but I can imagine the idea of turning something inside out. (…) so maybe you're reducing the visual weight of the object by, although it seems to be strange but, putting the details into the inside of the object and keeping the external very simple, lot less decorative so that all of the detailing are still there technically but it's only inside. May be you reveal inside somehow but that becomes the central of attention" (A4, 01:08:30).*

Apparently, this idea was conceived within the pursuit of investigating the relationship between the viewer's perception and visual presence of the object based on A4's personal interest. The idea, however, also derived from A4's childhood memory:

*"What I can imagine… I don't know how… when I was younger, I found this rock in my garden and it was not crystal but it was kind of a crystal form. The rock was very very simple and I thought I must through it onto the ground, and it cracked and opened and there were these crystal forms inside. (…) this form (the rock)… you wouldn't even consider as having any values. Once you then see find what's within then you find values… like surprise. (…) you wouldn't consider the rock as anything. It was just a dirt really but then suddenly… once it's revealed what's inside (…) it was just amazing" (A4, 01:10:24).*

This suggests that the idea was conceived in integrating the thoughts fostered within the reductive process and the A4's personal memory. The idea discovered during the reductive process prompted A4's memorable experiences as a stimulus within the practice of ideas exploration. Based on this idea, A4 evolved an idea where the clock details are covered and hidden inside of a plain box that demands the viewer to peer down to discover its value from the top (Figure 127). After adding another keyword "reveal", this thinking avenue was paused.

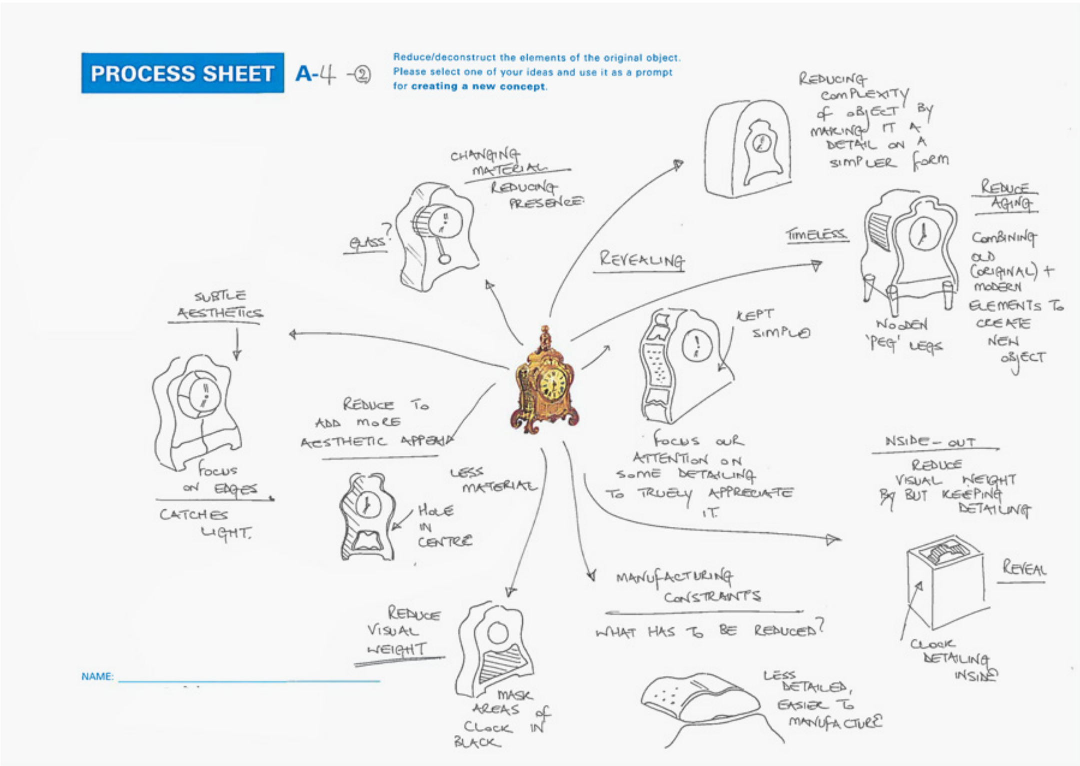



*Figure 127. The A4's Process Sheet at 01:12:58.*

Again, A4 returned back to the image of the original prompt and stared at it, and then developed the new thinking avenue. In this avenue, the focus was on the "reduction of accuracy" by increasing human error (A4, 01:13:24). As the intricate ornamentation of the original clock requires accuracy in its production process, A4 considered the inaccurate nature of hand making as a mean for reduction. A4 also described that if the intricate details of the original clock are reproduced by hand, its inaccurate characteristics become a distinctive feature of the object. This possibly allows the viewer to perceive the object differently. A4 regarded this inaccuracy derived from poorer manufacturing techniques as an opportunity to conceive new design concept:

> *"(...) you are reducing accuracy by using different manufacturing processes. (...) this is cast in certain ways but maybe you are reducing materials or reducing the time you spend on it by using different processes (...) using carving and encouraging human errors so that it becomes very original pieces" (A4, 01:13:44).*

The observation of the detail of the original clock encouraged A4 to consider its production method and it provided an idea of making use of poorer manufacturing techniques as means of reduction and also as a technique for creating original ideas. A4 then sketched out the idea after writing the keywords "carved object", "reducing precision", and "encouraging human error". This thinking avenue was paused.

After staring at the original image, A4 reflected the processes developed and described which thinking avenue A4 liked. A4 acknowledged that A4 was particularly interested in the idea of which the object is veiled with a drape as it intrigues the viewer's curiosity to imagine the inside (A4, 01:16:50). Meanwhile, A4 was also thinking of a new idea in which the prominent details of the original clock are represented as three separate objects. This approach allowed A4 to reduce the complexity of the original object and create a different object (A4, 01:17:51). Based on this perspective, A4 drew the concrete idea and added the description "3 objects – breaking form up to place emphasis on each detail" (Figure 128).

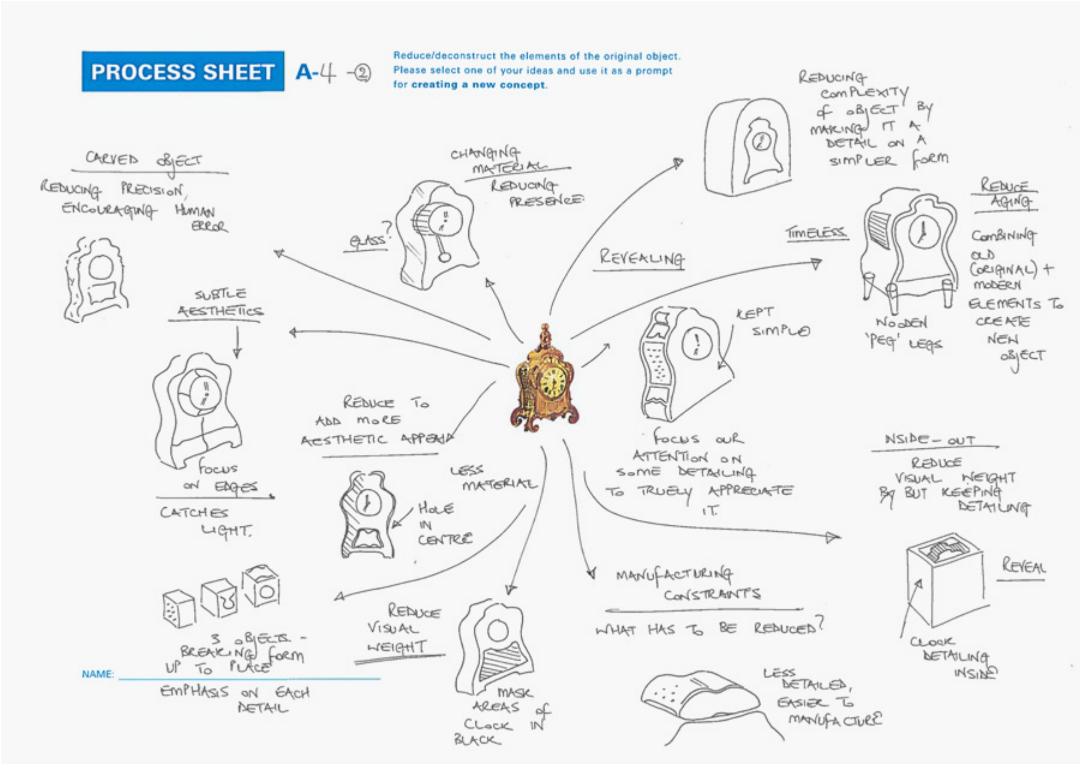
At this point, A4 again reviewed the entire process developed and mentioned the prominent processes/ideas. It seemed that A4 was trying to reflect and find patterns of thought that represent A4's major interest within the process:

> *"So, like the idea of trying to reduce the visual weight but keeping intricacy of the object (the idea of a clock whose details are concealed in a cube). (...) it's quite conceptual but just trying to keep the detailing but making it less heavy, less truth or obvious... but I quite like this (the idea of an object that is veiled with a drape) again. (...) You are using this clock to inspire a new design and this net (drape) which is quite natural and flow using its points of*

*the clock to define sort of structure (…). So again, it's reducing visual weight, reducing complexity, it's making it more contemporary… I quite like that" (A4, 01:21:41).*

A4 finally moved to the *Idea Sheet* at this point of the process (Figure 129).

***Figure 128. The A4's Process Sheet at 01:19:41.***



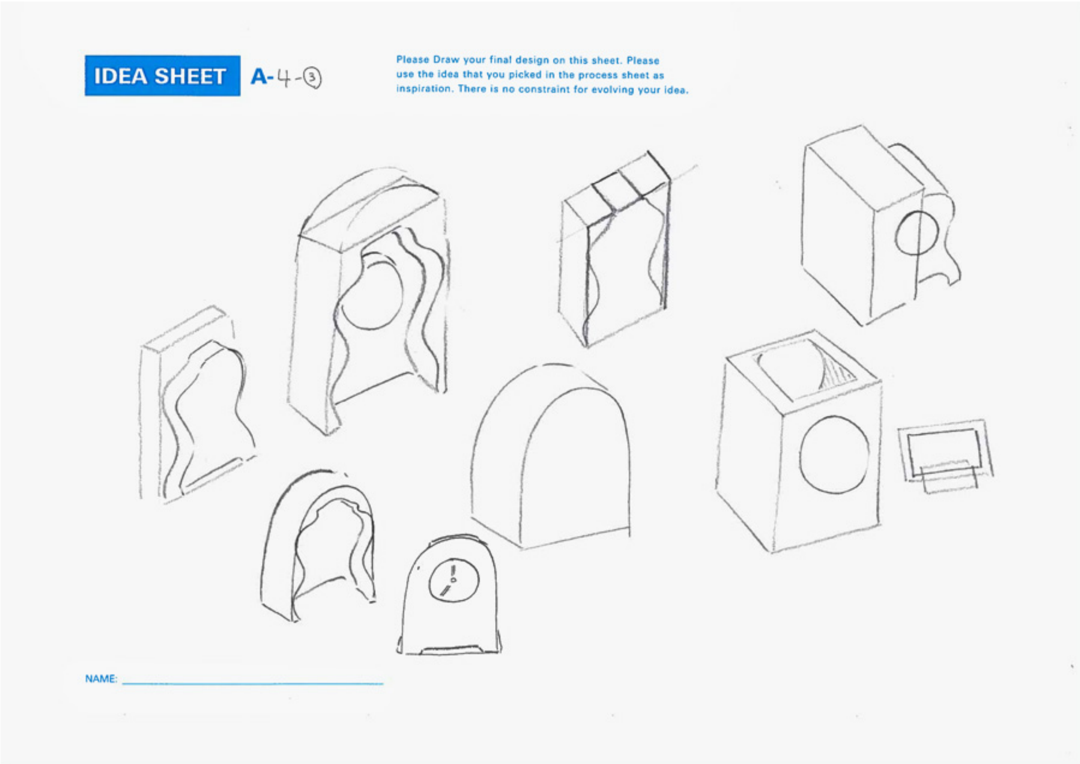



*Figure 129. A4's final design depicted on the Idea Sheet.*

#### 4.7.3.1.8 The Participant A4: Summary

Most of the A4's thinking avenues started from investing the original object. Several kinds of aspects of the original prompt such as texture details of the ornament, its physical structure, the roles of each component, manufacturing process and so on were focused throughout the process and were used as a clue for generating ideas and/or finding out keywords. It appeared that it was important for A4 to start the process with understanding about the object in order to develop the processes rather than evolving thoughts without the connection with the original prompt: *"I think, for me, reduction is trying to understand the object better, understand the constituent parts. Maybe it's just trying to reveal characters or what I was trying to perceive" (A4, Interview 00:12:41).*

A4's process can be roughly separated into two phases: the early (*Process Sheet* 1) and later (*Process Sheet* 2) stages. In the early stage of the process, A4 cyclically developed ideas correlating multiple elements discovered with each other (Figure 130). The ideas, the keywords or the insights identified within the processes led further interpretations or discoveries one after the other. It appears, however, that as the thoughts of A4 deepened, A4 were more likely to evolve ideas directly through the observations of the original object. This characteristic appears to suggest that A4 steadily produced ideas when the direction of thinking approach became more solidified. Even though, however, the thinking approach at the later stage seemed to be relatively linear and direct, the researcher could still identify some mutual influences amongst the keywords/key concepts that A4 discovered across the stages. For instance, one of the A4's major concerns within the reductive/idea exploring process was how to control the viewer's attention by accentuating or reducing visual elements of the object. In the middle of the process, A4 discovered the keyword "simple form, complex pattern" with the idea of object whose exterior design is simple but the original ornamentations were kept on its surface (A4, 00:20:22). Meanwhile, at the later stage, A4 also found the keyword of "reduce visual weight but keeping detailing" with the idea of object whose exterior form is neutral cuboid but the details are concealed in its inside (A4, 01:08:32). Although both concepts share similarity with each other, the correlation was not indicated within the verbal data. Accordingly, this fact suggests that the multiple elements identified within the process influenced each other across the stages even if they were not particularly mentioned by the participant. The researcher regarded such similarities as a relevant subject.

Another prominent characteristic of this participant was that A4 focuses on a wide variety of aspects regarding the original prompt for reduction. The focuses were not only on physical aspects of the object but also the conceptual subjects that the original object includes. A4 described that the abundance of the information of the object encouraged A4 to challenge in addressing the different attributes of the original clock:

> *"It (the ornamentations) was so bold for me to work with (...) as soon as I saw the object I was drowning in these ornate features, and this figurine, the curvatures, or these features (the ornaments on the feet) here. I wanted to play with those. Barely thought the functionality of the clock itself or the face (...) . I think the form itself has such a presence so you almost wanted to do something with it (...). It's obviously quite old clock so it's not something that I'm too familiar with so you almost want to challenge it, question it" (A4, Interview, 00:11:07).*

The richness of the ornamental information let A4 even dismiss the functional aspect of the object but, instead, allowed A4 to read and interpret its attributes of the original prompt in depth.

In conclusion, the process of reduction offered the opportunity to A4 in understanding the original prompt. The richness of information of the ornamentation allowed A4 to find informative clues for reduction in a variety of ways. Additionally, the in-depth observation provided A4 with the opportunities to conceive ideas and to find key concepts that subsequently used for further idea explorations.

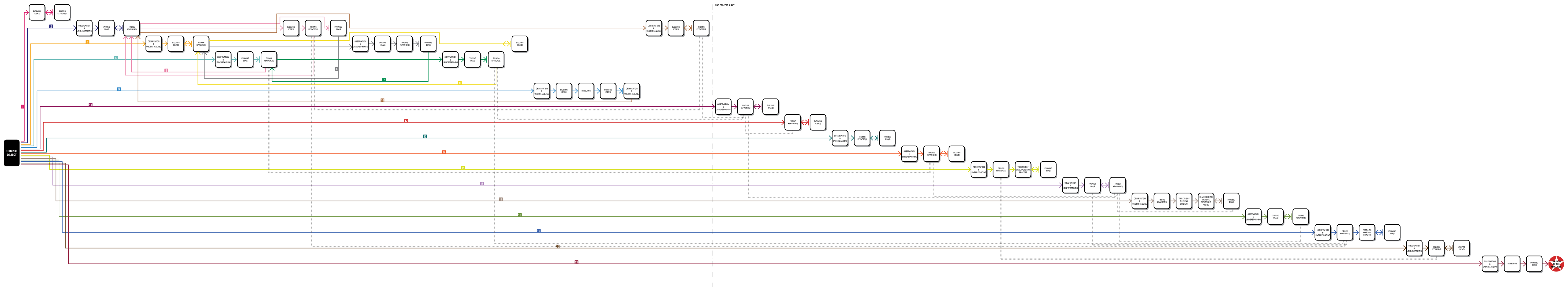


*Figure 130. The diagram that represents A4's reductive process.*

### 4.7.3.2 The Outcome of Group B (low-fidelity Prompt)

The outcomes of the group B that was provided with the low-fidelity visual prompt (represented by dotted line) were presented here. Although the outcomes of group A kept the same functionality as the original prompt, the results of group B were even more radical. Even though three out of four participants created time-related objects, they were more conceptual and/or suggestive of new ideas.

#### 4.7.3.2.1 The Participant B1

The participant B1 redesigned the famous game, Jenga, whose timber material is replaced by charcoal/coal. Jenga is a game of physical skill in which players enjoy tensions of unbalancing within the process of removing and placing the pieces within a block on a tower (Figure 131). B1's design intention was to enhance this aspect of the game by replacing the original wood material with fragile charcoal. The fragility of material creates additional tension to the players as the charcoal can easily be broken when the pieces fall on the floor or the table top. Additionally, the material fragility allows the user to enjoy changes of its appearance over the time. Additionally, the broken charcoal pieces can become a drawing tool as a by-product.

*Figure 131. The reproduced image of the outcome of the participant B1.*

As the first step, B1wrote down the key theme, “time” underneath the image of the original object on the *Process Sheet*. B1 immediately remembered B1’s previous design project and related the past experience of having a conversation with a traditional clockmaker, to the thinking calling it as “traditional route” (B1, 00:00:54). B1 continued developing the process remembering the contents of the conversation. B1 then wrote the keyword “process” next to the original object. B1 interpreted the fundamental concept of time as the notion of the process that implies the state of moving or progressing towards something (B1, 00:01:05). Following this, B1 immediately conceived the keywords “material quality” based on the previous keyword. Then, B1 glanced at the image of original prompt stating that the object is made of “nice antique timber” (B1, 00:01:36) and imagined a mahogany plank. At this point, B1 pointed at the top figurine on the original prompt and identified that it is the important element on the object. B1 then combined the idea of polished and smooth mahogany finish with the top figurine. Further, B1 conceived the idea of which the material of the top figurine is replaced by black charcoal (B1, 00:02:36). At this point, B1’s focus shifted to tactile aspect of material: *“I can almost imagine like really touching it rather than actual visual presence. I thought of what’s the feedback from the clock” (B1, 00:02:55)*. This thought regarding tactile materiality triggered the B1’s memory regarding an object that B1 used to interact with and discovered a key concept within the thinking process: *“Almost like grand father’s pieces. Grand mother’s house has really nice traditional clock in it. It does almost seem to be polished itself over time. Actually, it’s nice phrase ‘polished itself over time’” (B1, 00:03:04)*. It appeared that B1 gradually evolved thoughts in a variety of ways being inspired by the ideas came to B1’s mind one after another. B1 further continued to develop ideas based on the same focus: how materials progress (B1, 00:03:33). B1 evolved the idea of a clock whose clock-hands have nails to scratch the surface of the clock-face made of polished brass material. The process of time passage changes the appearance of the clock-face by being scratched the surface texture (B1, 00:03:38). The notion of changing material appearances over time seemed to provide B1 to explore a further idea. B1 conceived the idea that an object hung from the wall, that swings and hits another material, create gradual changes of form as a reaction of the process of time (B1, 00:04:15). In this idea, the specific functionality as an object was not specifically mentioned but rather focused on the interaction between material changes and time. B1 further continued to evolve another idea that the appearance of a clock that gradually deteriorates over the time referring to the decline of human physicality (Figure 132):

> *“What if the property of the materials gradually slumps or something? As you get older, the clock is eventually dying out. It’s like how older person almost becomes afraid or not. (...) It’s almost like melting process. It could be quite cool I guess if it is more of how you can see the physical changing… growth and becoming smaller” (B1, 00:04:42).*

At this moment, B1 seemed to explore ideas purely focusing on the key concept previously discovered: changing material appearances over time. The discovery of a key concept prompted B1 to evolve various interpretations of ideas. At this point, B1 paused this thinking avenue.

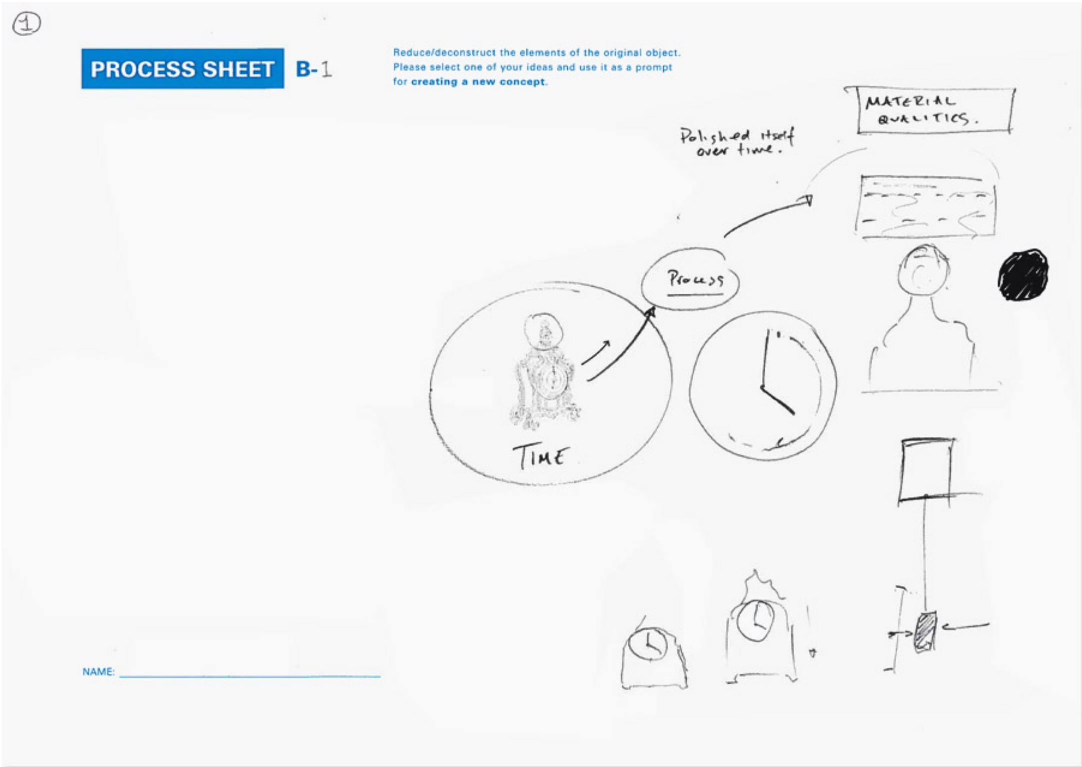



*Figure 132. The B1's Process Sheet at 00:06:13.*

B1 returned back to the original prompt and discovered a new keyword: "movement". This keyword was then interpreted into multiple notions. The first notion B1 identified was the physical movement on a clock-face. B1 continued further interpretation of the keyword and conceived the movement of leaves of a tree by wind in nature. B1 interpreted the idea of movement in a conceptual way in relation to the concept of time: *"(...) time isn't necessarily... it's very fluid rather than being very stagnant so it's more of like indication of time" (B1, 00:07:40).* B1 continued further interpretation and associated with the phenomenon of movement by artefacts that generate wind e.g. a fan or an air conditioner. This interpretative process allowed B1 to evolve the idea of a table that has a fan mounted on the table-top and a sheet of paper that is fluttered by the air generated by the propeller. The intention of this idea was to create movement by the air generated by the fan at a regular interval, and the motion allows a user to perceive the sense of time in an alternative way (B1, 00:08:15).

At this point, the instructor asked the order of the process as the drawing elements were not correlated with arrows on the B1's *Process Sheet*. The instructor, however, also informed that B1 could continue the process without using arrows if B1 preferred. B1 then reflected the processes that had been developed so far. In the reflective process, B1 described that B1 thought of the Japanese traditional technique of charred timber called “Shou Sugi Ban” (B1, 00:11:09). Shou Sugi Ban is the processing technique for timber materials that make them durable by burning its surfaces. B1 remembered this specific technique while thinking of materials. B1 also returned back to the idea of the charcoal material that was previously developed and jotted down what the material is. B1 further continued to think of the process of how coal material is made in nature: “I guess I could look at the process how the timber rots away… it’s built up like almost on a bedrock to create this coal so it’s almost the process of how the material has developed” (B1, 00:12:20).

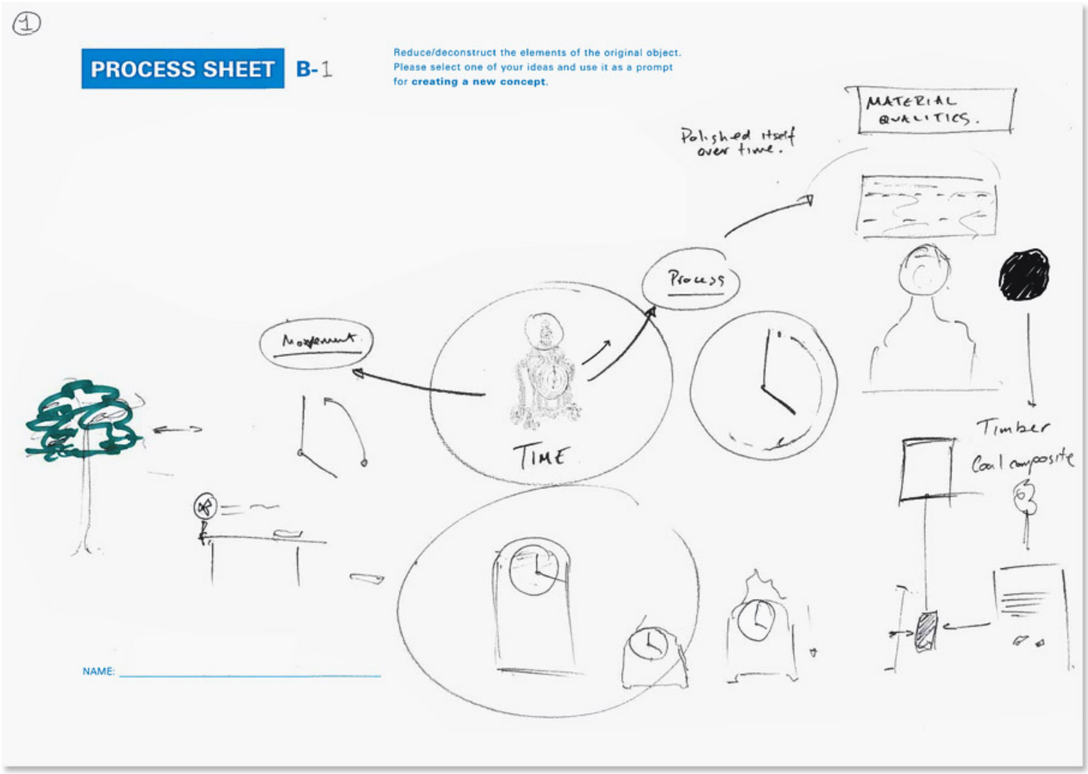



*Figure 133. The B1’s Process Sheet 1 at 00:14:01.*

B1 also described that the idea of charcoal was from the assumption that it was timber material used in the original clock. This suggests the idea regarding materiality was discovered within the integration between the notion of “time passage” and the assumed timber material was used in the original clock. Based on this focus, B1 evolved an idea of a clock whose surface of the exterior case represents different states of the timber derived from natural changes of the material (Figure 133).

B1 returned to the keyword “movement” and continued to develop the idea of physical interaction in which a movable object is placed on a seesaw structure (Figure 134). As the seesaw swings the object placed on the top moves as a reaction (B1, 00:14:42).

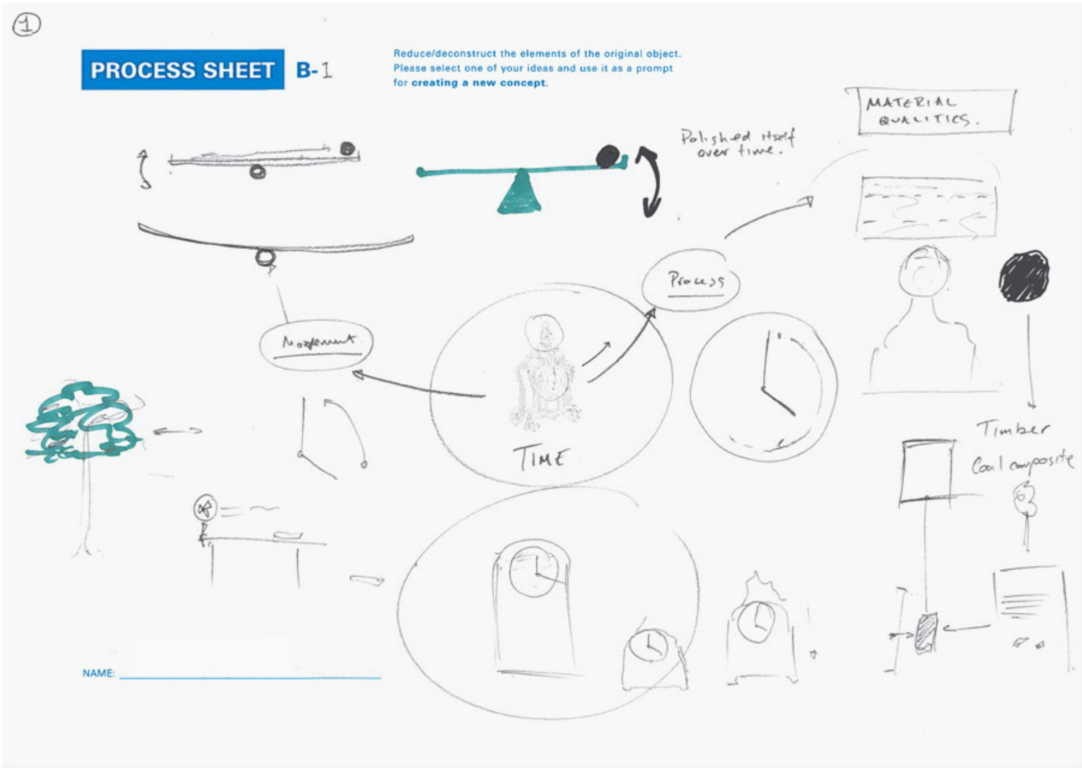



*Figure 134. The B1’s Process Sheet 1 at 00:15:46.*

At this point, B1 moved to the second *Process Sheet*. B1 described that B1 was trying to find value in the focus of “movement” and to relate it to the other key concept “material progressing” (B1, 00:16:18). It appeared that B1 was attempting to develop ideas within the integration of the two key concepts discovered. B1 then made a table and wrote down the questions that are derived from the key concept of both “movement” and “process (of material)” (B1, 00:16:47). B1 also described that B1 was trying to find the focal points within the original object, that people are not usually aware of, breaking it down into different areas (B1, 00:18:20). This suggests that deconstructing the original object into multiple elements helped B1 to discover specific characteristics of the clock that B1 have never been aware of. B1 also referred to the influence of B1’s previous design project, where B1 focused on material aspect, on the thinking avenues:

> *“(...) because I touched on the material in the previous project that’s probably a bit more in my head. (...) I was quite interested in materials so I was just trying to work it out what sort of values I can extract from the*

> *materials so it was never like designing a clock or something but I had thought of, I guess, some ideas of this process to things" (B1, 00:18:40).*

B1 further continued to jot down the concepts that are relevant to the keywords of both "movement" and "process (of material)". The words of "physical–human" and "factors of environment" were written in the column of the table named "movement". Also, the words of "materials" and "hardwood – brass/metals" were added in the column titled "process (of material)". It appeared that B1 attempted to find clues for ideas, interpreting the connotations of these concepts separately. B1 then focused on the aspect of materiality within the column, and considered stones such as a pebble or a flint, that B1 had never dealt with, as a possible material for ideas (B1, 00:21:26). B1 drew these materials on the sheet (Figure 135) and conceived the pebbles on a beach. B1 considered whether or not the smooth surface-texture of a pebble that was naturally polished over time can be applied to B1's idea (B1, 00:21:50). At this point, B1 asserted that B1 explores ideas using stone materials (B1, 00:22:00). B1 then drew another image of stone whose form is rough and associated with slate material (B1, 00:22:31). B1 also mentioned the relevance of the material imagined to the locality describing that the place where B1 originally came from is close to the home of slate (B1, 00:23:12). At this point, B1 identified the relevance between the production of natural materials and one of the notions jotted down in the previous table: "factors of environment" (B1, 00:23:39). At about this phase, the concept of the interaction between human attention and changes of material that will eventually be the core concept for the final idea appeared:

> *"(...) humans or the physical person interacts with things. Therefore, it's almost like an experience of it. (...) if the rock is just left on the table to do its own thing you might not ever really notice it… if you happened to actually interact with this rock or stone and you're almost experiencing how it's changing. Whether or not that has a bit more values to it" (B1, 00:24:26).*

Within the consideration of the influences of environmental factors on the changes to stone materials, B1 considered the impact by human interaction is a much faster way to affect its transformation of the material (B1, 00:25:09). This idea seemed to allow B1 to focus on the interactive aspect between human behaviour and material state. B1 then drew a sketch that shows a person is hitting a rock to shape into something.

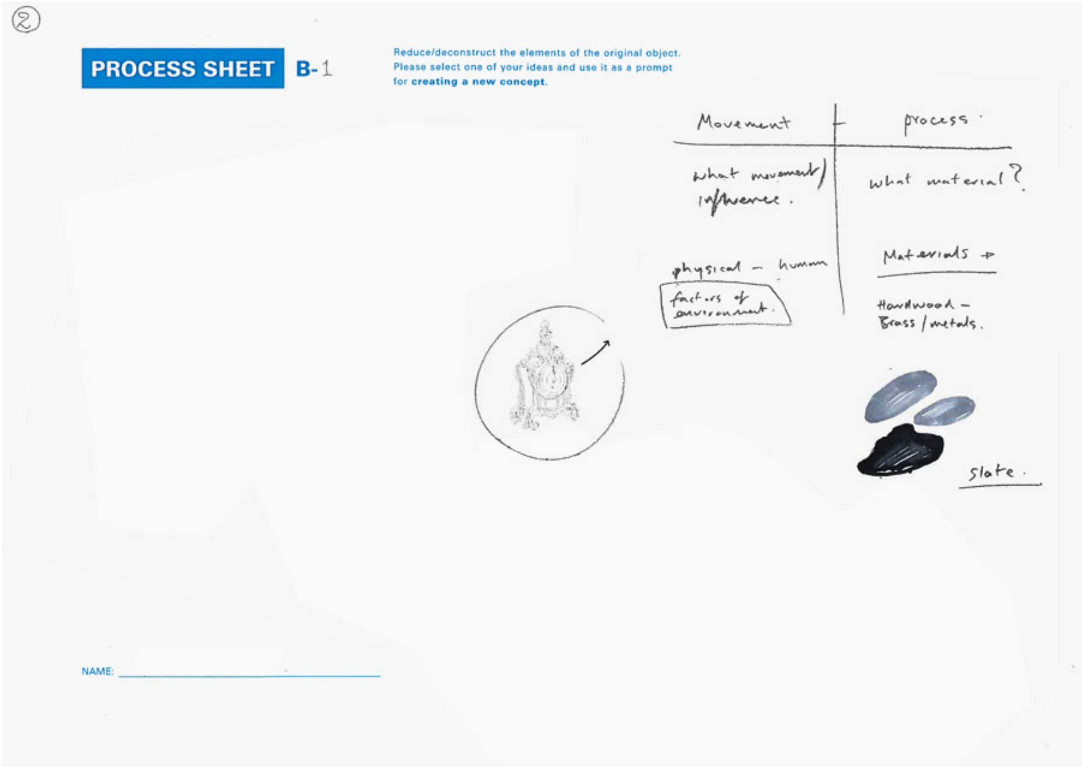



*Figure 135. The B1's Process Sheet 2 at 00:22:24.*

Here, B1 returned back to the previous idea of a pendulum object hung from the wall. In this idea, the swinging movement of the pendulum mechanism scratches or hits another material and the contact creates a form. It appeared that the idea was fostered combining the current thinking avenue with the previous idea.

At this point, B1 asserted that B1 realised the importance of going back the essential theme/concept that the overall process was originated from: time (B1, 00:27:01). B1 decided to focus on this essential aspect of the original object again. B1 then evolved the idea of a cuckoo clock whose bird pecks away at the object placed outside coming out from the clock-case. B1 further continued to develop the idea and evolved another cuckoo clock that the inside bird regularly comes out and hits a wineglass to make a characterful sound (B1, 00:29:40). Through this incremental ideation process, B1 explored ideas of interaction between a user and an object using different modalities: *"(...) it's almost giving a bit more feedbacks. You could have visual feedback and hearing or… it's giving a bit of noise to it" (B1, 00:30:22).* After coming up with the ideas, B1 seemed to be unable to progress B1's thought process any further (B1, 00:30:40).

B1 reread the instruction again and returned back to the previous thinking avenue where B1 focused on the stone materials. B1 rephrased the focus within the thinking avenue as "how the physical material might reduce over time" (B1, 00:31:38). B1 seemed to focus on how the physical appearance of the object's material could be reduced in some ways: *"whatever the material is… them material is essentially reducing may be its appearance or its actual physical presence… I'm trying to think what other things could be… form-wise" (B1:00:31:55).* B1 then evolved an idea that is similar to the previous pendulum idea (Figure 136). In this idea, a block of charcoal hung from the top scratches the surface of a paper. Following this, the notion, "over time–it changes from a physical/tangible object to nothing", was identified and written on the sheet (B1, 00:33:40). At this point, B1 stopped progressing this thinking avenue since B1 considered the current approach had become too artistic (B1, 00:34:15). In relation to this consideration, B1 described the similarity between the focus within this task and B1's current on-going project. However, even though both projects were rooted in the B1's strong interest in material qualities, B1 bears in mind that having a purposeful functionality in the designed object is important. Therefore, B1 was not comfortable to continue exploring ideas without a functional purpose (B1, 00:35:15). B1 then moved to the third *Process Sheet*.


***Figure 136. The B1's Process Sheet 2 at 00:34:15.***

The thinking avenue in the third *Process Sheet* was started from focusing on the coal/charcoal material. B1 interpreted the material characteristics of coal/charcoal in order to understand what it is and how it is utilised: *"(…) at the quality of the material… what you can actually do with it is, I guess, coal and stuffs seem to be very much like burnt and convection. It's almost like for another purpose to it. (…) coal/charcoal is more like a pencil and the idea of drawing or producing a drawing from the physical thing" (B1, 00:37:55)*. B1 then depicted a conceptual drawing that shows a lump of coal is physically changed or reduced within the same external case (Figure 137). B1 attempted to consider how the changes of only a state of the contents (but the external case remains as it is) interact with the user (B1, 00:40:46).

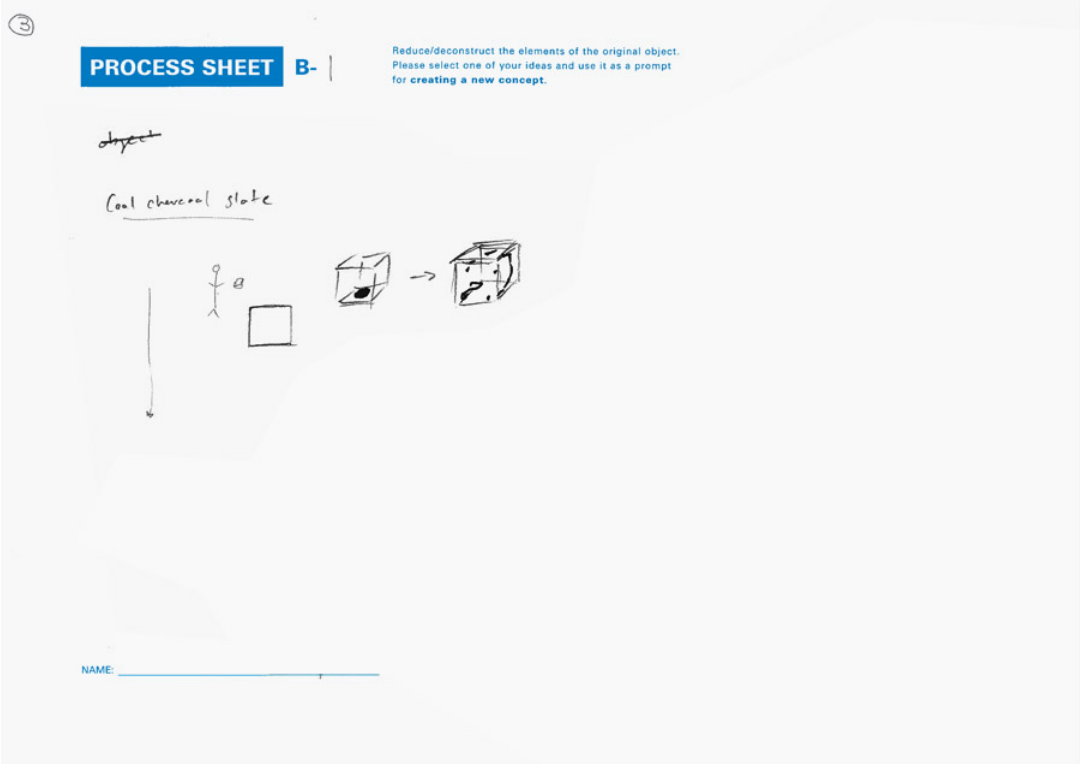



*Figure 137. The B1's Process Sheet 3 at 00:40:51.*

B1 also considered that the original object has a similar characteristic to this relationship between the inside contents and the outside case: *"I guess it's almost like that. The clock body. The mechanism almost wears out… the inside but the physical external skin seems to last" (B1, 00:41:10).* As the technology of clock mechanism progresses, the inside instrument can be constantly renewed and replaced. Nonetheless, the exterior of the object is not directly influenced by the interior alteration but stays as it is. B1 evolved an idea of an object that keeps a material inside and the user enjoys its changes over time.

At this point, B1 stated that B1 felt it is better to step away from focusing on the clock category in the idea exportation process (B1, 00:43:29). B1 then started searching everyday items other than the clock. B1 also asserted the importance of focusing on an anonymous object for idea exploration at this stage (B1, 00:44:18). This thought led B1 to conceive the idea of a simple vessel that holds something inside over a period of time. B1's idea exploration further continued, and a couple of similar ideas were conceived following the same concept. At some point in the process of idea seeking, B1 focused on the material characteristics of coal again, and it allowed B1 to find a key notion:

> *"(...) I quite like the idea of using coal (...) just because it's quite like anonymous in itself and its black colour of it. I guess coal is almost like a drawing tool so that responses of it. It will obviously be reduced down (over time) but also leaves a mark essentially. I guess at the same time that is like… the idea of 'visual feedback'. (...) in that idea you can really see how something is transformed" (B1 00:45:56).*

The idea of "leaving a visual mark" also seemed to encourage B1 to consider possible materials that can be used for the vessel: *"(...) the vessel could be like a ceramic or something as well… really pale ceramic so if it's got a piece of coal and round and round… how does it (coal enclosed in the vessel) change?" (B1, 00:47:14).* Following this, B1 further evolved another idea. In this idea, B1 focused on the physical change of the materials enclosed in the vessel by dropping them from top to bottom (Figure 138). Even though B1 conceived multiple similar ideas following the same concept, B1 seemed to have difficulty with exploring ideas: *"(...) I feel like I keep bouncing between few ideas. I need to be more decisive and really focus on this is what it is. I narrowed it down to this use of coal or stone… but just struggling with almost… thinking of the application" (B1, 00:48:13).* At the same time, B1 was spontaneously thinking of famous designers' works and tried to avoid following their approach:

> *"I guess other things pop into my head (...) I'm quite interested in looking over designers' works as well so almost like steer away from something that may be already existed. I know there is a couple of projects where… I don't think it's specifically coal but how a material might wear of... a period of time and stuffs. I guess almost see them in my mind but I don't want to sketch on the same sort of ideas. I'm just trying to keep it a bit different" (B1, 00:49:04).*

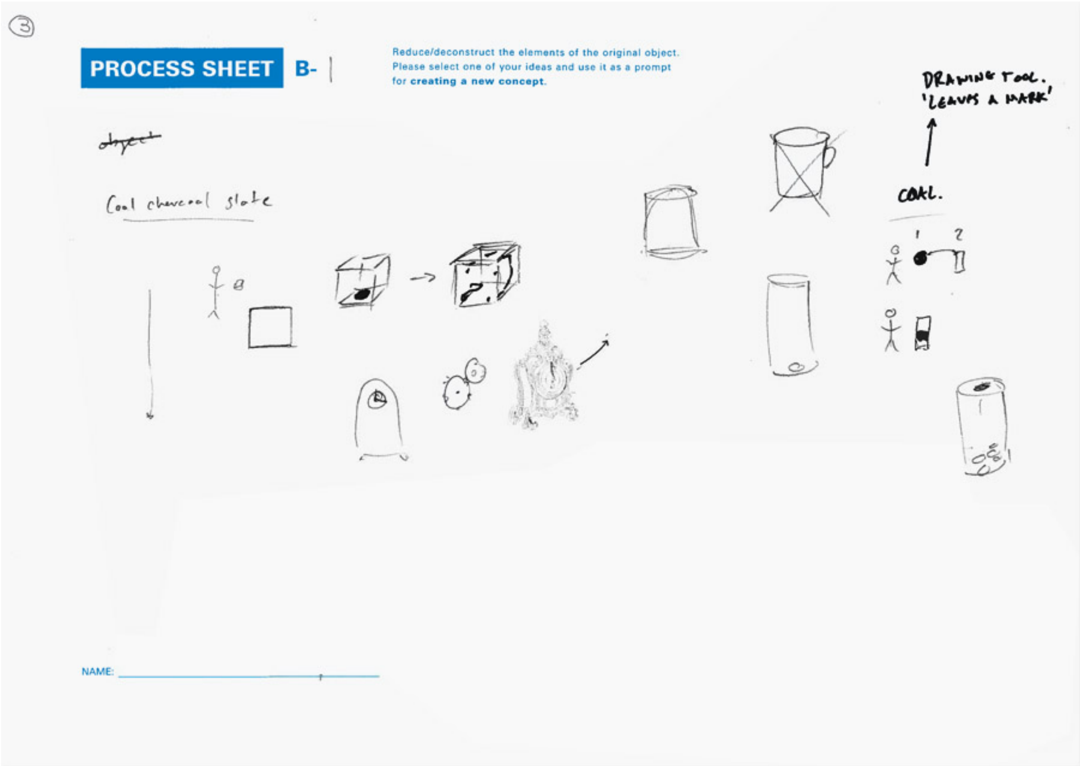



*Figure 138. The B1's Process Sheet 3 at 00:48:08.*

B1 seemed to naturally reference existing examples not only to use it as a clue for idea exploration but also to differentiate B1's thought from them. Then, B1 concluded this thinking avenue with the idea of leaving the material changes visible permanently (B1, 00:49:46).

At this phase, B1 reflected all the processes developed so far and returned back to the idea of vessel developed just before. Then, B1 summarised the characteristic of this thinking avenue by jotting down some keywords identified: "visual response" and "function". B1 particularly focused on the fragile property and the capacity for drawing of coal material and considered these characteristics as the fundamental functionality for developing ideas. This allowed B1 to evolve several ideas of a drawing tool (Figure 139):

> *"(...) coal or charcoal and this idea of reducing it but may be as like a drawing tool so you're getting visual response. (...) it's almost like a tool for drawing. It's got a function to it now so that's the original purpose (as a designed object). (...) A charcoal stick with different sized segments and you almost snap off the stick to (...) draw whatever you want. (...) whether or not a stick or a physical form that you can crumble away" (B1, 00:53:47).*

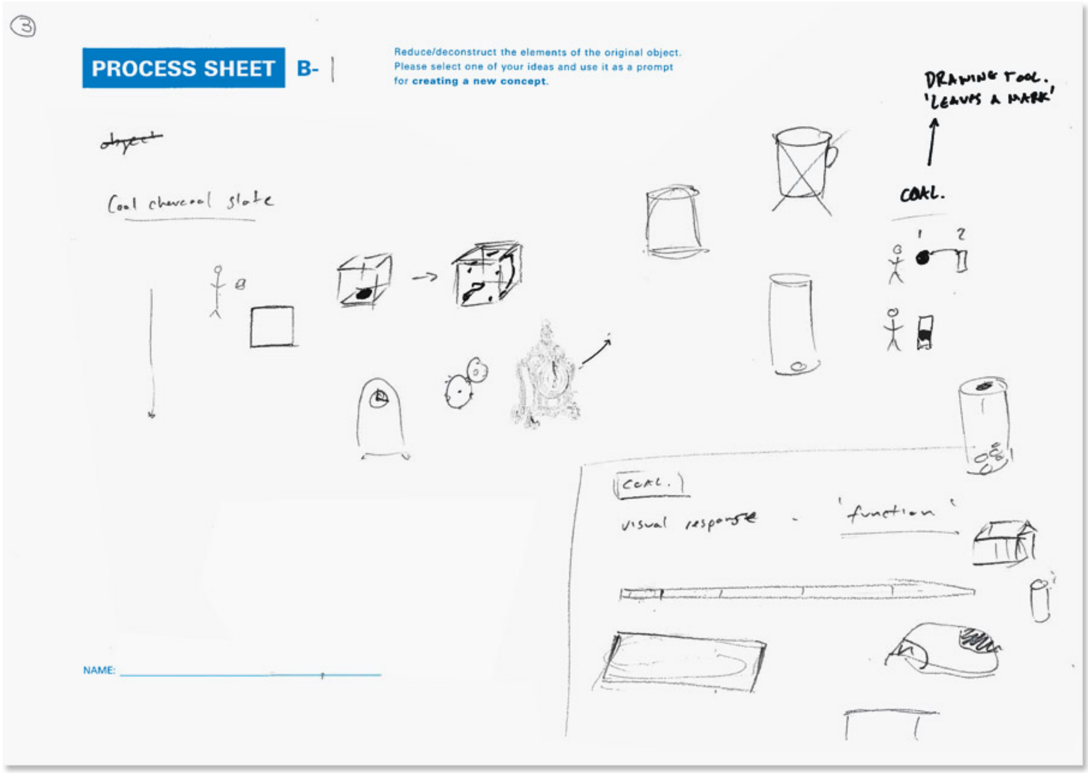



*Figure 139. The B1's Process Sheet 3 at 00:55:32.*

Additionally, it appeared that the discovery of the main function encouraged B1 to develop ideas as B1 had been uncomfortable and struggling with a shortage of functionality in B1's ideas (B1, 00:35:15). The ideas fostered focusing pretty much on the interaction between the material property and the user's behaviour. B1 stopped continuing to progress idea exploration here.

B1 then started reinterpreting the definition of the concept "reduction" all over again in order to better understand its possible connotations (B1, 00:58:43). The following words were identified and written on the *Process Sheet* (Figure 140):

- *Changing/simplifying*
- *Changing form*
- *Smaller*
- *Different memory*

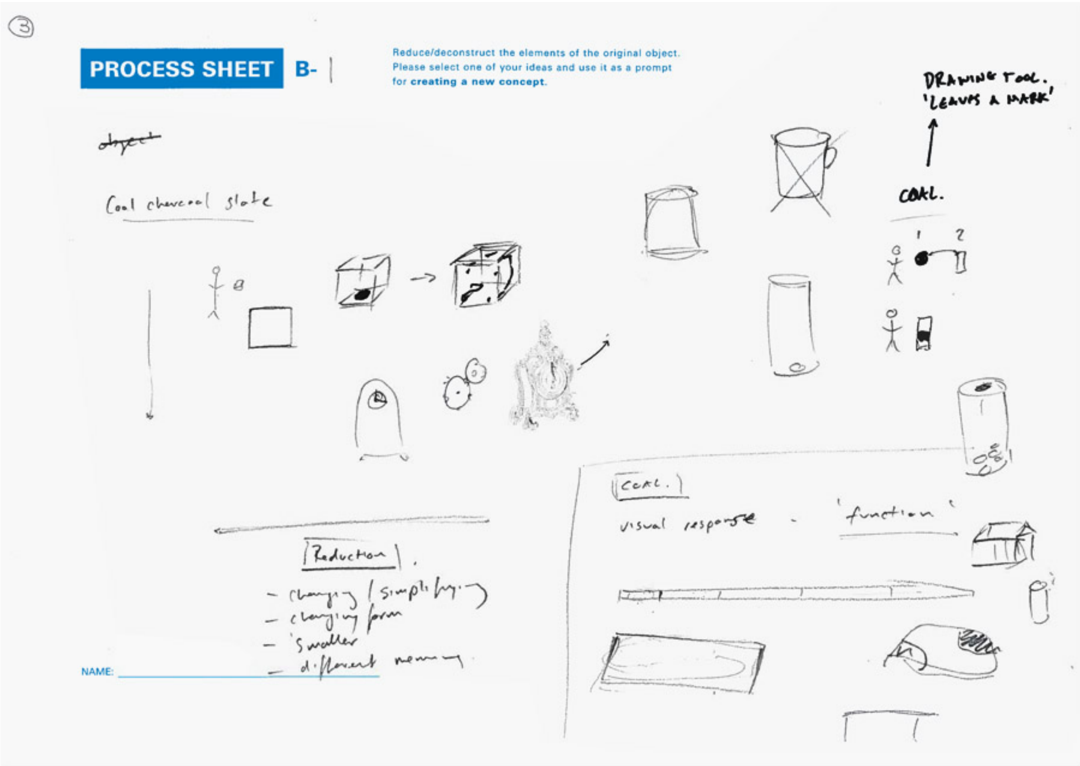



*Figure 140. The B1's Process Sheet 3 at 00:58:57.*

B1 seemed to be trying to objectively understand what B1 is thinking at this moment: *"I think, in my head, it's just trying to work out what is actually doing" (B1, 01:00:14)*. B1 continued to assert that the importance of the ideas of drawing tool lies providing a freedom in using the material with a certain function (B1, 01:00:33).

B1 then stated that B1 completely changes the focus and moved to the fourth *Process Sheet* (B1, 01:04:25). The fourth *Process Sheet* was initiated by evolving a new thinking avenue selecting the key concepts identified within the processes. B1 then came up with an idea of water purifier system using charcoal integrating these key concepts:

> *"In summary of all these sheets, I really like the material (charcoal) and I like the idea of reducing by being used for something. (...) Almost like the charcoal… I can imagine drinking water and stuff and it purifies the water essentially. It's almost a block (of charcoal) that you have to snap the stuffs off and then put it into a water purifier so essentially you are reducing it for the function of it" (B1, 01:04:42).*

The concrete form of the water purifier system was developed based on the concept. A lump of coal is placed on a plate as if it is displayed in a showcase and it exhibits the presence of material itself (B1, 01:07:17). The user breaks pieces away from the lump and put them into the separate water vessel or the beaker. Following this, several designs of the water purifier system were developed (Figure 141). B1, however, described that B1 felt the ideas are boring and paused this thinking avenue (B1, 01:09:00).

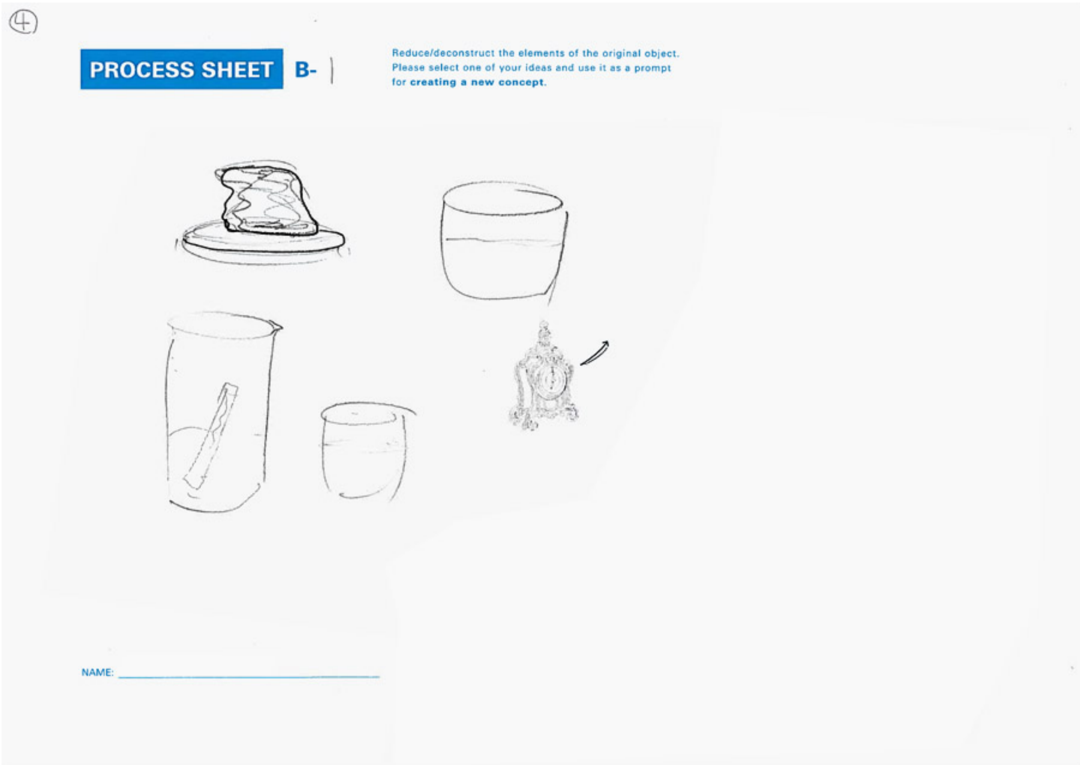



*Figure 141. The B1's Process Sheet 4 at 01:09:00.*

B1 returned to the previous idea of drawing tool and considered different forms of charcoal. In the process, B1 explored several geometric forms referencing examples of building blocks for adults e.g. modelling materials for architecture (B1, 01:10:11) and this attempt consequently led B1 to conceive the idea of Jenga (Figure 142):

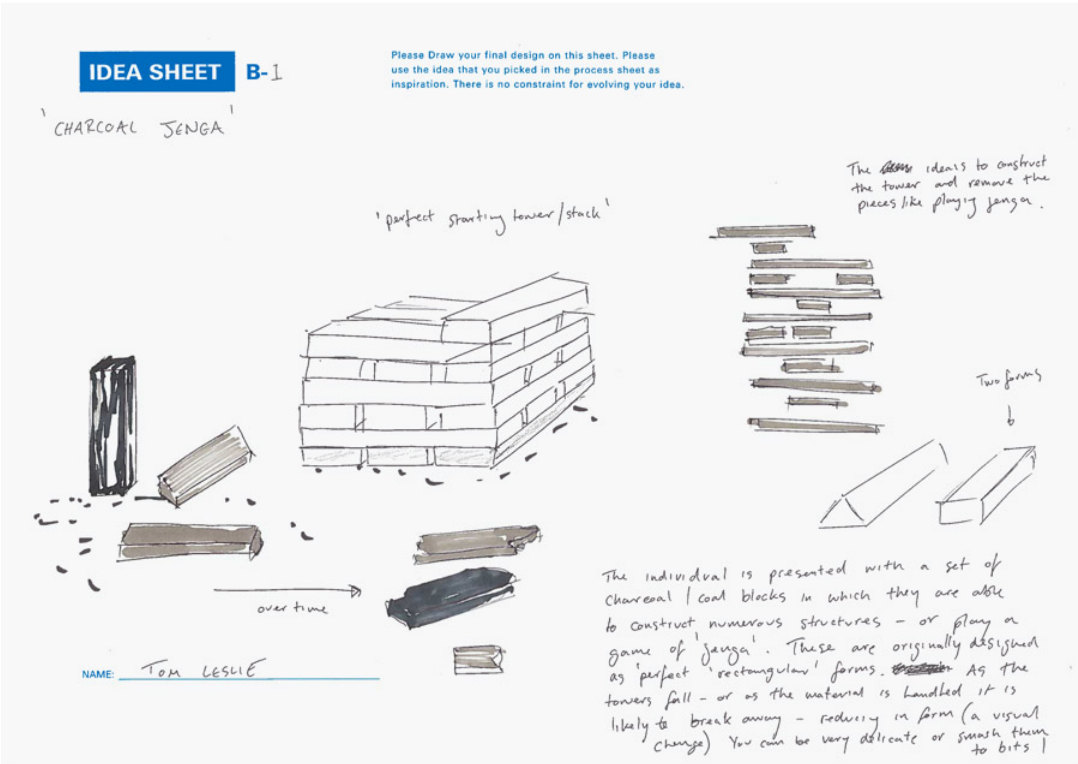
> *"(...) may be not for a child but more of like an adult building block certain sort of... get these different (geometric) shapes. It's very playful but may be a piece of architecture or something so you can sort of build on. Whether or not you can crack it or... almost like a game of Jenga... whether Jenga is made of charcoal. You start off with these perfect (geometric) form but as you sort of play with the material... obviously as soon as it falls they start like chip off" (B1, 01:09:52).*

The encounter with the idea of Jenga was made within the process of form exploration. The image of geometric components and the assumption of the way they are assembled suggested B1 to spontaneously associate with the idea of Jenga. Additionally, it is obvious that B1's key notions aforementioned (the idea of charcoal and the reduction by being used) had an influence on fostering the idea. The details of the idea of charcoal Jenga was refined recalling B1's memory of touching materials and the experiences of playing Jenga before. Within the process, B1 also found the value of using fragile material that creates an additional tension to the game itself:

> *"(...) I think the idea of Jenga is because you know it will fall essentially then that's why it's quite nice going back to the reduction theme. (...) Jenga you might be really delicate you almost stop before the pieces fall because you knew it would be damaged" (B1, 01:15:34).*

B1's focus on the aspect of the interaction between the material and the user continued until the very end of the reductive process and it became the primal concept of the final conclusion. Also, the notion of reduction was not only applied to the idea exploration process but also to most of all the ideas evolved in relation to the user's behaviours.

***Figure 142. B1's final design depicted on the Idea Sheet.***



#### 4.7.3.2.2 The Participant B1: Summary

This participant had little chance of starting thinking avenues by understanding the original prompt. In fact, the first action was recalling a conversation that B1 had with a clockmaker in the previous project. B1 almost never observed the original prompt for understanding, but rather focusing on the meanings that the clock implies (B1, Interview, 00:11:01). Through the interpretative process of the meanings, B1 developed the thinking avenues finding key-theme, keywords or key-concepts, such as “time”, “material quality” or “polished itself over time”, as a clue for B1’s idea exploration (Figure 143). Additionally, although the processes were not completely linear B1 had a tendency to concentrate on one thinking avenue and cultivated ideas within it.

The prominent characteristic of this participant was B1’s consistent interest in the interaction between materials and human behaviour throughout the process. The key concepts of both “(material) process” and “movement” were found, at the early phase of the task, and the ideas were mainly fostered in combining these conceptual aspects. Many of the ideas evolved within the processes, focused purely on the phenomena, wherein the state of materials is changed by the user’s actions, and often they did not even have a functional purpose. The focuses of these conceptual aspects were rooted in B1’s previous project around clocks and they were applied in this reductive task:

> *“(…) provably because I touched on these ideas (keywords of ‘movement/interaction’ and ‘(material) process’) in the past and to do of like material process. I almost saw the clock and thought about that opportunity to refresh what I was thinking at the time then. I guess I almost interpreted it for… meaning of time rather than a physical clock or something” (B1, Interview, 00:11:09)*

The limited visual fidelity as a prompt seemed to discourage B1 to focus on the details of the clock but rather on the conceptual aspects of the object. In fact, B1 explained that the primal focus was on essential concepts regarding “time”, and having such a perspective allowed B1 to consider more than what the object visually represents (B1, Interview, 00:17:44). Additionally, it appeared that having a broader level of conceptual thinking encouraged B1 to challenge to envisage different types of objects from the original prompt: *“It’s obviously, I quite like sort of antique decorative style (…). I’d happily design a clock and stuff too but it would be too expected I guess. I like the opportunity to do something completely random and to see what happens” (B1, Interview, 00:17:54).* B1 further described that the limited fidelity image naturally suggests avoiding a literal interpretation of the original object: *“(…) it’s obviously dotted and it’s almost suggesting you shouldn’t take it for its literal values. (…) It might be* *completely different if there was actual physical thing here" (B1, Interview, 00:22:11).* The limitation in visual fidelity appeared to allow B1 to focus on the conceptual aspects of the original prompt and also to prompt to reflect B1's own interests/concerns and the past experiences.

In conclusion, the reductive process encouraged B1 to take conceptual approaches where B1's memory and past design experiences were highly reflected. Many key concepts were identified within the self-reflective approach and they prompted B1's idea exploration. Additionally, the attributes of the original object were dismissed throughout the processes but, instead, such a conceptual approach allowed B1 to encounter the unexpected outcome.

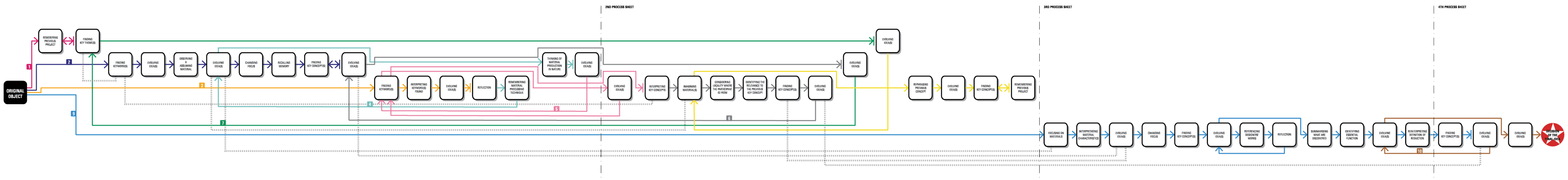



*Figure 143. The diagram that represents A4's reductive process.*

#### 4.7.3.2.3 The Participant B2

The participant B2 created a timer behaves like a human being (Figure 144). This timer visually represents time passage with the movement of the object as well as the digital display. As the time passes by, the timer falls over mimicking a tired person. This timer fits for all purposes and acts as a "time buddy" for the user. This design aimed at offering more intimate and emotional interaction with the user by the human-like movement. The timer function is controlled with the switch located at the bottom of the object, and the user stops the alarm by tapping the top. The digital display also functions as 24 hours clock. The main body of the object is assumed to be made of soft silicon and ABS material is used for the switch.

B2 started with generating fundamental questions regarding the original prompt such as "what is time?" or "what is a clock?" on the *Process Sheet* as the first step. Then, B2 continued developing the thinking avenues, reducing the concepts of the abstract questions down to the concrete and relevant notions. Following the question of "what is a clock", B2 identified the definition of a clock as a "tool for measurement" and further continued extracting the relevant notions such as "hours" or "years" from the concept:

> *"What is a clock? And it's basically a tool for measurement of time so you can break it down into "present times" or "minutes" as well as "hours". Maybe you can get further… I'm going to deeper like days, months, years… as time is always happening (...) very fluid I think" (B2, 00:01:53).*

The conceptual reduction continued as almost self-questioning and a notion identified was interpreted into another concept or question one after the other within the process (Figure 145). This conceptual reduction encouraged B2 to consider the idea of how we interact with the notion of time in a broader interpretation:

> *"You look at the things how many you've actually got like yearly basis or monthly basis… things look differently, different sort of time so… maybe we just consciously looking at day to day, hour to hour basis that's why it's going quickly so you can look at it in a bigger picture I guess. Maybe you think differently? I think bigger picture is nice" (B2, 00:05:46).*

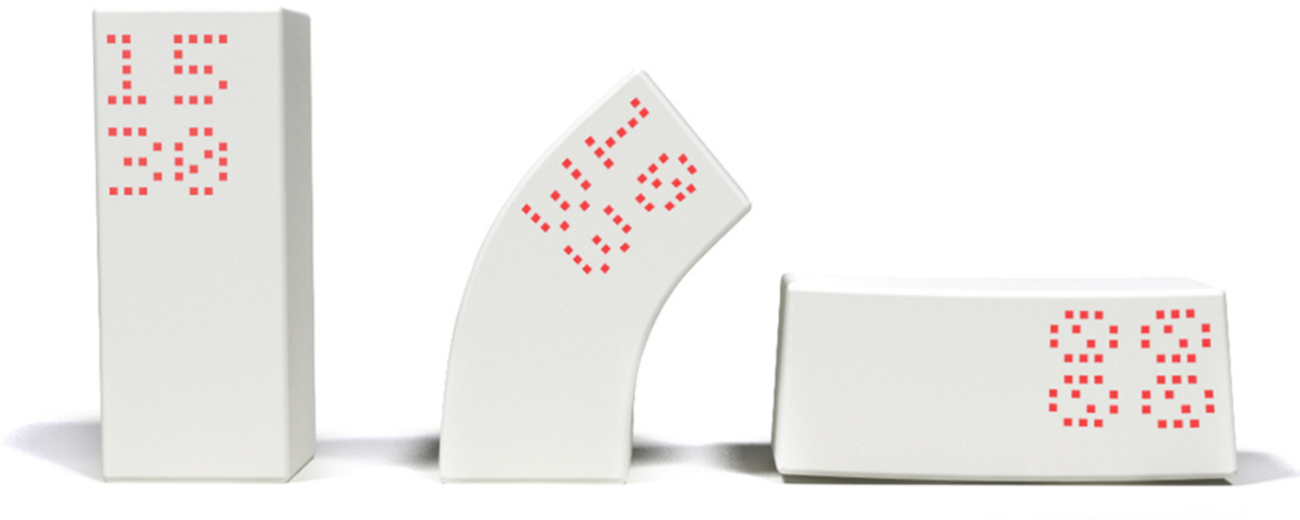
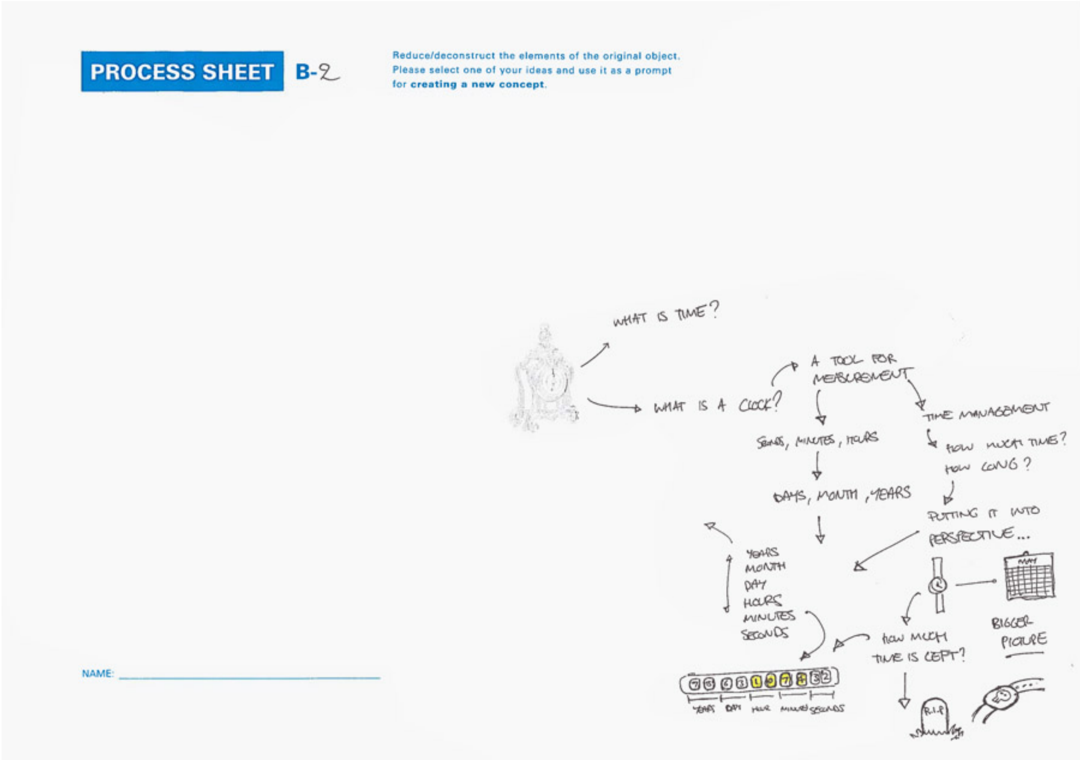


*Figure 144. The reproduced image of the outcome of the participant B2.*

The process of reducing concepts even led B2 to even radical question: *"what if people knew that they are going do die? I wonder if people live differently? Like a time where you saw how many days until you will die" (B2, 00:07:06)*. The idea of "clock as a tool for measurement" was interpreted as a mean of knowing person's remaining days. Following this, B2 conceived the idea of a wristwatch that tells a person's remaining days. It appeared that this approach allowed B2 to interpret concepts regarding time in a variety of ways and to conceive challenging questions simultaneously.

B2 then returned back to the previous concept "putting it into perspective" and evolved another idea of time indicator. In this idea, B2 attempted to visually represent the idea of time with a graphical display.

***Figure 145. The B2's Process Sheet 1 at 00:11:26.***




At this point, B2 returned back to the definition of a clock as "a tool for measurement" that was derived from the question "what is a clock?". Then, B2 explored a conceptual idea of "measuring happiness" and returned back to the previous question "what is a clock?". Following this, B2's focus shifted to our senses i.e. sight, hearing and so on, generating a question "what senses?". Within this process, B2 considered alternative ways of perceiving time using different senses: *"(...) most clocks are visual, visually see the time... so what if people can't see? What if the other senses are involved? Maybe taste? I don't know it will probably be a bit weird? Maybe smell? Yeah, maybe different ways of telling time" (B2, 00:13:30)*. The reduction and interpretation of concepts continued and several themes as a question evolved: “taste?”, “smell?” and “touch?”. B2’s focus shifted to the five senses where humans perceive time:

> *“So, what senses do we use when we look at a clock? “Sight”… you have the sight to look at the clock. “Noise”… quite relaxing… what other senses involved in that… and taste not really sure… “Smell”… different smells of the day linked to rituals, coffee getting up at the beginning of the day. Kind of relaxing… I don’t know, cooking or lavender or unwinding and then “touch”, I’m not sure about touch ” (B2, 00:23:40).*

At this point, B2 focused on the theme of “smell” and developed another question: “time of day and smell?”. This question led B2 to the idea of morning odours such as the smell of a coffee or a toast. B2 then discovered another keywords “daily rituals” within the process. B2 returned back to the previous question “time of day and smell?” and wrote down “evening” on the sheet. It appeared that B2 was considering the key notion from multiple angles in this process. Following this, B2 found other keywords “relax/unwind” and drew the symbol of “yin and yang” and lavender leaf (Figure 146).

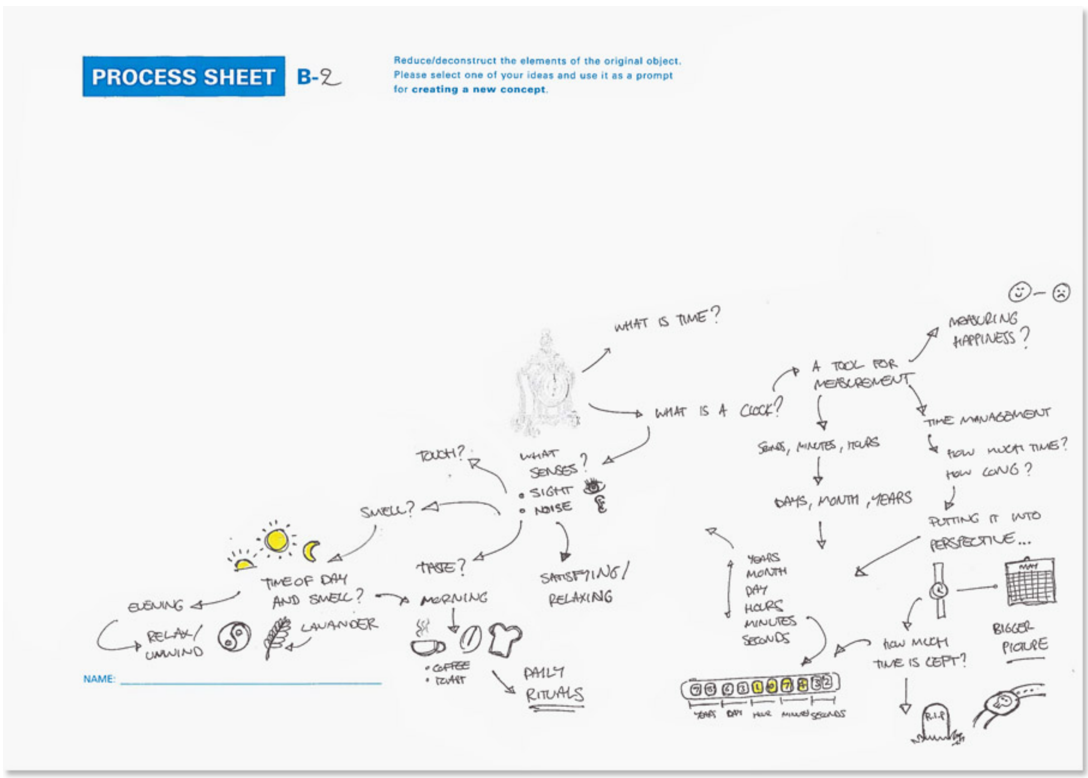



*Figure 146. The B2’s Process Sheet 1 at 00:18:34.*

B2 then returned back to the previous question “what senses?” again and added another sensorial element “sight”. Following this, B2 developed the idea of an indicator that shows time as length. Based on this perspective, B2 continued developing a further idea in which the timepiece whose form changes depending on the length of the cord that represents time passage. B2 was trying to evolve the ideas of an abstract interface where the user perceives time in an alternative way: *"(...) How detailed does it need to be…? This is almost the length kind of... visually saw how much time in front of you in physical and tangible way. How you perceive that. I don't know how you react to that." (B2, 00:24:33).* B2 went back to the keyword "sight" again and generated another question "what information do we need?". Based on this question, B2 evolved the two opposing concepts: "detailed" and "abstract". Then, an idea of the way which shows time in an abstract way was developed from the keyword of "abstract": knowing time through abstract information. In this idea, two kinetic objects that overlap with each other, and the changes of its appearance suggest the time to the user in an ambiguous manner:

> *"In a way it's more of the graphic way. (...) how two objects create different… may be colours… pictures or something? You can roughly know. It's not detailed. But may be there are another levels you can go further. You can glance and if you want to know more you can go further." (B2, 00:24:50).*

This idea of abstract interaction let B2 remember B2's past memory that is the colour of the sky B2 had been impressed (B2, 00:25:30) and wrote it down as a keyword on the *Process Sheet*. Following this, B2 depicted the patterns of the colour gradation that represent the hue changes of the skies. This ideation process further encouraged B2 to come up with another idea in which the object shows the time with changeable colour patterns (Figure 147).

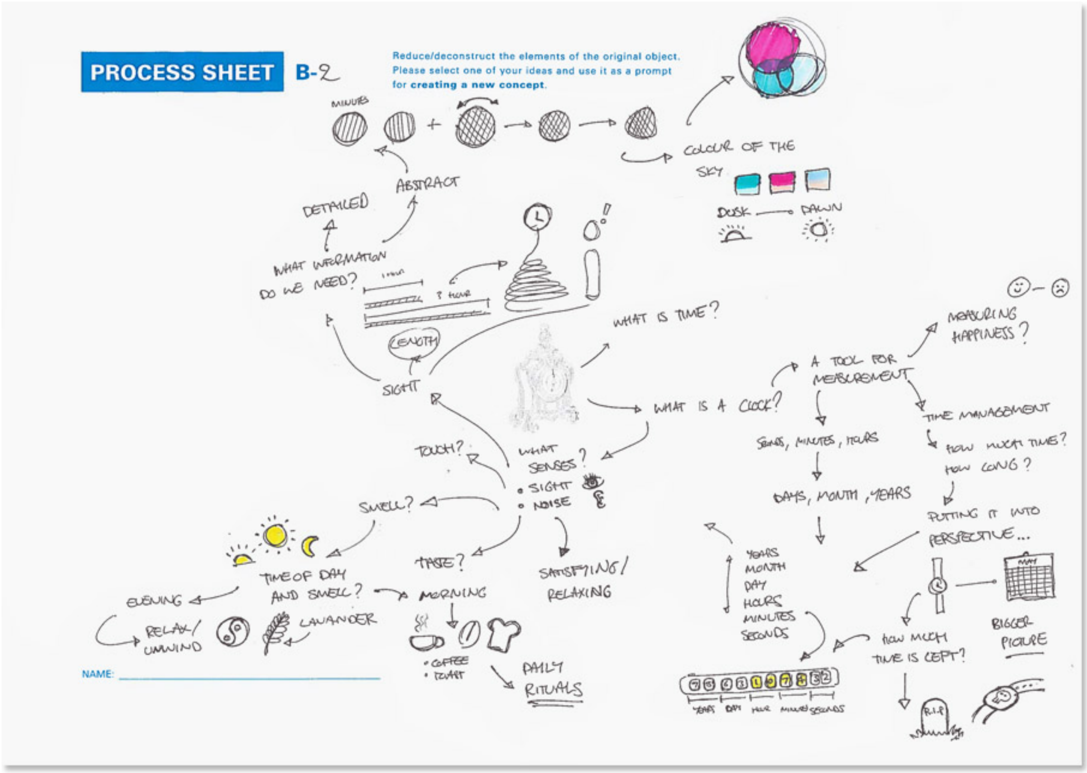



*Figure 147. The B2's Process Sheet 1 at 00:29:39.*

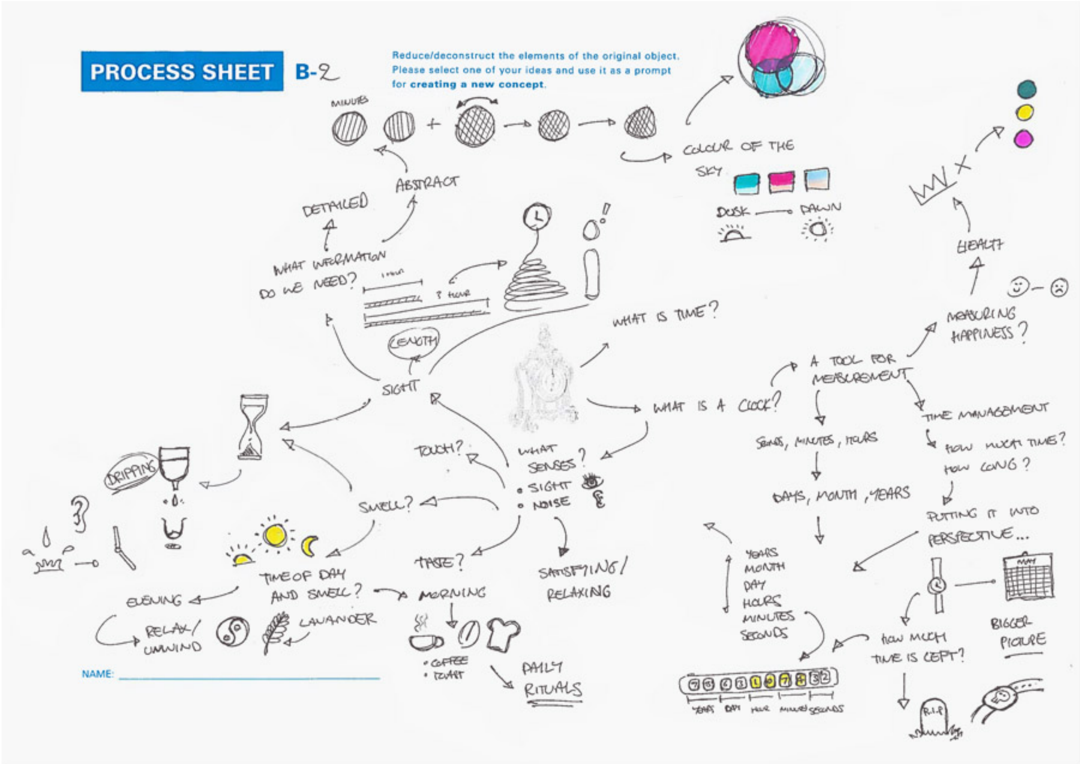
At this point, B2 suddenly returned back to the previous question, "how much time left?" and continued further reduction/interpretation of the concept. Within the process, the concept of "goal" was generated from the question, and the sub-notions of both "new car" and "holidays" were found from it. B2 also interpreted the concept of "how much time is left" in both positive and negative ways:

> *"If you can look at the time… maybe goals where you are striving towards. How much time is left towards… you know. I'm trying to think what else it could be… because that's a bit like (pointing at the gravestone's sketch)… it's sad… People are reacting in the same way whereas if it's turning it into positive maybe it fits into like goals and striving towards something if people look at it differently" (B2, 00:32:10).*

Then, B2 returned back to the previous question "measuring happiness?" and further continued reducing/interpreting it into another question "health?". B2 described that the subject such as happiness cannot be measured so that B2 conceived the idea of "health" that is more measurable (B2, 00:33:58). Following this, B2 considered the idea in which the object shows the user's health conditions in an abstract way.

B2 returned back to the previous keywords of the human senses and developed ideas, integrating the elements of both "sight" and "smell". Within the process, B2 imagined a sand clock and developed multiple ideas that focused on human senses (Figure 148).

*Figure 148. The B2's Process Sheet 1 at 00:39:24.*




B2 was also remembering B2's past memories during the ideation process and used them as an element for generating ideas:

> *"I find kind of relaxing listening to (the ticking sound of) my watches… just the mechanics of it. I find quite relaxing the noises… it's the quite big part of time telling. I wonder if I can use it in another way combining it with… may be smell… so dripping of something (…) it drips every minute or five minutes. That's quite like a ritual as well" (B2, 00:39:25).*

B2 then found the keywords "meditation" and "ritual" within the ideation process and continued developing the previous idea. B2 also linked the question "time of day and smell?" that was previously generated with the current ideas with an arrow. Following this, the idea of an object that drips liquid depending on the time of the day. This suggests B2 developed ideas combining the multiple elements that had been discovered already.

At this point, B2 drew directional lines from the keywords "sight" "touch" and "abstract" respectively, and developed another conceptual idea that describes how human emotion reacts depending on the different temperatures (Figure 149). According to B2, this idea was developed, referring to humans' daily habit:

> *"I was thinking how I can tell time by touch. (...) I was thinking how you could reduce the temperature so... I was thinking, in the morning when you wake up, a bit cold and they like to take a cold shower to wake them up, and then to relax they warm up... but then people prefer different things... people have different waking up routines... may be people don't like cold to wake them up and some people like a nice and warm cup of tea to wake them up" (B2, 00:46:35).*

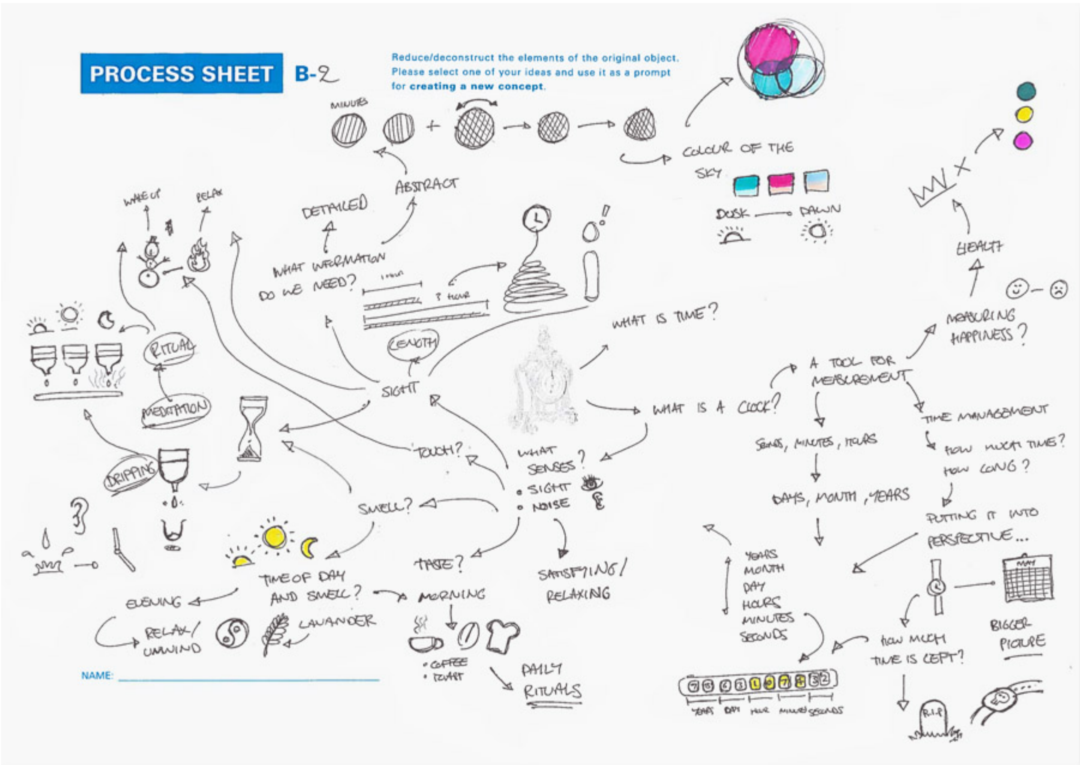



*Figure 149. The B2's Process Sheet 1 at 00:49:22.*

B2 then returned back to the idea of "dripping liquid" that was previously developed and considered the phenomenon of "dripping" as a mean of erosion of materials (B2, 00:49:11). The effect of constant water-drip gradually erodes the material and this phenomenon visually represents time passage. At this point, B2 stopped this thinking avenue.

B2 returned back to the idea in which the object, consisted of the three translucent circles, that shows time with the changeable colour-patterns and developed a further idea. However, this idea did not seem to be embodied within the drawing. Following this, B2 went back to the previous keyword "sight" and developed another conceptual idea that focused on the size as a factor to visually represent time (Figure 150).

At this point, B2 moved to the second *Process Sheet*. As the first action, B2 reflected the processes that had been developed within the first *Process Sheet*, and asserted that B2 continues focusing on the idea of "dripping" (B2, 00:59:54). B2 then started a new thinking avenue jotted down the keyword "sight". Following this, the idea of a clock that the opacity of its clock-face changes was developed. Within this ideation process, B2 came up with the key concept that subsequently taken over to the final outcome: *"As we get tired gradually in the day, so the clock doesn't give off. The information is not as clear… I don't know how useful it would be" (B2, 01:01:28).* Although the focus of idea within this ideation was on the visual opacity of object, B2 gained the key notion of "an object mimicking a tired human being". This notion led B2 to the idea that is quite similar to the final outcome:

> *"It's kind of a different variation of this (opacity gradation). The object is getting tired as well through time. So it falls over and you wake it up. Actually, that could work because that could be a visual and then it could be another level of detail if you want to interact with it" (B2, 01:05:09).*

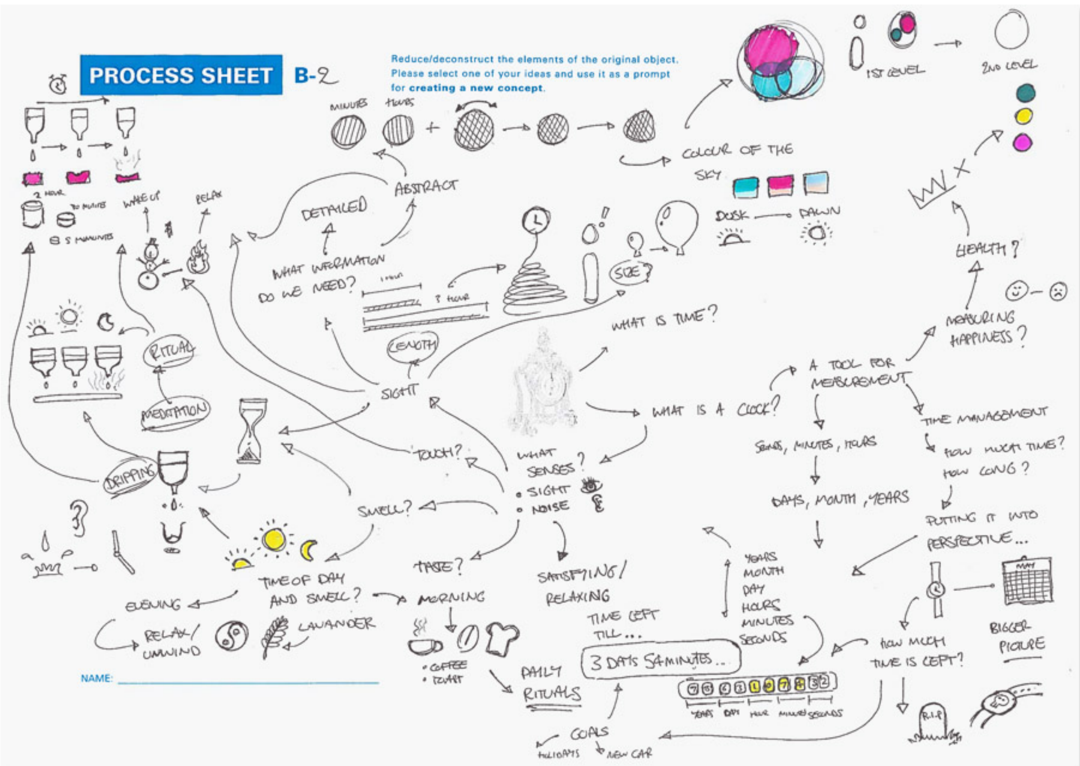



*Figure 150. The B2's Process Sheet 1 at 00:59:28.*

Even though B2 had already discovered the key idea that became the final outcome, the ideation process was further continued. B2 returned back to the idea of "dripping" that was developed in the first *Process Sheet*, and developed another idea that shares the similar concept with the previous idea. In this idea, the drips of the liquid that are released at regular intervals from the vessel gradually erode the material placed underneath. Then, a smell is released when the liquid hit the substance that is placed at the bottom through completely eroded material (Figure 151). B2 also considered other similar ideas that use heat and liquid for emitting aromas. B2, however, stopped this thinking avenue since B2 felt that the idea involved too many elements and it was no longer be the process of "reduction" (B2, 01:15:20).

B2 then returned back to the idea of the "rigidity timer" and drew a more detailed sketch of the object and its use situation, and asserted that this idea is selected for the final outcome (B2, 01:20:31) (Figure 152).

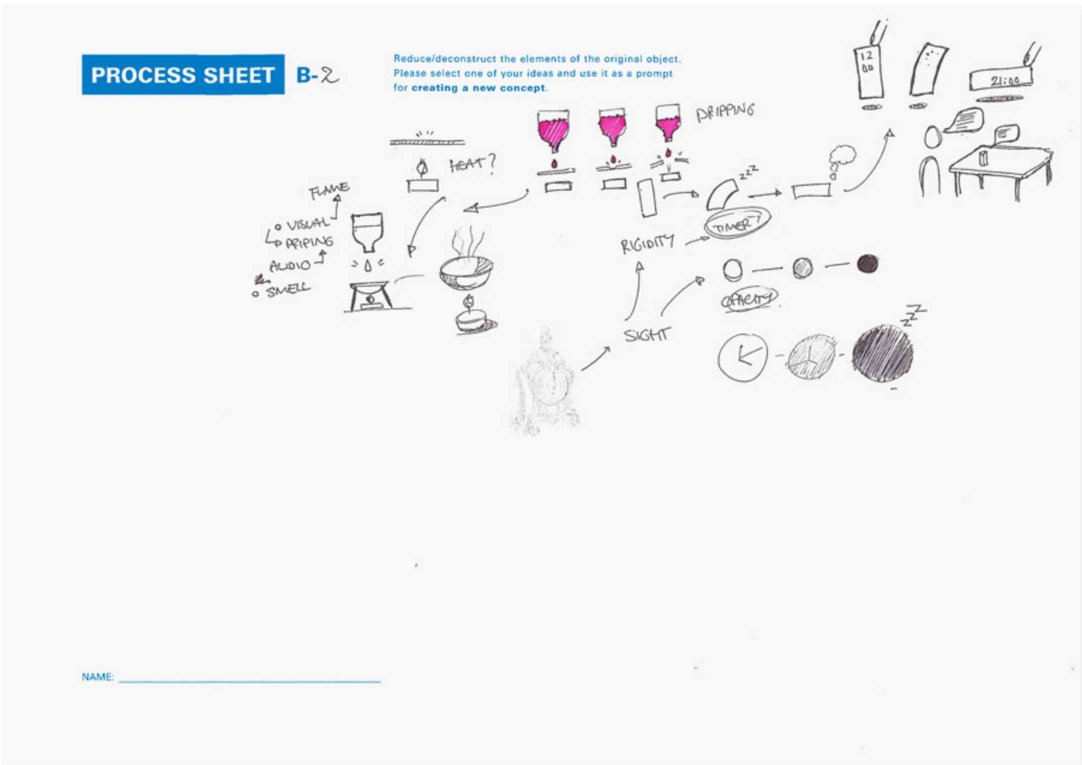



*Figure 151. The B2's Process Sheet 2 at 01:20:12.*

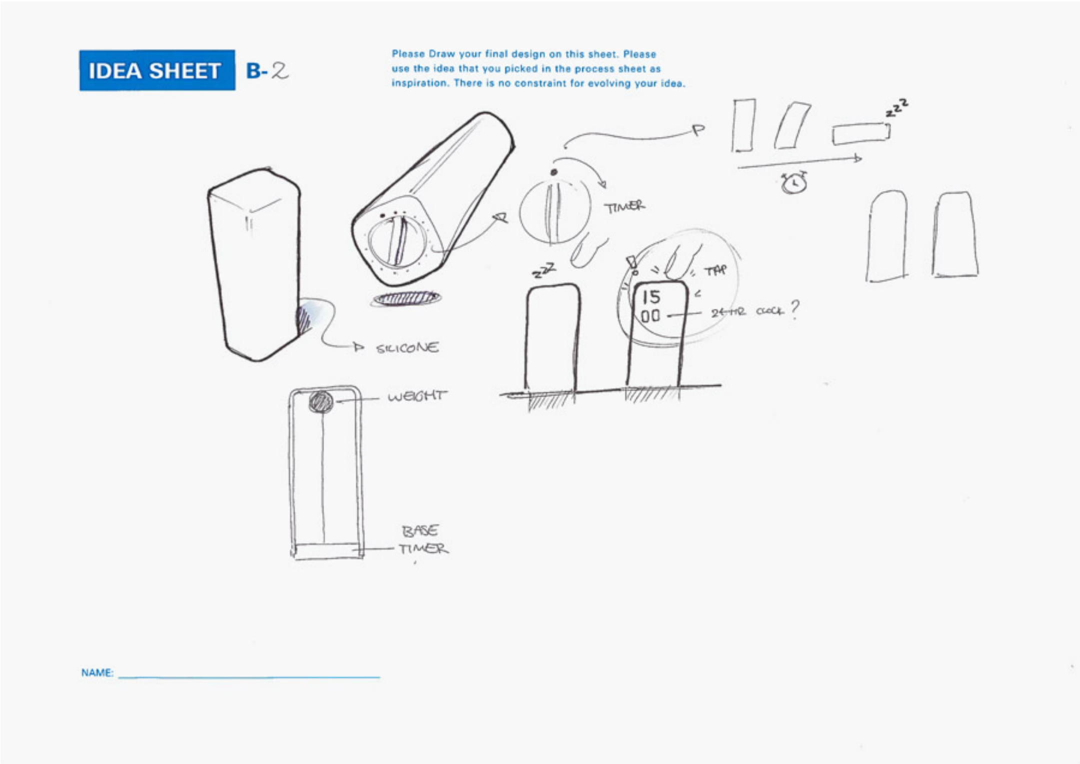



*Figure 152. B2's final design depicted on the Idea Sheet.*

#### 4.7.3.2.4 The Participant B2: Summary

Although the process of this participant was cyclical throughout the task, B2 built up the thoughts staying within the continued thinking flows (Figure 153). B2 never observed the details of the original prompt but rather developed the thinking avenues through conceptual reasoning. B2 initiated the process with generating questions regarding the original object i.e. "what is time?" and "what is a clock?". This approach of generating questions was frequently seen from the preliminary phase up to halfway through the entire process. The questions generated within the process allowed B2 to interpret concepts, recall memories and develop ideas. It appeared that B2 used those questions as a clue in order for the development of the thinking processes.

The centre of B2's concern was consistently on how time is perceived. This perspective stemmed from the conceptual question "what is a clock", and the thinking avenues were developed through reduction of concepts discovered within the process. This conceptual reduction helped B2 to conceptually understand several aspects of a clock, or to explore new perspectives regarding the interaction between the object and the user. B2 articulated that the reductive approach B2 took during the task was the process of knowing of what the object essentially means and exploring further ideas based on the understanding:

> *"I guess it's breaking down into basic components and exploring them... different levels of what it means and eventually get to the core of what it really is. And then, you can build that differently backwards so you deconstruct to the basic and then maybe you can add another element and build backup" (B2, Interview, 00:14:07).*

Through this conceptual reduction, the discovered notions e.g. a keyword, a key concept and a key question were interpreted/reinterpreted or integrated along with generating multiple ideas. Consequently, B2's approach was conceptually driven for ideation where the ideas were developed being followed by the concepts discovered.

In conclusion, the approach of B2 was concept-driven approach throughout the task, and the thinking avenues and ideas were fostered through the reduction of concepts identified. In this pursuit, generating questions played a significant role, at the preliminary phase of the process, for finding out what the original prompt essentially represents to B2 and B2 explored multiple ideas based on them as a clue.

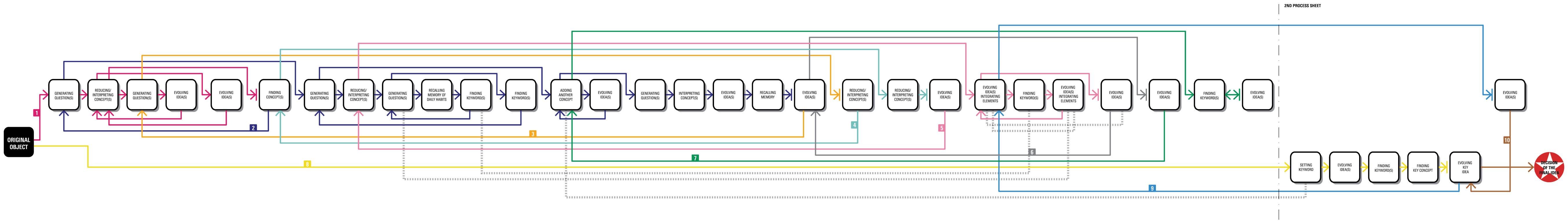



*Figure 153. The diagram that represents B2's reductive process.*

#### 4.7.3.2.5 The Participant B3

The participant B3 created a timepiece that tells time by the rotational movement of the pendulum hung from the top of the tetrapod structure (Figure 154). The concentric movement of the pendulum visually shows the time and the user perceives it in an alternative way. The aim of the design of this timepiece was to create an accent piece e.g. a sculpture in the interior. This object offers the user to feel what the time it is through the abstract movement of the pendulum rather than through precise time-indications such as a digital display. This subtle way of time indication suggests an alternative interaction in knowing time between the user and the timepiece. The height of the object is approximately 480mm and suitable to place on a desk. The structure of this object was made of black-anodised steel with a sandblast texture on its surface. Also, the bright red colour of the sphere attached at the top of the pendulum accentuates its design.

As the first step of the process, B3 sketched out the prominent element of the original prompt that instantly caught B3's attention i.e. the clock face, and sketched it out on the *Process Sheet*. B3 described that B3 was identifying the prominent elements/components of the original object and reduce them respectively (B3, 00:01:02). What B3 did next, however, was evolving the idea of a modern carriage directly from the leg part. Then, B3 focused on one of the ornamental elements shaped oval underneath the clock face and misinterpreted it as a pendulum component of a classical clock and sketched it out. Following this, B3 returned back to the original object and focused on the clock hands of the original prompt. Again, B3 returned back to the original prompt and focused on the top figurine and the ornament just right at the bottom of the main body of the clock. Following this, B3 developed an idea of legs whose shapes are simplified based on the structure of the original prompt. The approach B3 took up to this point was focusing on the prominent features of the original prompt in a variety of perspectives and extracted them or even developed ideas on the *Process Sheet*. The focus was not only on its particular forms of ornament but also on other elements such as the structure of the original prompt or the kinetic mechanism of a pendulum as well (Figure 155). It appeared that B3 was trying to understand the elements by externally extracting them on the *Process Sheet* and keep them as a trigger for the further idea exploration: *"It's something like a pendulum. How that clock kind of working… whether or not that element could be used. (…) Here is the old figure of statue" (B3, 00:04:11).* Within this process, B3 mainly concentrated on the identifiable elements that have a clear and concrete role as a component of the original object:

> *"Just kind of picking up the elements. They are really archetypal elements so ⋯ looking at the clock face, the clock hands, the pendulum and just pulling*

*other sides and some other elements are a bit more abstract, and a bit more vague. I'm pulling them out" (B3, 00:06:52).*

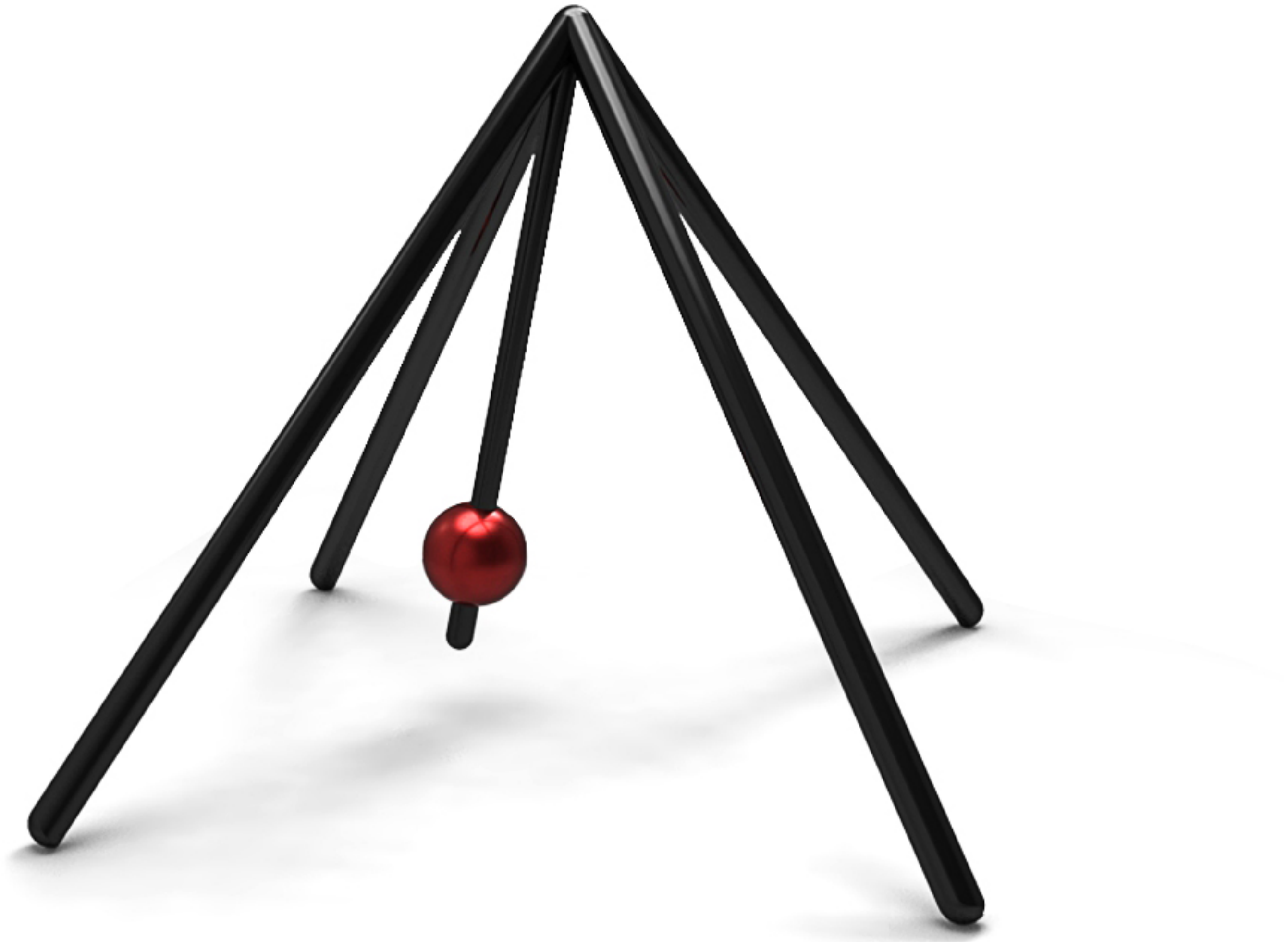


*Figure 154. The reproduced image of the outcome of the participant B3.*

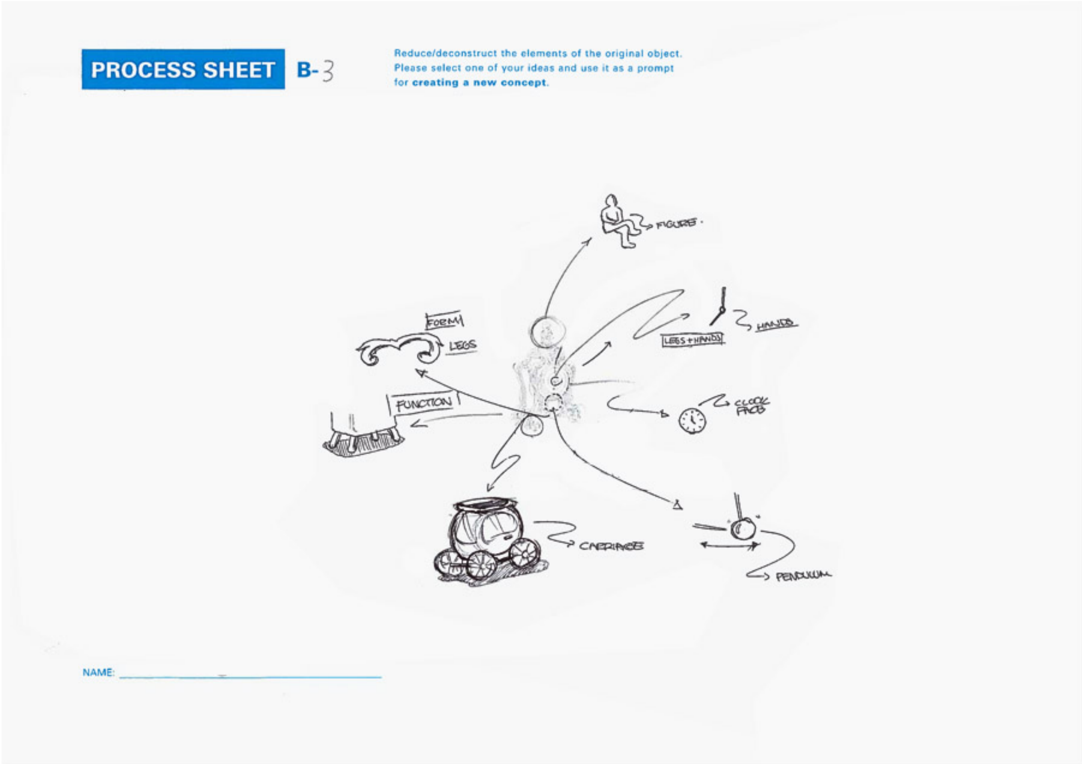



*Figure 155. The B3's Process Sheet at 00:09:21.*

At this point, B3 asserted to combine multiple elements that had been discovered so far (B3, 00:09:25). Within this integration process, B3 articulated that these elements were categorised into several groups in the first place. This categorisation process then allowed B3 to reflect what information B3 were gathering:

> *"I will combine some of these (elements already discovered). So, I think I'm going to split, break it down into 'functional', 'form' 'objects' so what I gather from its form is function, and then maybe I'm trying to simplify them down and combine them again" (B3, 00:09:25).*

B3 then drew a line with an arrowhead from the image of the simplified legs and depicted the sketch of a tetrapod structure. Following this, the images of the tetrapod structure were linked with the drawing of the pendulum by the arrow. B3 stated that this idea was developed by the combination of the two ideas: the simplified legs and the pendulum (B3, 00:11:54). Apparently, B3 reached the key idea that subsequently is selected for the final outcome at this phase. However, the object was still abstract without any functions. B3 returned back to the idea of pendulum here and continued developing the details of the pendulum (Figure 156). B3 described that this idea of a pendulum was iteratively developed, adding another element of form derived from a different object, in order to find the ideal shape of the pendulum that suits the tetrapod structure:

> *"It's just a… take the form of the metronome… a pendant… I'm just kind of iterating some different forms and looking at these (the tetrapod and the pendulum) how it complements this, better to try to be combined two halves. The idea of this is being suspended in this: kind of four-point structure. The metronome could be suspended inside and swing and move but then looking back and trying to think what form of this (the pendulum) would complement this (the tetrapod) here… so I'm trying to go back here (the image of the tetrapod structure with the pendulum) and iterates some different forms from this pendulum might suits this (the tetrapod) a lot about" (B3, 00:14:35).*

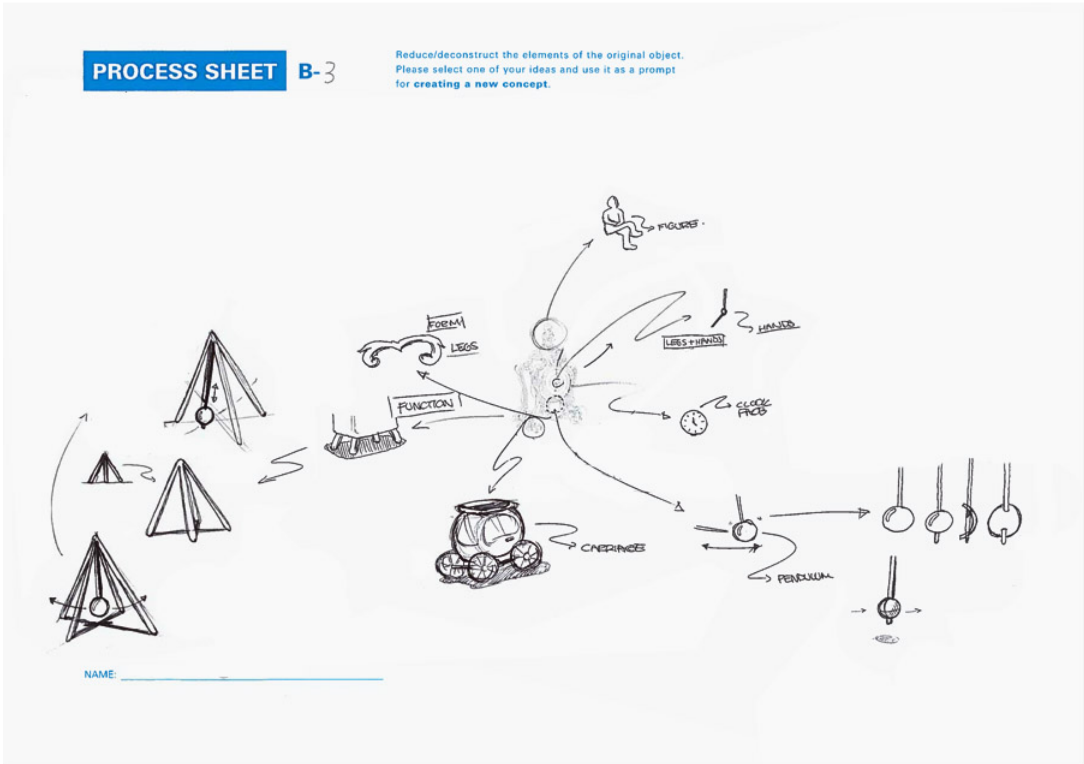



***Figure 156. The B3's Process Sheet at 00:17:30.***

Even though the idea of a tetrapod structure with a pendulum was developed, B3 was still considering its main functionality. After writing down the question "what could motion inform?" next to the drawing of the tetrapod, B3 tried to see this object as a time telling device: *"I'm thinking what could the motion of this inform. So, I'm kind of… obviously being a clock to start with. Could this (the tetrapod structure with a pendulum) just be performing as a clock or performing another function?" (B3, 00:18:12).* B3 paused this thinking avenue here.

At this phase, B3 reflected the previous processes and considered that the approach where thinking avenues were developed, being focused on fundamental elements of the original clock e.g. the clock face, the clock hands or the legs was “too safe” (B3, 00:21:39). B3 was not satisfied with the way to focus on the elements of the original prompt and presumed there must be other elements that B3 had not yet been aware of (B3, 00:22:05). B3 then returned back to the original prompt and developed a new thinking avenue. In this avenue, the focus was on the entire form of the original prompt, and B3 developed the idea of a clock whose shape is simplified. In this idea, the volume and the proportion of the form and the legs were taken over to from the original prompt yet other ornamentations were completely removed and the pendulum was housed within its main body. B3 continued developing the form reduction and conceived another idea. Although the object is still lifted with four legs, the entire form was even more reduced down to a sphere, and the pendulum was attached at the bottom of the body of the clock (Figure 157). B3 tried to understand how the object as a clock is converted if its attributes are completely removed: *“I’m thinking (...), with this being a clock, how can you reduce it down to the point where everything is removed, all other flows are removed, and it’s just purely how these can be something converted clock” (B3, 00:27:23).* Following this, B3 wrote down the questions “how can this object be reduced to its purest form or function?” and “to tell time?” on the *Process Sheet*. B3 described that B3 was considering how the object could be reduced down to the minimum in terms of its form and function that just tells time (B3, 00:31:45).

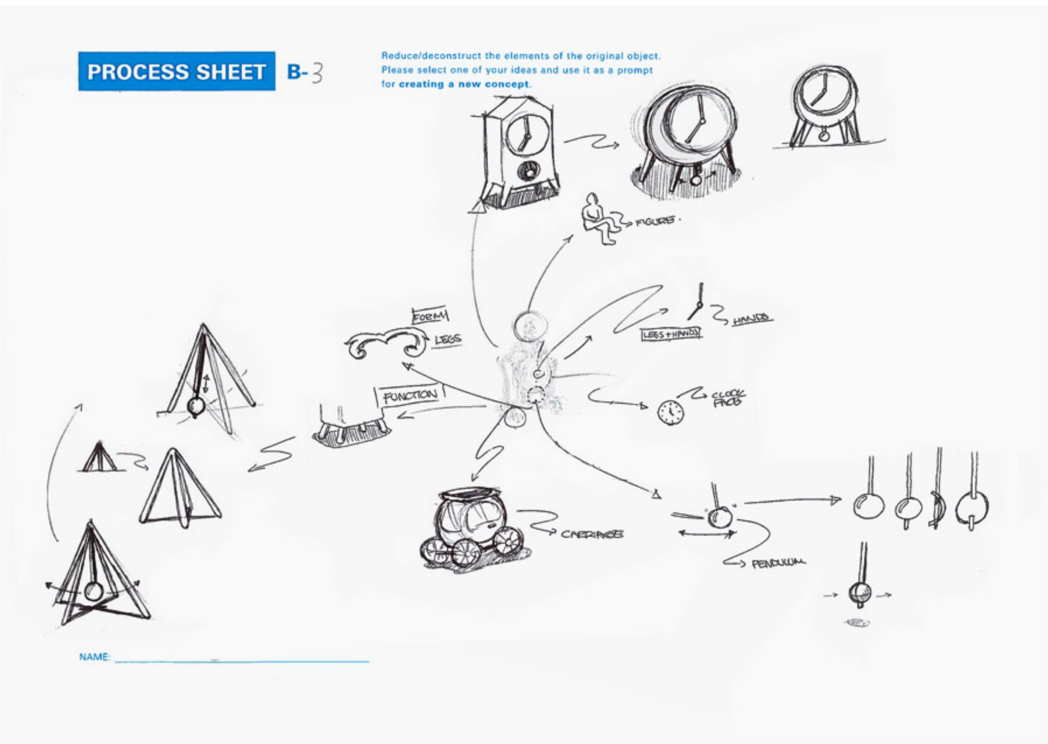



***Figure 157. The B3’s Process Sheet at 00:29:22.***

Here, B3 returned back to the previous thinking avenue in which B3 focused on the clock face and developed further ideas. After depicting a couple of familiar clock-face designs, i.e. the circular dials displayed with lines or numbers, B3 conceived an idea of a clock face that indicates time in a peculiar way. In this idea, the numbers of the clock face, represented by dots, are vertically arranged in the rectilinear order and the time is indicated by a linear motion moving up and down. B3 also combined this display style and the idea of a pendulum that was depicted just below the drawing and developed another idea (Figure 158).

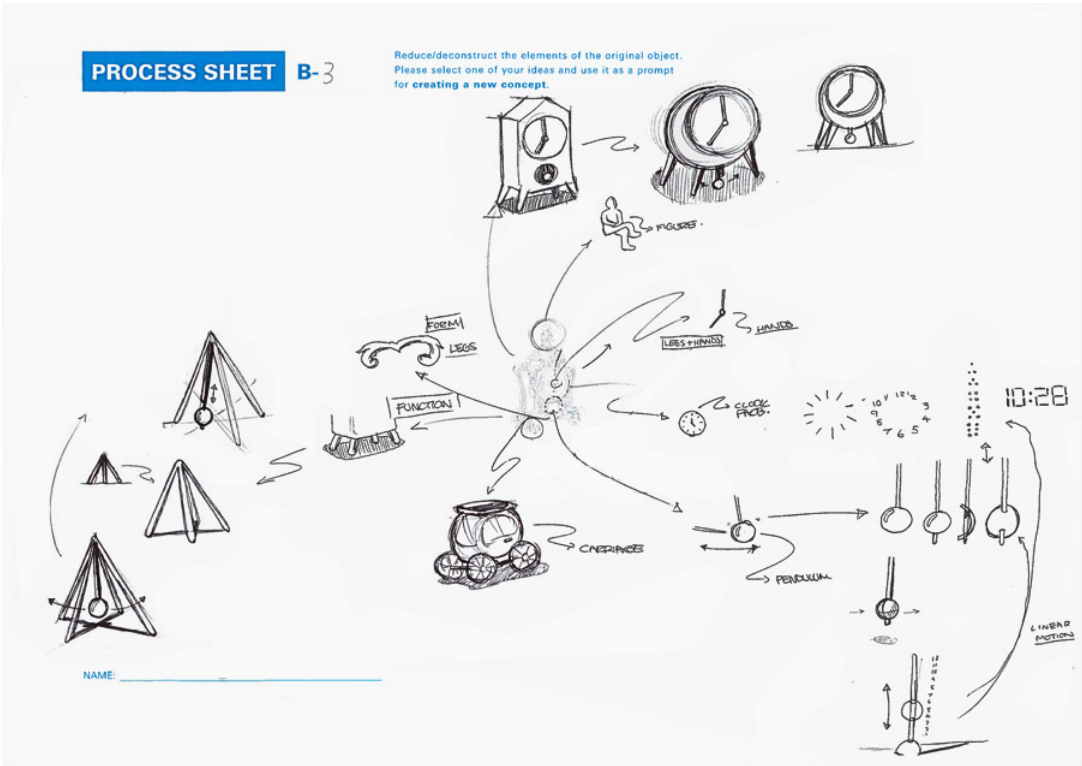



*Figure 158. The B3's Process Sheet at 00:36:17.*

B3 then returned back to the previous idea of the sphere clock, and developed another idea, combining it with the element of the top figurine. It appeared that B3 was trying to explore ideas by crossing different elements discovered: *"I just kind of jumping around all different ones. Maybe if I find a little bit from that one and… that one fits that one like compensating together" (B3, 00:38:16).* B3 also stressed the importance of not staying in one thinking avenue but rather quickly moving among different avenues:

> *"(…) if I just look at one idea for too long, you'll just get bored of it. If you can mix it up with a few other ideas and just keep it like… spending half a minute on this, half a minute on this, half a minute on this. (…) I think it's a bit better than just staying on one idea for whole time" (B3, 00:38:40).*

B3 returned back to the thinking avenue of the "clock hands", and developed an idea of clock hands. B3 also linked the "clock hands" with the "clock face" with arrows.

B3 quickly returned back to the thinking avenue where focused on the legs. B3 then added the keyword "movement" next to the drawing. B3 appeared to conceptually reinterpret the parts of the original prompt at this phase*: "I'm just thinking those… a lot of little feet just like little claws or wheels. (…) it made me think of movement and movement of time (…)" (B3, 00:41:40)*. B3 then wrote the keyword and the question of "legs" and "movement of time?" on the *Process Sheet*. Following this, B3 combined the keyword of "legs" with "hands".

B3 returned back to the drawing of the simplified legs, and wrote down the key concept, "movement of time" by combining the two keywords: "legs" and "movement". Based on this combination of the elements, B3 conceived the idea of "walking robot clock". In this idea, the creature look object with four legs indicates time by walking around the space on the clock face. B3 continued developing this idea further and conceived another idea where this robot clock linearly moves back and forth. At this point, B3 connected the drawing of the simplified figurine and the current key concept "movement of time" with an arrow. B3 then depicted another drawing of this "walking robot clock", adding a moustache. This figure of moustache derived from the previous drawing that represents the ornamental part of the original prompt and these elements were linked with the arrows. B3 developed ideas by combining multiple elements discovered (Figure 159).

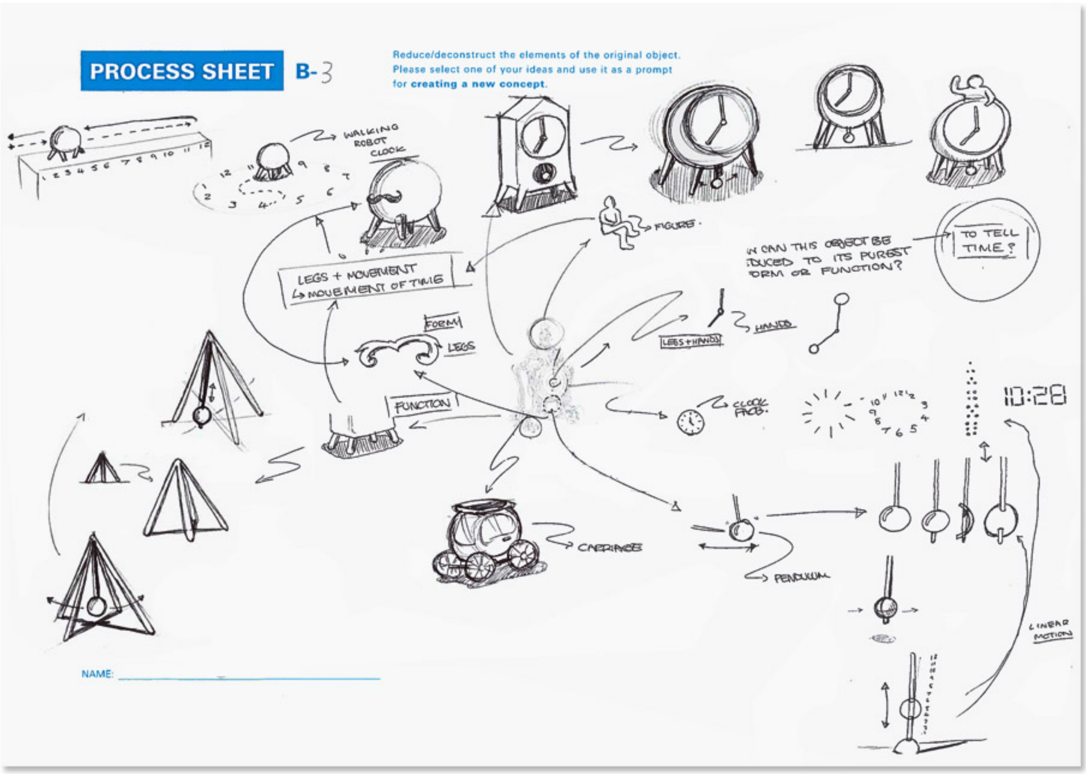



*Figure 159. The B3's Process Sheet at 00:50:20.*

B3 went back to the previous tetrapod idea again and tried to see it as a timepiece. B3 developed the functional details of this tetrapod structure as a clock referring to the possible movements of the pendulum:

> *"I'm thinking how this could tell time. It could be… when it's under this, this thing (pendulum) with four (legs) it's kind of rotate like that (spiral shape) but as it gets later in the day, the circle becomes bigger and bigger so it's spinning around so it's kind of mid-day and then as it kind of winds up smaller, smaller and smaller… So, go out to 12 (o'clock), and when it reaches 12 it goes back into 1 (o'clock). It goes out to 12 and back in to 1 so do that cycle twice a day" (B3, 00:56:13).*

At this point, B3 described that B3 satisfied with exploring concepts, and reflected the processes of which B3 had developed:

> *"I think I've pretty much done the concepts. (…) I think this one (the walking robot clock) is a bit funny and quirky. This (the sphere-shaped clock attached with a figurine) is kind of more domestic and marketable whereas this (the*

*tetrapod device) is a bit more abstract and a bit more sculptural" (B3, 01:01:37).*

B3 then respectively grouped the prominent thinking avenues by assigning numbers and the idea of the sphere-shaped clock with a figurine was discarded. It appeared that B3 tried to select the idea for the final outcome from the remaining ideas: the walking robot clock and the tetrapod time-telling device. B3 then jotted down the pros and cons of each idea and selected the idea of the tetrapod time-telling device for the final outcome. The decisive factor in this selection process was the feasibility of manufacturing the object (B3, 01:06:02) (Figure 160 and 161).

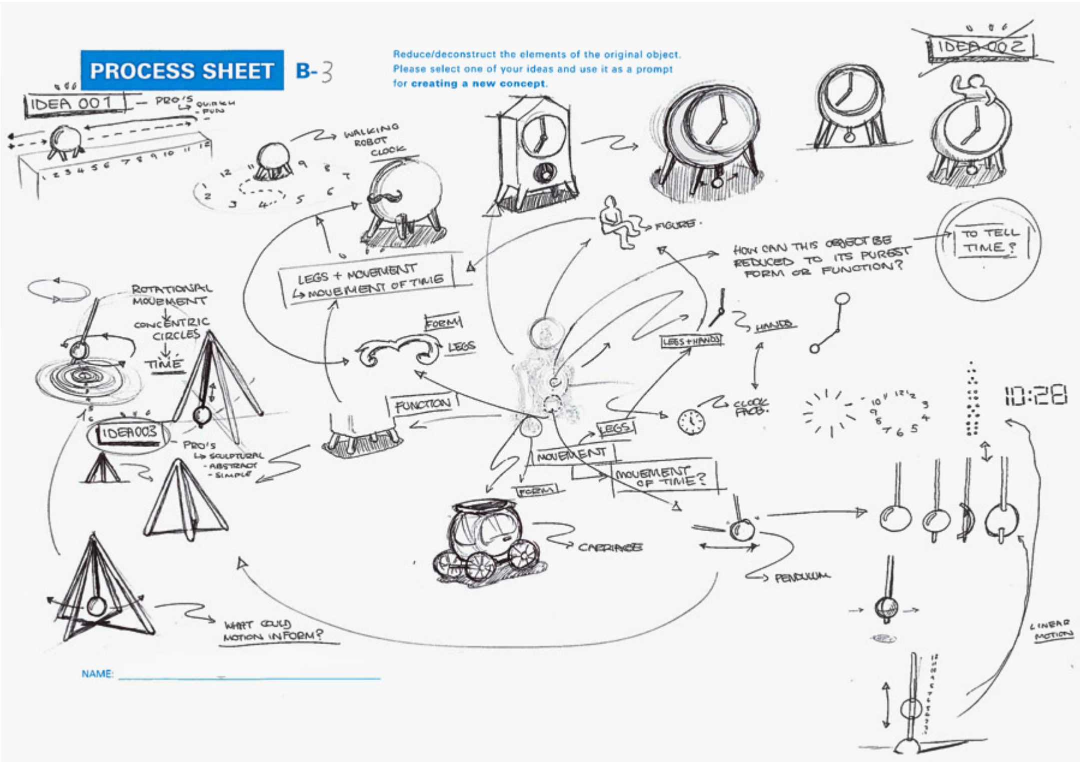



*Figure 160. The B3's Process Sheet at 01:06:00.*

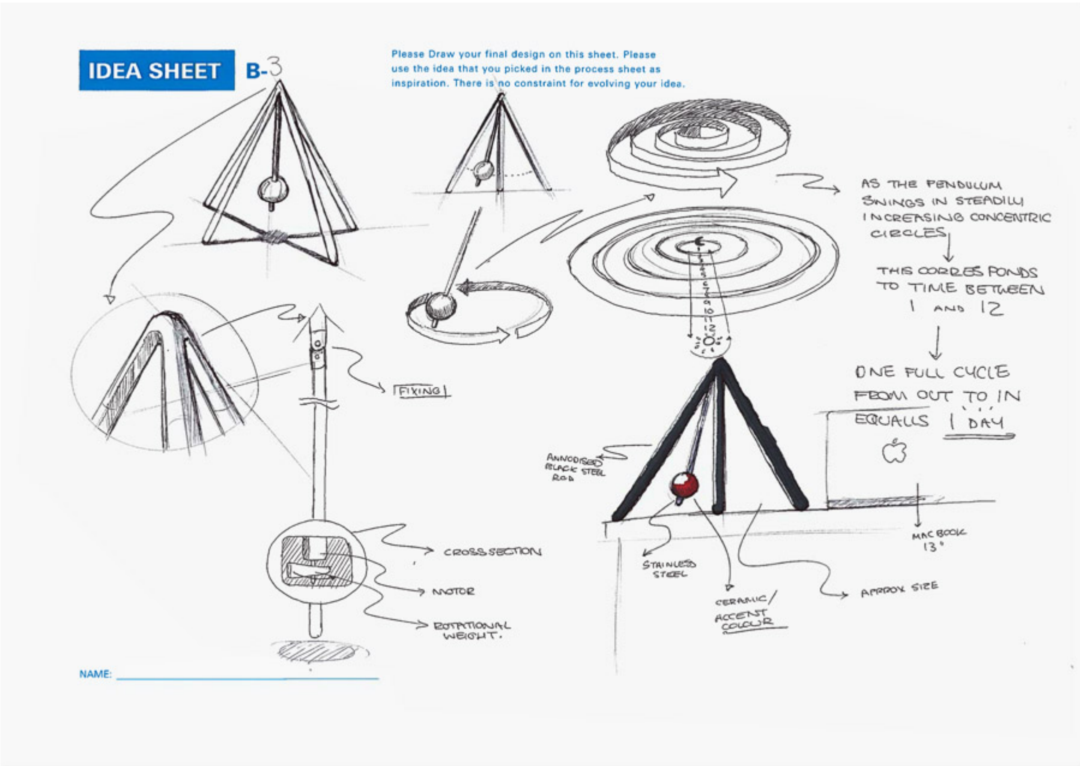



*Figure 161. B3's final design depicted on the Idea Sheet.*

#### 4.7.3.2.6 The Participant B3: Summary

This participant frequently returned back to the original prompt at the early phase (Figure 162). B3 observed the original prompt by sketching out the prominent elements on the *Process Sheet*, and used them as a clue for developing the thinking avenues. B3 understood the form and the function of each component through breaking down the original prompt into its constituent part (B1, Interview, 00:05:50). Further, each of these characteristics identified through the observation was simplified separately, and the keyword(s), key concepts or key questions were found within the process. These key factors were subsequently interpreted, organised and integrated in order for generating ideas towards the final outcome. For B3, the process of reduction essentially means considering what the pure essence of the original prompt is, through breaking the object into its constituent parts (B3, Interview, 00:22:00). Although B3 progressed this understanding process by observing the original prompt at the beginning, as the process became more matured, the thinking avenues were developed based on the insights discovered.

Even though understanding of the original prompt was the key factor for B3's process, B3 did not particularly observe the ornament details of the clock. B3 focused on several elements of the original prompt yet what B3 actually extracted was mostly about the generic concept of the components such as a clock face, a clock handles, legs, a figurine and a pendulum.

In fact, most of the simplified components that were depicted on the *Process Sheet* did not replicate the original figures. B3 described that B3's focuses were rather on how the object is constructed and how it interacts with the viewer:

> *"(…) those of the elements (ornamentations) were immediately discarded and I didn't really use and then focused on real… kind of what is functional elements of this piece (the original prompt) so what made it stand up, what made it work, how it interacts with… what is the means of the interaction with this so narrowed it down to the clock face and the hands and the legs. I just went from that" (B3, Interview, 00:13:15).*

Accordingly, this appeared to suggest that B3 was mainly extracting the conceptual elements of the original prompt through understanding the constituent parts of the clock, and these insights identified were interpreted and integrated in order to generate ideas.

Another feature of this participant was that the key element of the final outcome was derived from B3's misinterpretation of the original prompt. One of the key elements of B3's outcome was the pendulum, and this idea was derived from the discovery of the pendulum component underneath the clock face of the original component. In the original clock, however, the figure of this part was originally meant to be an ornament and it was not a pendulum. B3 literally interpreted this part as a pendulum and applied it for the final outcome as the key element.

In conclusion, B3's reductive process was understanding the essence of the original prompt by focusing on its constituent parts and also conceptually extracting key elements within it. The thinking avenues and the ideas were developed by interpreting and integrating these elements identified.

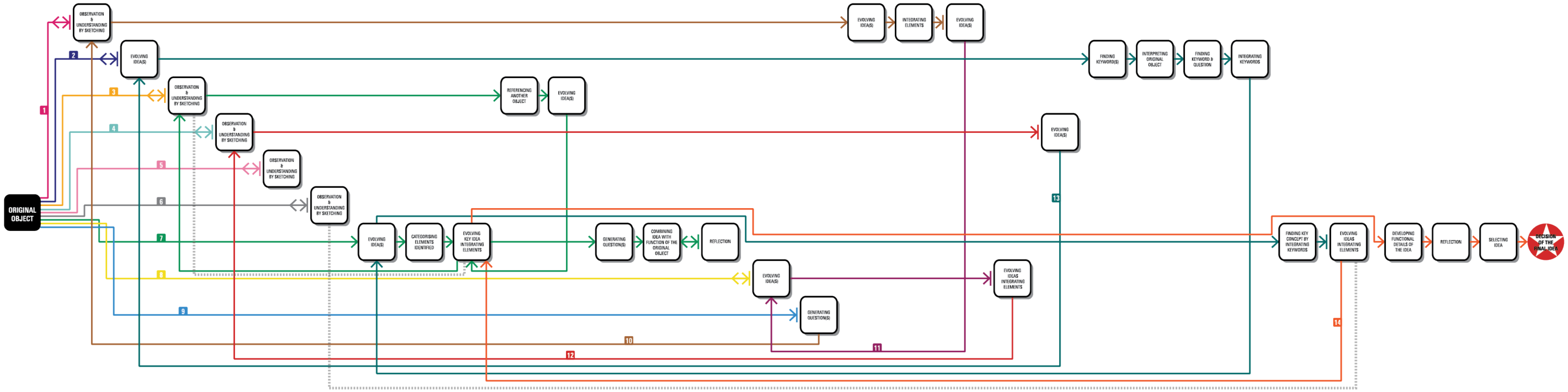



*Figure 162. The diagram that represents B3's reductive process.*

#### 4.7.3.2.7 The Participant B4

The participant B4 designed a sundial whose shape of the gnomon refers to the silhouette of the original prompt (Figure 163). The gnomon is set on the slanted surface of the base (the dial) and it visually shows the time of day through the shadow in accordance with the apparent position of the sun. The gnomon has a void in its centre part and the abstracted top figurine is used as a time indicator. This object was designed based on the question of "how to reduce its function as much as possible but it still represents the form". The centre part of the gnomon, where was originally the space for the clock mechanism in the original clock, was completely removed. Instead, the entire shape of the clock acts as the main function of time indication. This object playfully suggests thinking of the notions between function and form for the viewer. This sundial was designed to be placed outside where direct sunlight is available, e.g. in public spaces or individual gardens, as an ornamental object. The gnomon and the base were casted in concrete. The size of the gnomon is more or less the same volume as the original clock.

As the first step, B4 articulated that B4 intends to identify what the object means to B4 (B4, 00:00:30). Within this process, B4 sought the key themes regarding the original prompt that can assist B4 to explore thinking avenues and discovered the two concepts "clock as function" and "ornament as form". At this point, B4 tried to understand what the original object represents:

> *"So studying into the two themes to start with. I think about the function of the object and the aesthetic qualities of it. (...) there is a reason that is to communicate the time but obviously there's been a lot of caring attentions. It's got into making it beautiful… detailed… (...) It looks like there is a figurine on the top, these (the legs) are the pastiches. They are taken from other styles" (B4, 00:00:50)*

After finding these key themes, B4 immediately evolved a conceptual idea based on the keyword of "ornament". In this idea, B4 depicted the image of the square shape that has the void whose outline represents the original clock, as if the figure of the object and its background were inverted. This object, however, still keeps the function as a clock by installing a clock mechanism in the hollow. B4 described that, when B4 think of the aesthetic aspect of the original prompt, what came to B4's mind was about its silhouette, and B4 used this notion as a clue for reduction (B4, 00:04:20). Based on this concept, B4 further imagined the idea where the outline of the object is extruded as a flat surface. Following this, B4 also conceived the idea of a clock whose surface is flattened (Figure 164). At this point, B4 asserted that it is unable to progress the process any further (B4, 00:08:17).

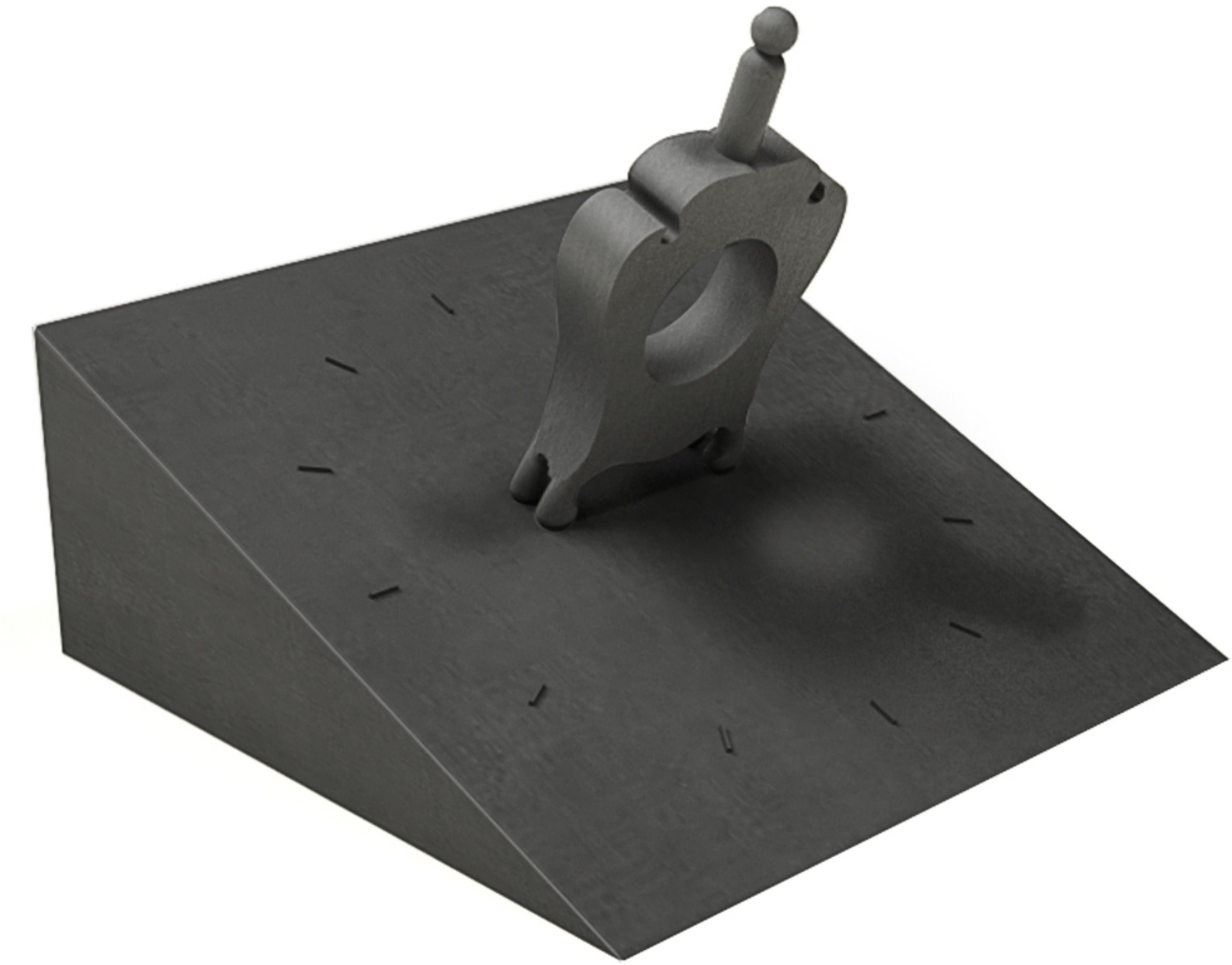


*Figure 163. The reproduced image of the outcome of the participant B4.*

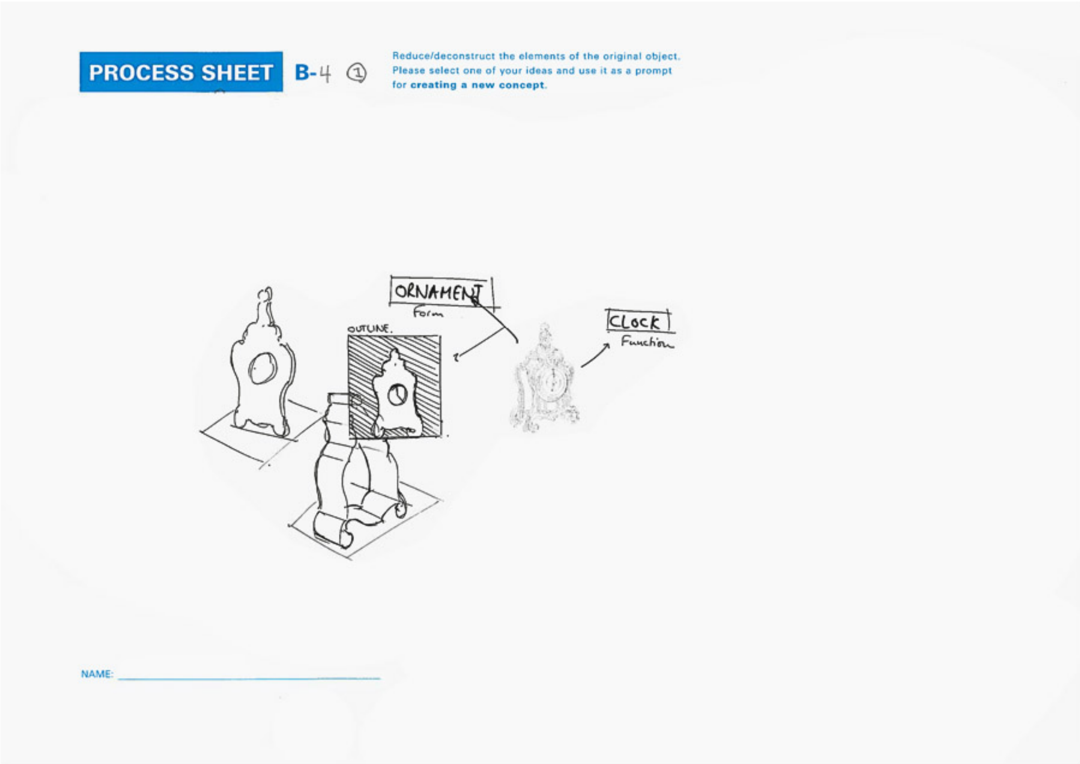



*Figure 164. B4's Process Sheet 1 at 00:08:17.*

At the end of this thinking process, B4 also envisaged the ultimate consequence of the current thinking avenue and presumed it will be something immaterial. This assumption encouraged B4 to recall the contents of an exhibition of the British fashion designer Alexander McQueen that B4 currently saw in London and B4 gained an inspiration for B4's idea exploration:

> *"I think about the absolute nothing. What this could be is absolute nothing. It'll just be 'air' I guess so maybe a hologram (...). There was the Alexander McQueen exhibition in London recently. (...) Essentially, you make a glass pyramid. You have a screen underneath and with an image on the screen. (...) the TV was reflected on the glass that gives you the illusion of the 3D image so it moved around the perspectives. And it just a video footage of a famous model wearing one of his dresses he designed. When I think about 'reductionism', it's going from physical object to photos. It's just light. It's kind of nothing. That's the far end of 'reductionism'" (B4, 00:08:45).*

B4 applied this experience to the idea and developed the object in which the 3D hologram image of the clock is projected inside of the glass pyramid structure. B4 further described that B4 was considering how the object can be represented without the actual substances by means of technology (B4, 00:13:03). This notion of "the object represented without substances" encouraged B4 to conceive another idea where the flat images of each side of the clock are printed on the surfaces of a cuboid. Following this, B4 considered that the current idea is relevant to the first idea where the object is represented by the outline of the surface around the void, and connected these drawings with the arrows. B4 then developed another object integrating these ideas. This idea was that the solid cuboid was cut from three directions (the top, the front and the side) with the shape of the original clock's silhouette (Figure 165). B4 also concerned that the current idea has no functionality within the ideation process so that B4 added a clock function in the hollow being hung from the top. Remarkably, B4 asserted that a different type of object cannot be conceived through the approach of reduction: *"Fundamentally, from reducing I can't just produce something different (from a clock). It still needs to be an object to communicate time (...)" (B4, 00:17:54).* This appears to suggest that even if the elements of the object are reduced, keeping its fundamental functionality of the original prompt was important for B4.

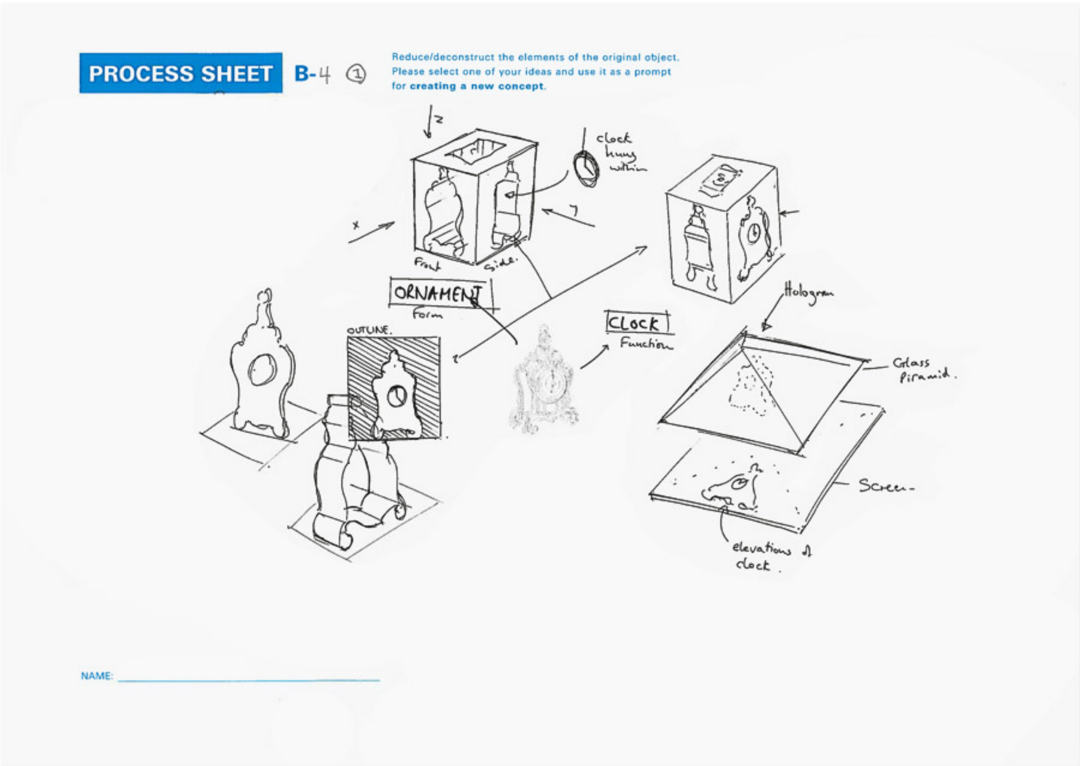



*Figure 165. B4's Process Sheet 1 at 00:18:56.*

At this point, B4 stared at the original prompt and assumed the material of the original prompt based on its appearance. Further, B4 used this assumption as a clue for reduction:

> *"What material is this? This looks like made of wood material-wise because it looks old, because it looks… kind of seventeen century something like that. It could be a lot newer than that. The fact is that it's got a figurine on the top. That is suggesting something classical. If I imagine it is made of wood, then I think about maybe reducing that wood so if I take wood veneer…" (B4, 00:19:44).*

B4 then returned back to the previous idea, where the different faces of the original clock were printed on each surface of the cuboid, and developed an idea. In this idea, the ultimately reduced veneer sheet that is thin enough for light to penetrate functions as a screen, and the image of the original object is projected from the projector behind the screen. This idea was conceived in relation to the assumption of the material of the original prompt. B4 also stated that it was important for B4 to apply the same type of material used in the original prompt to this idea (B4, 00:20:58). Apart from concerning with the materiality, B4's intention of this idea was to reduce the physicality of the original object down to two-dimensional representation.

At this point, B4 started explaining B4's attitude towards ideation within the reductive process. B4 was recalling the class B4 took before and stated that B4 consciously avoid conceiving easy and obvious solutions during the ideation process:

> *"I guess in the back of my mind, I have this idea that as I am (…) the last person designing this (idea). I would be thinking along the avenues that are my own and trying to avoid going down the routes that others might have done so subconsciously I stop obvious things" (B4, 00:23:50).*

B4 then illustrated an example of this "obvious idea" with a sketch on the *Process Sheet* (Figure 166). For B4, the "obvious idea" can be something very basic: *"For me, it's kind of a clock. The only bits you need is hands so for example, it's literally just like… no structure… just starting the idea of floating hands so this is kind of like basics (…) just absolute basic (…) I don't need anything else. Tell time with the hands" (B4, 00:25:24)*. B4 further described that B4 is not satisfied with this obvious idea whose elements were extremely reduced as there are not enough references between such an object and the original prompt (B4, 00:26:49). B4 also stressed the difference between the approaches of "reducing" and "removing": *"(…) I guess if I'm reducing… I'm not removing so these are two different things. So, if I'm reducing, (…) you should know where it's coming from" (B4, 00:27:14)*. For B4, the reductive process does not mean merely taking the parts of the original prompt away but rather reducing the elements in relation to the relevance to the original object.

At this point, B4 returned back to the previous idea where the image of the clock is projected on the veneer screen. B4 then continued to reduce the extra space around the projected image of the clock in the veneer screen. Further, the only clock part is projected from the projector. B4 then asserted that it is unable to progress this thinking avenue any further (B4, 00:30:40).

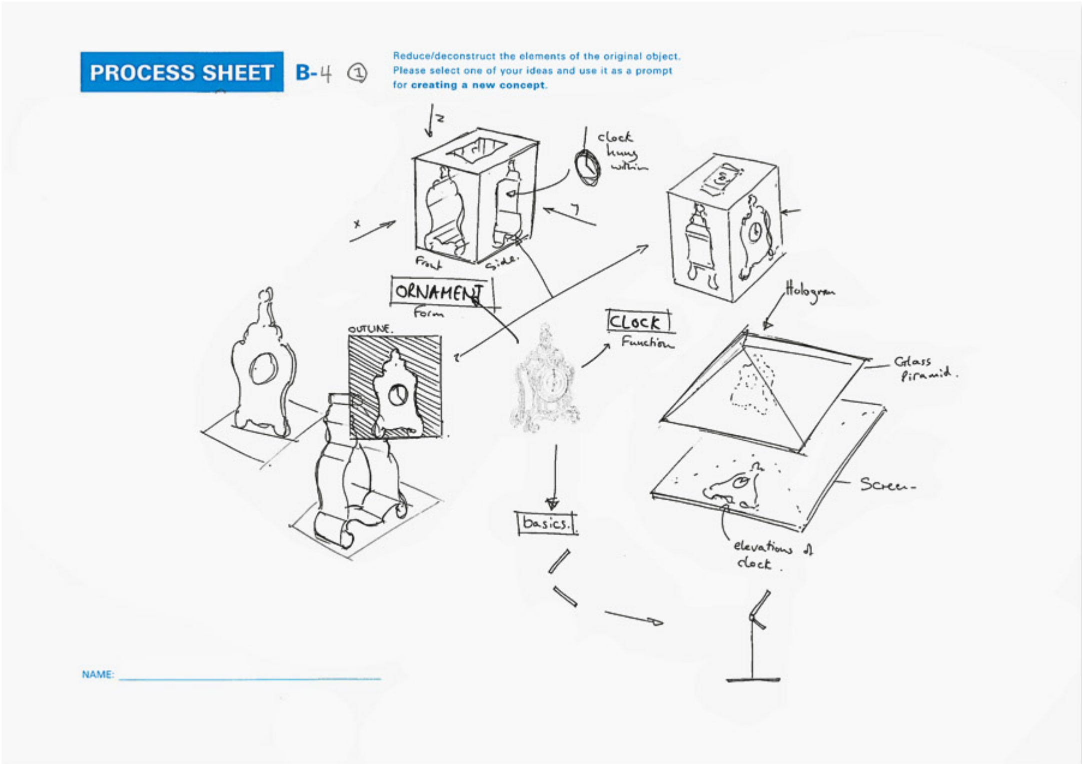



*Figure 166. B4's Process Sheet 1 at 00:26:52.*

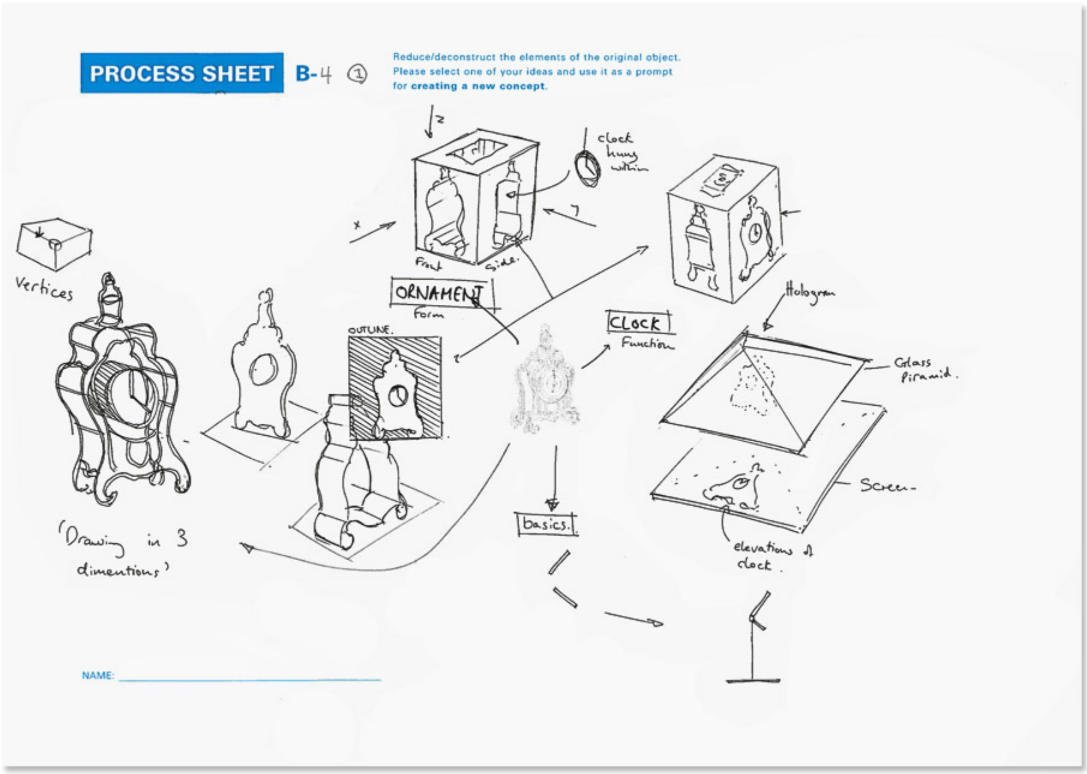
B4 returned to the original prompt and saw the dotted image of the clock as a three-dimensional structure and developed the idea of a timepiece made with wires (B4, 00:32:06). In this idea, the dots were connected as a physical line of metal wire (Figure 167). Within the ideation process of this idea, B4 recalled what B4 was taught by B4's teacher in a sculpture class at the previous school:

> *"I used to do sculpture and I was doing a project where I constructed a shape out of wooden sticks. My teacher used the phrase saying 'drawing in 3D'. (…) that phrase, 'drawing in 3D' I think it could be a good thing to think about. (…) The project I was doing was… I was trying to represent… I can't remember how I got to it… it was self-initiated so I decided to describe what I was doing. It was an object made out of lots of glued dowels, thin wooden dowels and I was making a figure but from all angles, it looks like a mess but from one angle, it had the outline and he (teacher) said 'you are drawing in*

*3D'. For this (B4's current idea), it's nothing how my sculpture looked but the phrase 'drawing in three-dimensions' if it was a wire frame, it represents all of the dotted lines" (B4, 00:32:26).*

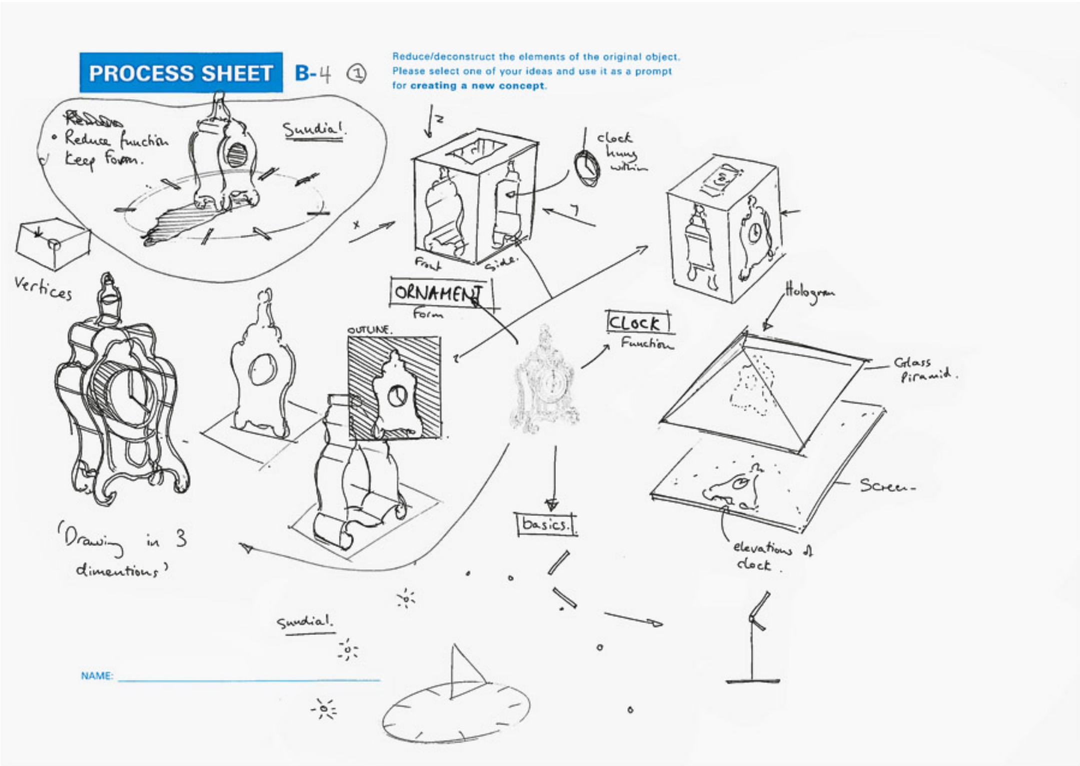
B4 specifically featured the phrase "drawing in three-dimensions" in B4's memory and applied it to the ideation.

***Figure 167. B4's Process Sheet 1 at 00:42:02.***




At this point, B4 returned back to the initial key themes "ornament as form" and "clock as function" that was found at the beginning of the process and described what B4 learned through the processes so far. In it, B4 asserted that the object does not necessarily have a form as long as it keeps the function of telling time (B4, 00:42:55). Therefore, for B4, the form is the main target for reduction. In the meantime, B4 also realised that the ornamentation plays an important role in the design of the original clock. Based on this awareness, B4 conceived a design concept, reversing what B4 just had described: *"I think my instinct says that the form isn't necessary so that is what can be reduced because the function is more important. But if I flip that instead… what if the form is more important?" (B4, 00:44:56).* In this concept, the function of the object, that was regarded as the necessary element, was removed but the form, that was the target for reduction, was kept. Based on this concept, B4 developed the idea of an object where the form of the original prompt is kept but the part of clock mechanism is removed. This perspective allowed B4 to come up with the idea of a sundial that will become the key idea for the final outcome: *"What about if the clock is replaced with the sundial which* *is the most basic form of telling time? (…) I think that's the most basic form of a clock, the most ancient, the most far reduced down (…)" (B4, 00:43:46)*. B4 continued developing ideation based on this concept and the refined idea was developed (Figure 168).

*Figure 168. B4's Process Sheet 1 at 00:47:57.*




In this idea, the gnomon of the sundial is replaced with the simplified original clock and the part of clock-face was completely removed. Additionally, the sharp form of the figurine plays the role of time indicator (B4, 00:46:50). The key concept of "remove function keep form" was written next to the drawing on the *Process Sheet*. At this point, B4 reflected all the processes that have been done so far and then decided to move on to exploring new ideas (B4, 00:50:59). Here B4 moved to the second *Process Sheet*.

B4 initiated the new thinking avenue on the second *Process Sheet* by imagining how the original prompt is manufactured in relation to the particular period in the history:

> *"Originally, I was thinking this was made from one carved… looks like it's been carved from one piece of wood: the front face. But, if I was wrong actually it's lots of different pieces of wood and nuts in its construction. Maybe it's forged or cast… cast metal. It seems likely, could be a Victorian clock. It could be like a piece of forged… die cast" (B4, 00:51:37).*

Following this interest in manufacturing, B4 dismantled all the possible components of the original prompt and depicted them on the *Process Sheet*. The purpose of this was to understand how the object is composed (B4, 00:53:31). The lack of visual information appeared to encourage B4 to associate with different materials:

> *"(…) it's difficult to tell from the drawing (the original prompt). It's dots so I don't know what the material is. My first guess was wood like how a violin is made or guitar or something because there are the frond and the back, and there are some bends on the side. But, then maybe if it was different, if it was lots of different pieces of metal or mixture of different materials" (B4, 00:54:23).*

Within this dismantling process, B4 considered those dismantled pieces as a set of a complete object that still functions as a clock. The dismantled components are placed on the two turning disks. Some of the components indicate the time, playing the role of clock hands (Figure 169). After depicting this idea, B4 discontinued this thinking avenue.

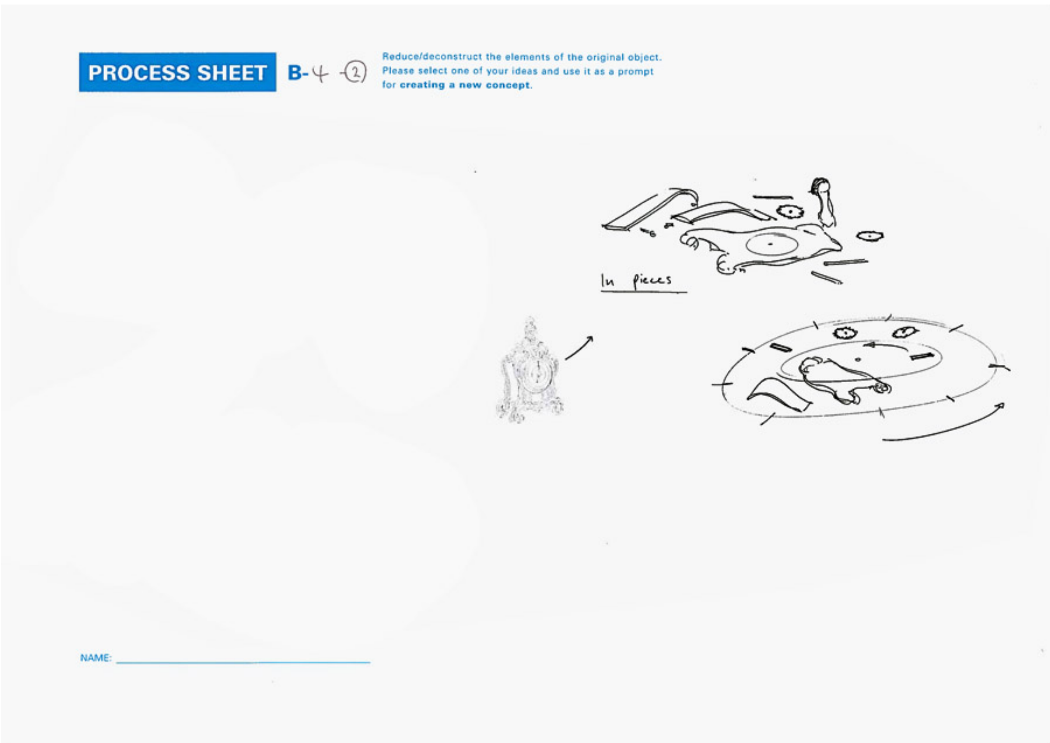



***Figure 169. B4's Process Sheet 2 at 00:57:59.***

B4 returned back to the original prompt, and developed another idea focused on the way to interact with the object, following the key question identified: "what if it is a miniature instead?". B4 asserted that the focus was on reducing the size of the object (B4, 00:58:46). In this idea, the user sees the miniature-sized clock in the same size as the original prompt through a magnifying glass. After depicting this idea on the *Process Sheet*, B4 reflected the processes that had been developed so far. B4 stated that B4 was considering which idea should be further developed at this phase (B4, 01:05:40). B4 then decided to continue the current thinking avenue where B4 developed the idea of the clock seen through a magnifying glass. B4 particularly liked the playful aspect of this idea, and imagined if these two separate objects (the miniature clock and the magnifying glass) are integrated into one device (B4, 01:07:30). B4 then developed the idea of the goggles for perceiving the clock in virtual reality, returning back to the previous idea where a 3D hologram was projected within the glass pyramid structure depicted on the first *Process Sheet*. B4 also described the relevance between the current idea and the previous 3D hologram idea:

> *"Actually, (...) I had an idea how I can reduce and reduce and reduce… this idea (the 3D hologram) was having a digital representation of the object… for me it's kind of like cheating but it's also the pure reductionism. There is no longer be an object but I can believe there is it" (B4, 01:08:16).*

B4 then returned back to the second *Process Sheet* and continued developing another idea based on the same concept. B4 developed a device where the user perceives the miniature clock placed in the box, seeing through the loophole (Figure 170). At this point, B4 decided to select the idea of sundial for the final outcome. The completed two *Idea Sheet*s were shown here (Figure 171).

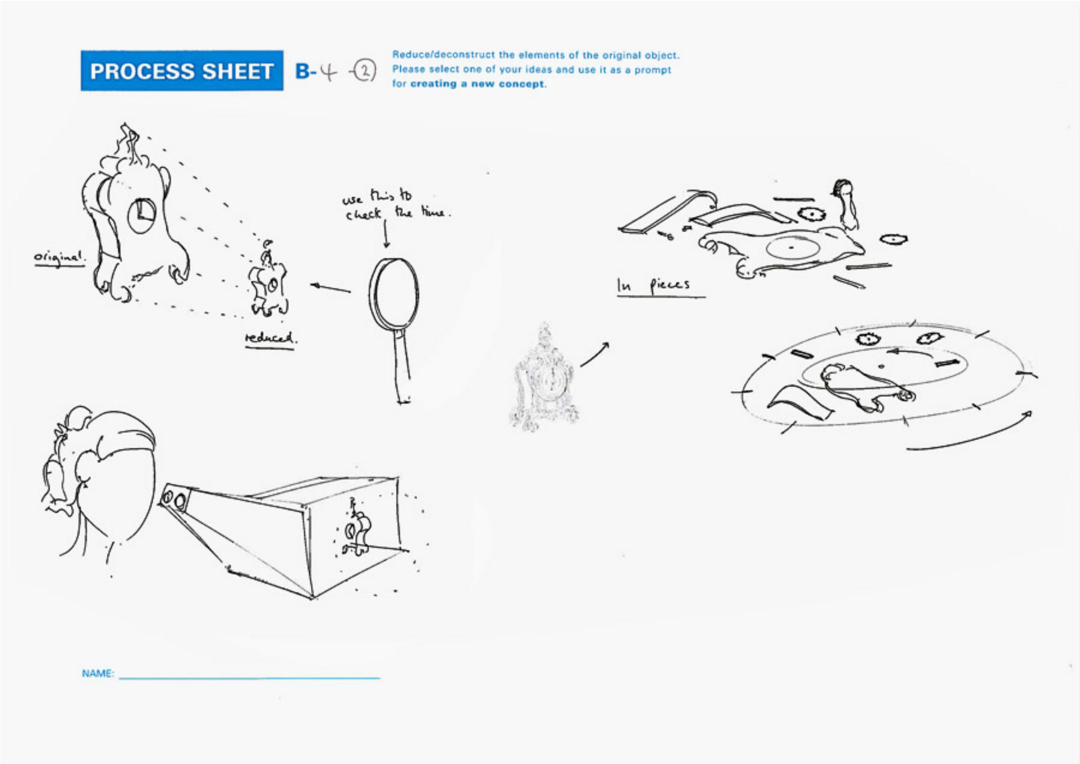
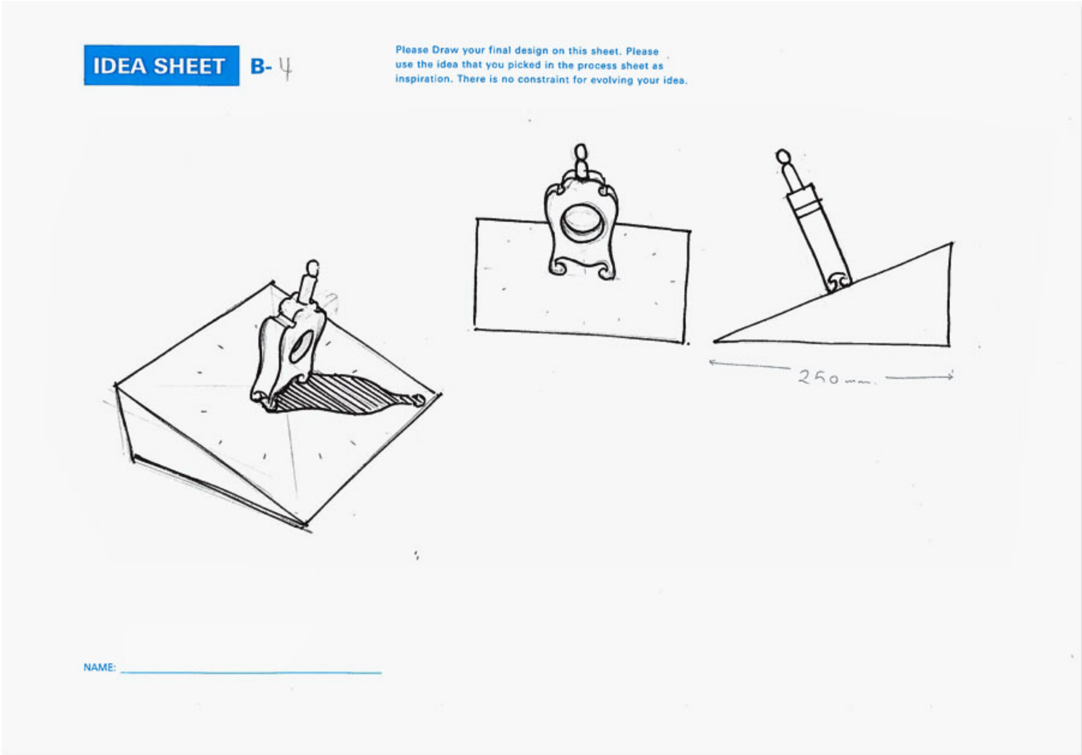



*Figure 170. The B4's Process Sheet 2 at 01:13:02.*



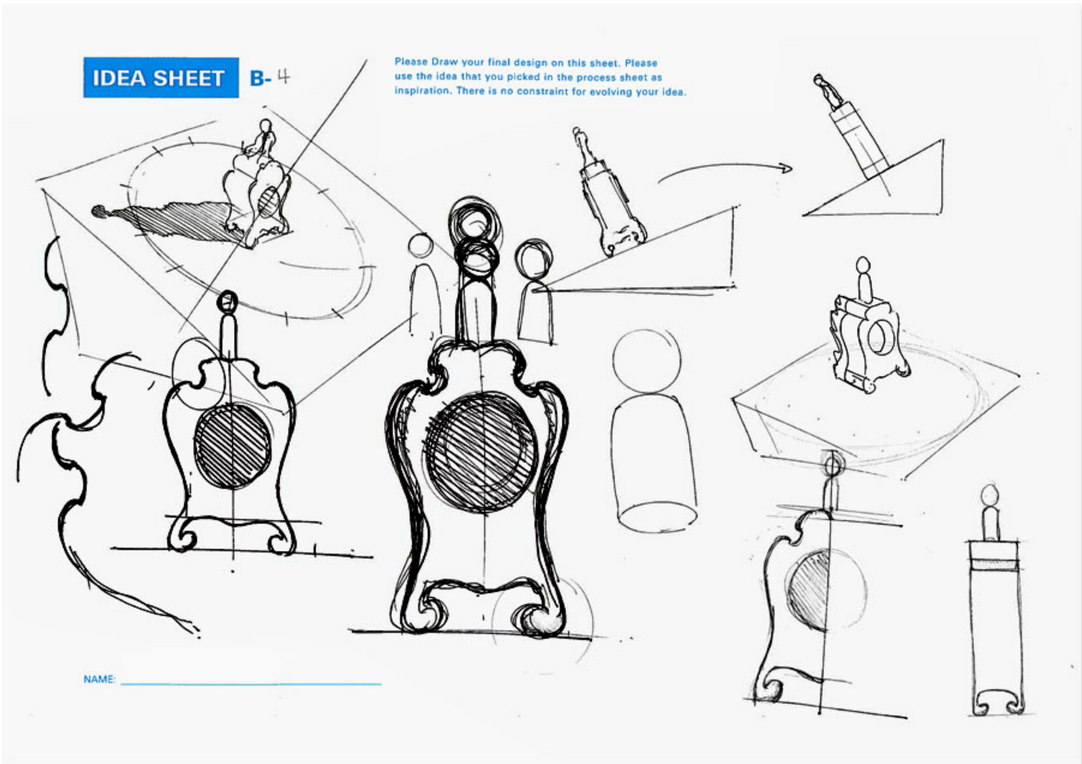




*Figure 171. B4's final design depicted on the Idea Sheet 1 (above) and 2 (below).*

#### 4.7.3.2.8 The Participant B4: Summary

This participant developed the thinking avenues, staying long in one thinking avenue, and deepened the thoughts (Figure 172). Although B4 returned back to the original prompt five times, the core thinking avenue was always the one that was developed in the first instance. Even though several thinking avenues were developed along with the progress of reduction, B4 had a tendency to return back to either ideas or key themes that were explored in the first thinking avenue. Additionally, the final outcome was also relevant to this thinking avenue. Accordingly, the first thinking avenue appeared to play an important role in B4's reductive process.

B4's process was initially started with identifying the key-themes. The thinking avenues and ideas were then developed based on these themes, finding keywords, key concepts/phrases/questions, recalling memories, integrating ideas and so on. The approach was conceptual driven and the ideas were often conceived based on the keywords, the concepts or the phrases. B4 described that the abstract nature of the original prompt naturally encouraged B4 to consider the conceptual aspects of the object:

> *"Something about the image, because it's slightly abstracted because it's not very true representation… you know, this is not a picture. This is the collection of dots. It made me think of more about the conceptual nature of what that is and maybe everything from there begun the idea led, not aesthetic or... you know it wasn't an iterative sketch process. It was like… I know an idea which led to a drawing, which led to another idea of a set of drawings. The fact is that I even couldn't tell what this ornament was clearly made me imagine more and think more about ideas and concepts (…)" (B4, Interview, 00:18:21).*

At the later stage, however, B4 also observed physical details of the original prompt and assumed its possible manufacturing process, materiality, structure and the period of time when the object is produced.

For B4, the act of reduction does not mean just removing the elements but rather exploring ideas that represent the original prompt in a refined manner:

> *"What I think I have learnt that… I think reduction requires some sort of representation… it requires the start point and, therefore, the end should represent what the start point was. I think it's about simplifying, about*

*removing things unnecessary, about challenging what's necessary, what is needed" (B4, Interview, 00:16:37).*

B4's reductive process essentially demanded B4 to conceptually interpret and understand what the original prompt represents, generating questions about the object. This process, where the original prompt was broken down into the elements, also provided multiple perspectives on perceiving the object in a variety of ways:

*"I definitely had to challenge why the object exists, so why… more its purposes which are really important. (…) the reductive process I think… I guess it keeps challenging why you are justifying the certain parts of it like "why is that there? why is that there? why is that there?… can I take this away? can I take this away?". (…) I think it's breaking down kind of different layers of view of the object" (B4, Interview, 00:25:52).*

In conclusion, the reductive process encouraged B4 to consider the conceptual aspects of the original prompt, through the questions being generated. Additionally, the in-depth understanding of the original prompt allowed B4 to explore ideas, keeping the essence of the original object.

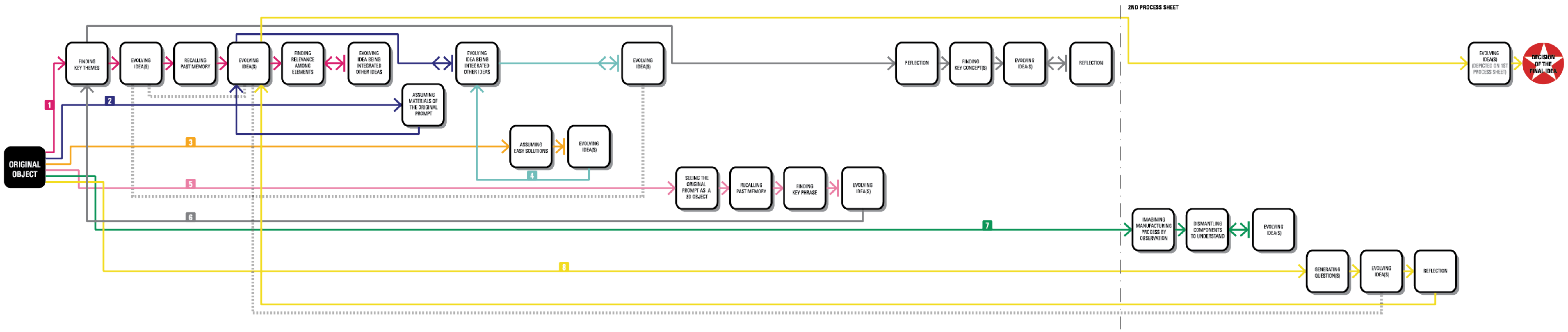



*Figure 172. The diagram that represents B4's reductive process.*

## 4.7.4 Findings

This section describes the findings identified in the results of both groups revealed through the analysis. The reductionist process developed by all the participants was very complicated. Their reductionist processes were not developed through linear and straightforward thinking but rather through the consideration of different facets of the original artefact, or by recalling their personal memories. These fragments of thought were then integrated into the design process and reflected on the final product outcomes. Therefore, it was very challenging for the researcher to summarise the participants' behaviours as they occurred during the reductionist process. However, strong patterns emerged through the analysis methods used for both groups. In this section, the characteristics of the participants' reasoning process identified through protocol analysis are shown. This section describes the findings of Group A (high-fidelity group) followed by the ones of Group B (low-fidelity group).

### 4.7.4.1 Reductive Process of Group A (high-fidelity prompt)

In the process of reduction/ideation, the participants of Group A had a tendency to observe the original object through a minute investigation. The rich visual information appeared to encourage them to focus on the detail attributes of the original prompt in order to find clues for further process. The subsequent reduction and ideation were conducted based on the information obtained through the investigation of the original prompt.

#### 4.7.4.1.1 Overall Characteristics

The approach of Group A can be divided into three phases: understanding of the original object, idea generation, and making decision for final idea (Figure 173). Most of the participants of this group started the process by closely observing the original object, through looking or sketching, in order to understand the characteristics of its physical property. The participants then carried out their reductive process focusing on the specific aspects of the object. Within the observation process, the following aspects were particularly focused: form, structure, specific components, design intention, functionality, surface texture, ornamental details, the impression they received, section view, problems the object involves and so on. The participants of the high-fidelity group appeared to critically scrutinise the attributes of the original prompt by looking at the object from multiple angles.

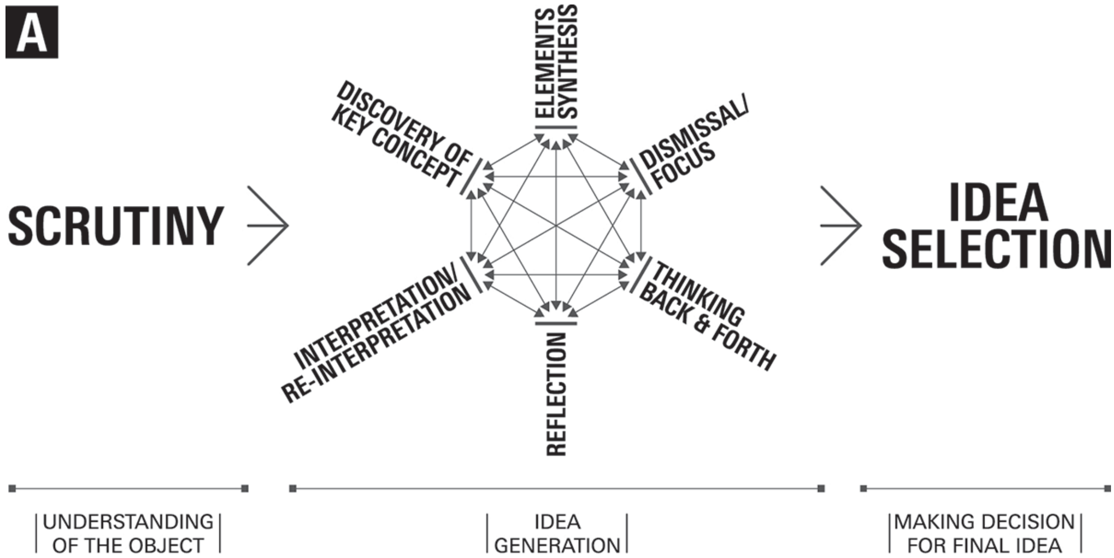



*Figure 173. The approach of Group A.*

Within the idea generation phase, the six behaviours were identified. The participants carried out the reductive/ideation process through these actions:

- *Discovery of key concept*
- *Dismissal/focus*
- *Interpretation/re-interpretation*
- *Thinking back and forth*
- *Elements synthesis*
- *Reflection*

These behaviours were constantly seen throughout the process amongst the participants of Group A. The process of reduction was conducted through these actions and the ideas were explored within the idea generation phase. The detailed descriptions of these behaviours are described below illustrating relevant examples.

The first behaviour is “discovery of key concept”. Within the reductive/ideation process, the participants often discovered key concepts, sentences, or words and used them as clue for further exploration. The participant A1, for example, identified three key concepts halfway through the process: “technical”, “ornamental” and “cultural” (A1, 00:31:24). These key concepts played significant role for A1’s ideation process and they eventually became the core concept for the final design proposal. The participant A3 discovered the key word of “modular” within the iterative process of idea generation (A3, 00:18:52) and that subsequently supported A3 to conceive the idea of a speaker unit. Or, the participant A4 found the key concept, “revealing object through reduction” (A4, 00:33:35), and this notion led to deduce the idea of “controlling user’s attention” that became the core concept for the final design proposal. The act of discovering key concepts was often seen in the reductive process and ideas were generated based on them.

The second behaviour is “dismissal/focus”. The participants had a tendency to prioritise certain information derived from observing the original prompt while they were engaging in reductive process. The information that the participant regarded as important were kept, whereas other elements were dismissed as unimportant. This selection and concentration of information appeared to support the participants in finding what information should be focused as a clue for further exploration. For example, the participant A1 stated that it is hard to engage in the reductive process unless A1 focused on one aspect since the original prompt includes so many factors (A1, 00:55:32). It appeared that A1 was overwhelmed by the richness of information where the high-fidelity prompt represents. This experience naturally encouraged A1 to concentrate on particular aspects of the original object for reduction. A1 also stressed that putting information discovered in a hierarchical order is important in understanding which elements should be focused or disregarded:

> *“I guess the hierarchy to me is the key to reduction. Highlighting the most important things and (...) removing unnecessary information or placing it in the form where you can really understand what is more significant (A1 00:25:46).”*

The participant A2 identified the more essential elements that consist of the object as a clock. This action seemed to be helpful for A2 to clarify what information needs to be kept as an essential element: *“I’m just trying to think what feels the most interesting… you know, what to keep and what to take away. (...) this figurine, to me, sort of just an addition. Not essential. I’m trying quickly getting rid of things (A2, 00:35:25).”* Or, the participant A4 disregarded all the ornamental elements and concentrated on the form of the profile of the original prompt: *“(...) and then, now I’m thinking again looking at the profile and just maybe avoiding the details but keeping the same form (...) (A4, 00:05:35).”* The participants focused on the aspects of the original prompt in a variety of ways. Prioritising information, however, appeared to be the important strategy for developing thinking avenues when the participants engage in reductive/ideation process.

The third behaviour is "interpretation/reinterpretation". The acts of interpretation and re-interpretation were also constant throughout the reductive/ideation process. The participants interpreted the attributes of the original prompt (such as forms, details of ornaments, structures, historic/cultural backgrounds, symbolic meanings of the specific components, materiality, texture, possible design intensions and so on) into their own understandings. The deduced interpretations or conceived ideas were then also re-interpreted in order for further understanding or idea explorations. For example, A1 interpreted the structure of the object through observation and reinterpreted it into a simpler form:

> *"I'm looking at this edge door house (the side structure of the object). I guess you have a solid mass and solid form then you have a cavity and it feels like this is almost continuous surface (...) you just have one surface or three surfaces but linked. And then, because it seems to be a void or emptiness there (inside of the object), it's kind of an immateriality to this (side) face and contrasting with the rest. And then if you rework it or reinterpreted it, it would be a single sheet of material which is just folded around (A1, 00:07:45)."*

Or, A1 also described that A1 reinterpreted the particular forms of the original prompt, based on the key concepts that A1 discovered (A1, 00:59:04). This process allowed A1 to understand which parts of the original prompt can accommodate with these key concepts. The participant A2 interpreted that the proportion of form of the original prompt implies a strong impression and subtle changes do not even affect it: *"This... such a big (...) broad shoulder (...). it's quite masculine shape so if you take little curves it doesn't reduce masculinity. It's just a very strong block piece (A2 00:02:31)."* A3 associated with different type of object through reinterpreting the idea of form A3 had conceived before: *"I drew a simple rectangular like and a circle as a clock face as my first starting point. This shape makes me feel like... because it's sort of rectangular it feels like start taking the form more of like a washing machine because of the no sense of scale (A3, 00:02:07)."* Interpreting and re-interpreting concepts one after the other were an essential factor within reductive/ideation process.

The fourth behaviour is "thinking back and forth". None of the participants developed their thinking process in a single linear avenue from the start to finish. Their reductive approaches were neither simple nor straightforward. Instead, they developed multiple thinking avenues and moved back and forth crossing over the pathways. The participant had a tendency to cease continuing the development of the current thinking avenue and to quickly move back to the original image or to other avenues or when they felt satisfied with the exploration or were simply bored. They also returned back to the previous thinking avenues where were previously developed and paused and continued further exploration from there. The participant A3, for example, appeared to figure out whether or not A3's current exploration is on the right track by moving back to the previous thinking avenue: *"I'm thinking of going to revisit the washing machine. (...) I got bored of the speaker. I did satisfy my needs. (...) I'm jumping from one to the other, but it feels right about what I am doing (A3, 00:15:36)."* The participant A4 returned back to one of the previous thinking avenues where A4 paused and continued to explore another idea with the opposite approach:

> *"So, originally this one was focusing on the form and tying to avoid all of the detailing and the surface texture. And now I'm reversing that. I'm thinking about maybe reducing the form but keeping the surface texture quite ornate, quite elaborate (A4, 00:23:25)."*

The results appeared to suggest that returning back to the thinking avenues that were already developed was very common. Revisit of existing thinking avenues allowed the participants to resume their thoughts, reconsider the ideas from different angle or making connections among multiple avenues within the reductive process.

The fifth behaviour is "element synthesis". All sorts of ideas generated within the reductive process were frequently integrated. The participants often developed ideas by combining different concepts or visual elements they discovered. For example, the participant A1 stressed that the act of reduction is not just eliminating unimportant parts, but rather reintegrating the essential elements that A1 had discovered within the process:

> *"(...) it's kind of picking up distinct parts (of the original object) to me. They might be graphic (graphical elements on the clock face) I guess, but it's how do you translate those graphic elements to something more integrated into it. I guess it's reduction of superfluous parts, but not just removing things. I'm trying to reintegrate them (A1, 00:59:04)."*

The participant A2 also attempted to combine a couple of similar elements produced in the sketch into a single idea (A2, 00:26:52). Or, A2 also reassembled multiple elements that A2 had discovered already into another object (A2, 00:43:11). A3 discovered the concept of "modular speaker" by combining both the key concept "modular" derived from the idea of "modular kitchen" and the idea of speaker that A3 had previously conceived (A3, 00:18:57). The participants selected and integrated some key elements, within the thinking avenues that had already been developed, and discovered new ideas or concepts.

The sixth behaviour is "reflection". The participants reflected their thinking avenues developed halfway through the process or at the very late stage of the idea exploration. The processes were looked back and reconfirmed what aspects had been considered so far or identified which ideas possibly be the key for further exploration. For example, the participant A2 reflected the approach, where A2 started with at the early stage of the process, when A2 lost track: *"I'm just looking at what I've started with. I've gotten lost in this area and I'm just looking back what this (the original prompt) is (A2, 00:44:04)."* Similarly, the act of reflection enabled A3 to move forward to the process:

> *"I started looking over what I have done. It's a big mess of stuff, where I just did a washing machine or radiator. There are so many products here, but I think I like the speaker route (A3 00:37:04)."*

The participant A4 reflected the sequence of the development of thinking avenues by numbering (A4, 00:27:45) (Figure 174).

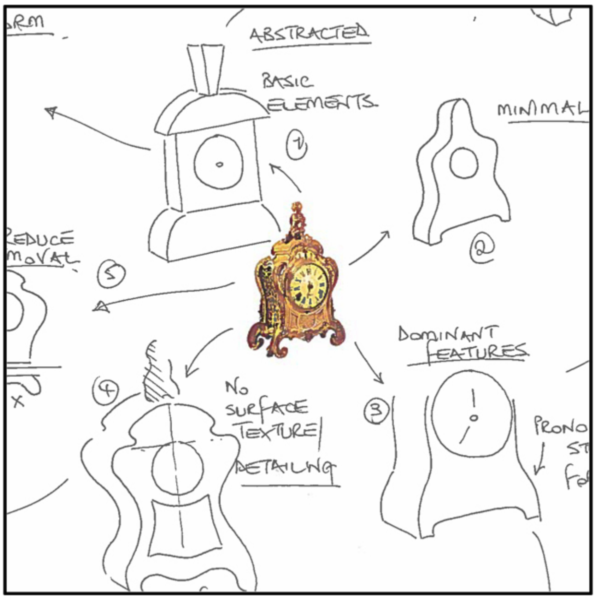



***Figure 174. The numbering by the participant A4.***

The act of reflection appeared to provide the opportunity to clarify and arrange their development of thinking avenues. Additionally, the style in which the participants were required to signify the traces of the development process using arrows seemed to help the participants to quickly grasp the paths of their idea explorations.

These were the prominent patterns that were commonly seen within the reductive/ideation processes of the participants of the high-fidelity group (A).

#### 4.7.4.1.2 Characteristics in Detail

Another display style was developed based on the mapping aforementioned. The contents of the mapping previously shown were further categorised and the actions that share similar characteristics were grouped and represented with multiple colours. This mapping enabled the researcher to visually understand what types of actions occurred at which particular phase of the process.

The actions were coded and categorised into nine themes, and they were represented with different colours. The actions represented with the coloured squares are arranged in chronological order from left to right. The positions of the actions were placed in accordance with the time when the event happened. Accordingly, each mapping visually describes what type of action was occurred and when it happened within the process. The lines with arrowhead show how the participants' thinking process exactly developed and moved among several thinking avenues.

The identified actions were categorised into the following nine themes and each is represented with different colours. These key themes were commonly seen in the both groups:

1. *observing original prompt (light blue),*
2. *discovering key concept (yellow),*
3. *generating idea (red)*
4. *recalling memory (violet)*
5. *reflective action (blue)*
6. *imagination about materials (brown)*
7. *imagination about structure or manufacturing (light green)*
8. *generating question (orange)*
9. *other actions (white)*

The definitions and the examples of the concrete actions are shown in the following table (Table 15).

***Table 15***. *The description about the 9 themes identified and examples of Group A.*

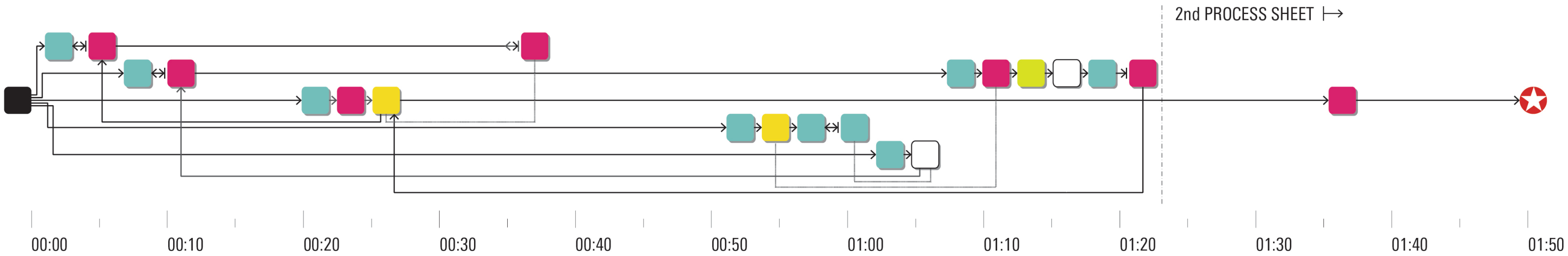
| | THEME | DEFINITION | EXAMPLE (GROUP–A) |
|---|---|---|---|
| 1 | Observing original prompt | The actions in which the participant observed the original prompt. | "I want to see a detail of a metal. I'm looking at the detail here (A3, 00:06:19)." |
| 2 | Discovering key concept | The actions in which the participant discovered keywords and/or key concepts. | "(…) the 'hierarchy' to me is really the key to reduction (A1, 00:25:47)." |
| 3 | Generating idea | The actions in which the participant generated and depicted ideas. | "(…) these patterns… It can be reduced in an order instead of being random. I'm trying to organise it (A2, 00:11:26)." |
| 4 | Recalling memory | The utterances regarding personal memories. | "when I was younger, I found this rock in my garden (A4 01:10:26)." |
| 5 | Reflective action | The actions in which the participant looked over the process already developed. | "I'm looking over to now thinking… I think my original turn was going to be a speaker (A3, 00:36:15)." |
| 6 | Imagination about materials | The actions regarding materiality. | Not Applicable for Group A |
| 7 | Imagination about structure or manufacturing | The actions regarding structural or manufacturing matters of objects. | "(…) it's just partly about how it's manufactured (…) if it's just a flat sheet (…) (A1, 01:21:02)." |
| 8 | Generating question | The actions in which the participant generated key-questions. | Not Applicable for Group A |
| 9 | Other actions | The actions other than the themes listed above. | |

The first theme is "observing original prompt". The actions in which the participant observed the original prompt by looking at, sketching out elements or verbal explanation were categorised into this theme. The second theme is "discovering key concept". In this theme, the actions in which the participants discovered keywords, key-phrases or key-concepts were categorised. The third theme is "generation idea". The actions in which the participants generated any kind of ideas were categorised in this theme. This theme includes not only complete ideas as an object depicted on the *Process Sheet*, but also somewhat vague, incomplete or conceptual ideas represented by sketches and/or sentences. The fourth action is "recalling memory". The actions in which the participants recalled their episodic memories were collected in this theme. The fifth theme is "reflective action". The actions in which the participants reflected the processes that had been already developed by looking over the *Process Sheet* and/or verbal explanation were categorised. This action was generally observed halfway through or at the late stage of the reductive/ideation process. The sixth theme is "imagination about materials". The actions in which the participants envisaged or associated with materiality of the object during the process were categorised. None of the participants in Group A was identified in this theme. Accordingly, this theme was not applicable for Group A. The seventh theme is "imagination about structure or manufacturing". The actions in which the participants envisaged fictitious/possible structures or manufacturing process of objects were categorised in this theme. The descriptions regarding the visible parts of the original prompt derived from observation were not included in this theme. The eighth theme is "generating question". The actions in which the participants generated key questions that were used as a clue for further explorations in the process were categorised in this theme. Again, however, none of the participants in Group A was identified in this theme. The last theme is "other actions". Any other unique, random actions were categorised in this theme.

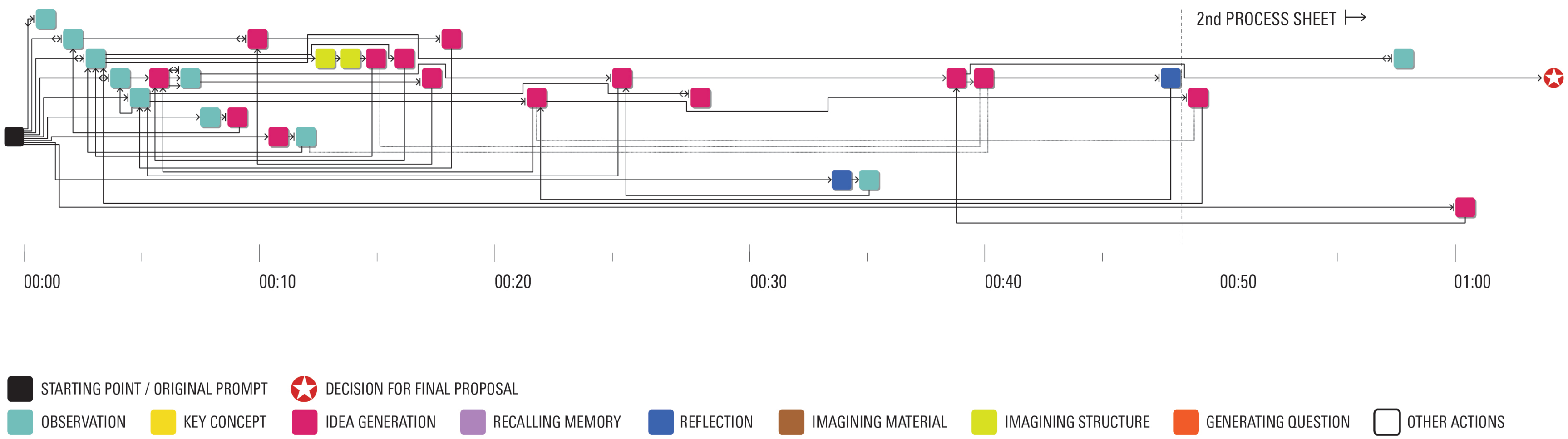
The mapping that illustrates the processes of all four participants is presented (Figure 175). The two features were identified through the analysis based on this mapping. The first feature was the moves of the participants' thinking process. The process has not been developed linearly but more cyclically. The participants often stopped or suspended the thinking avenues, and moved back to the ideas, the concepts or the insights derived from observation that were previously discovered, and then continued the process. Even when they were at the late stage of the process, all participants except for A4 returned back to the ideas or awareness derived from observation that were explored at the early phase and continued the development. Additionally, even though the mapping shows that the participant A4 exceptionally took relatively linear processes after moving to the second *Process Sheet*, the thinking avenues were still correlated among them. Hence, it appeared that the process and the ideas were fostered within the multiple thinking avenues, correlating among different elements discovered.

# PROCESS MAPPING GROUP A (1/2)

## A1

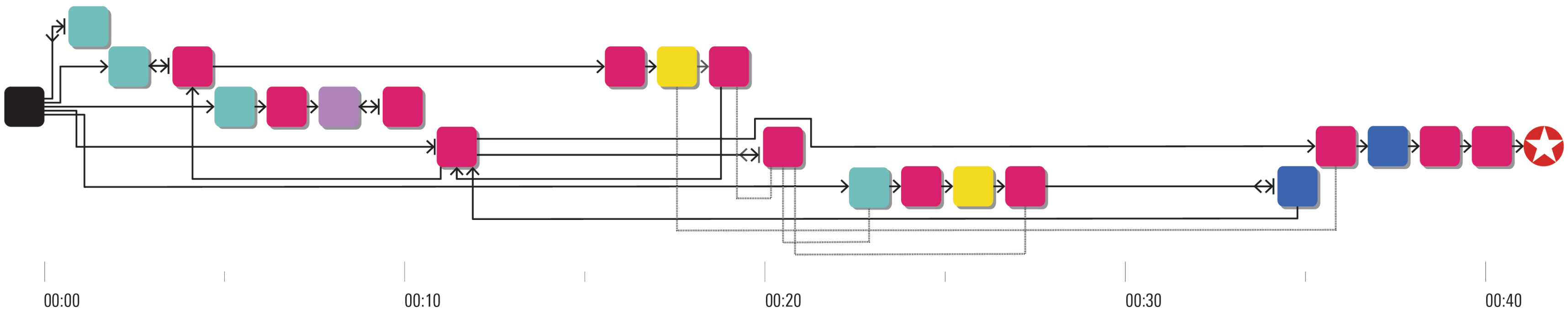



## A2

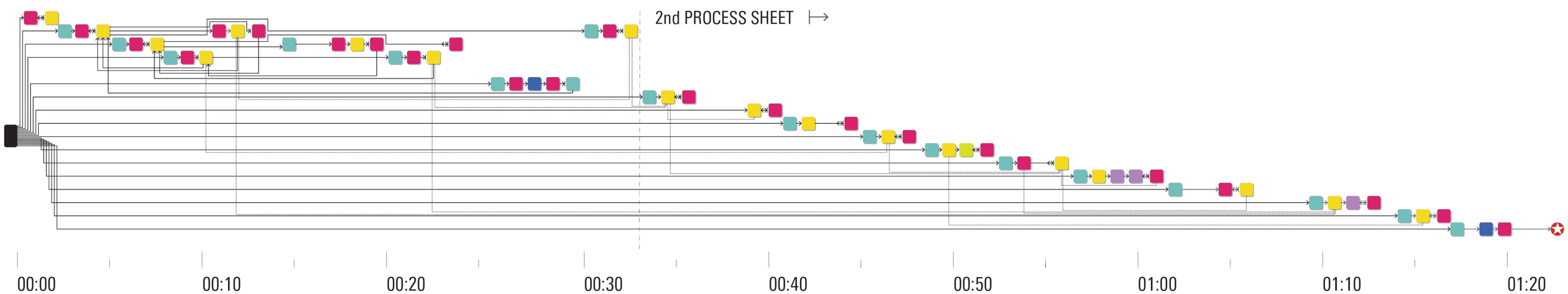


# PROCESS MAPPING GROUP A (2/2)

## A3




## A4




STARTING POINT / ORIGINAL PROMPT
DECISION FOR FINAL PROPOSAL
OBSERVATION
KEY CONCEPT
IDEA GENERATION
RECALLING MEMORY
REFLECTION
IMAGINING MATERIAL
IMAGINING STRUCTURE
GENERATING QUESTION
OTHER ACTIONS

The second feature the researcher identified was that, as aforementioned, most of the participants of this group had a tendency to start by scrutinising the physical aspects of the original prompt. They returned back to the prompt and examined it in order to seek clues for further developing process. Although this action was marginally seen here and there throughout the processes, the ideas were often generated right after the scrutiny. The participant A1, for example, identified the fact that the clock face of the original prompt includes both Roman and Arabic numerals (A1, 00:25:07). This awareness allowed A1 to conceive the idea of a transparent clock that has multiple layers of display in different styles (Figure 176).

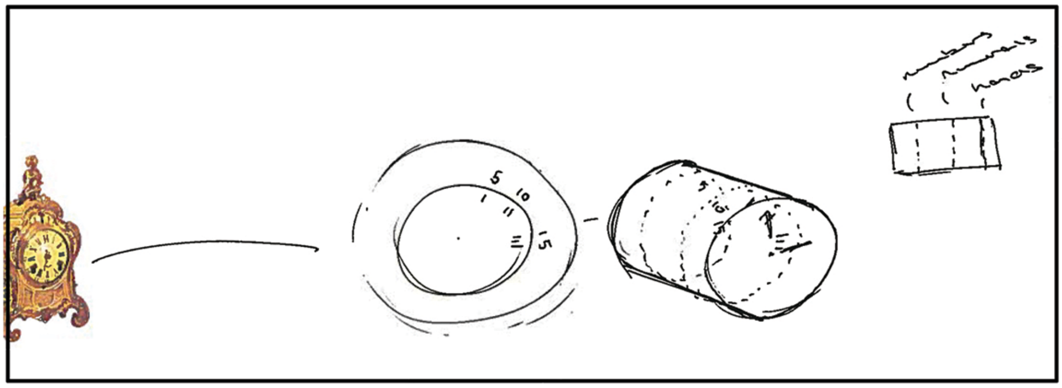


*Figure 176. The idea development of A1 at 00:25:07.*

A3 focused on the entire form and proportion of the original prompt as a first step. Then, an idea was developed, removing all the ornamentations but keeping the same form and volume of the original prompt (A3, 00:00:59). Based on this idea, A3 continued exploring further ideas altering its functionality and forms (Figure 177).

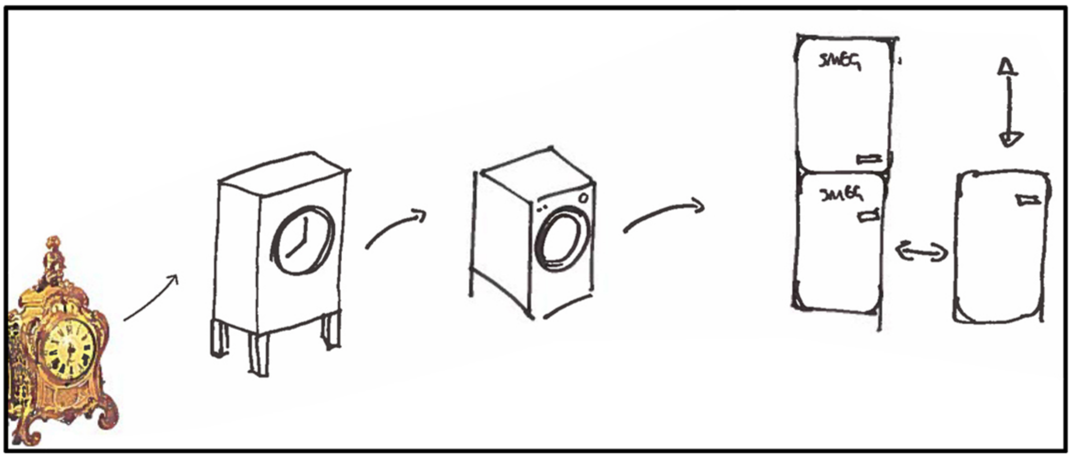



*Figure 177. The idea development of A3 at 00:00:59.*

Or, A4 focused on the legs of the original prompt and considered it as a strong element (A4, 00:05:18). This awareness was then represented with the idea of an object whose form of the legs were exaggerated into a solid form (Figure 178).

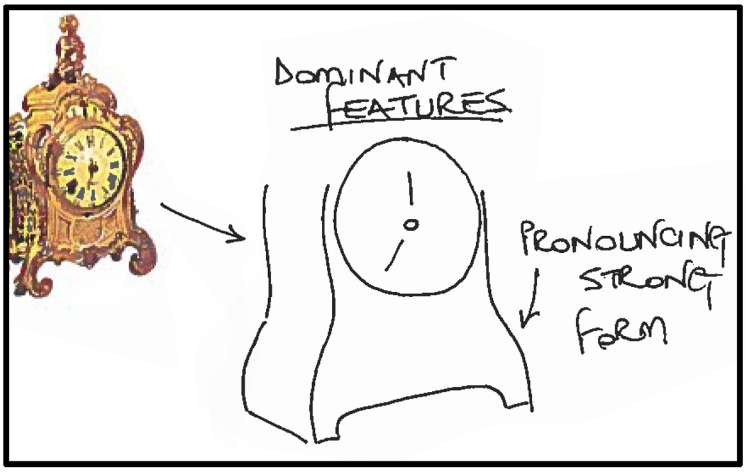



*Figure 178. The idea development of A4 at 00:05:18.*

This fact appeared to suggest that the participants sought for clues within the physical property. The act of reduction naturally demanded the participants to investigate and interpret the details in such a high level of resolution of the original prompt. The information, regarding the physical aspect of an object provided as a prompt, extracted from the observation then acted as stimuli for their design imagination. The researcher believes that this attitude encouraged them to consider the features of the object specifically as a timepiece, such as its proportions or the interaction between a clock and the user, from multiple angles. Consequently, these were reflected upon their final design proposals.

## 4.7.4.2 Reductive Process of Group B (low-fidelity prompt)

The approach where the participants of the low-fidelity group took was different from the other group. Although the high-fidelity group had a tendency to take a scrutiny driven approach, the characteristic of the low-fidelity group was more conceptual oriented. The participants sought and discovered key concepts and used them as a clue for the subsequent reduction/ideation. The ideas were then explored through the seven prominent behaviours identified.

### 4.7.4.2.1 Overall Characteristics

The approach of Group B can be divided into three phases: “seeking clues”, “idea generation” and “making decision for final idea” (Figure 179). Although the participants of Group A initiated the process with scrutinising the physical properties of the original prompt, all participants except for B3 sought out key concepts as the first action. The participants extracted words, sentences, phrases and/or questions as a key clue from the original prompt and used them for the further development of their reductive/ideation processes. The key concepts discovered were focused mainly on the essential notions that the original prompt embodies or implies e.g. clock as a tool for measurement. The result appears to suggest that the visually limited access to the prompt encouraged the participants to focus more on the conceptual aspects that the original prompt involves. The further reductive/ideation processes were conducted based on the key concepts identified.

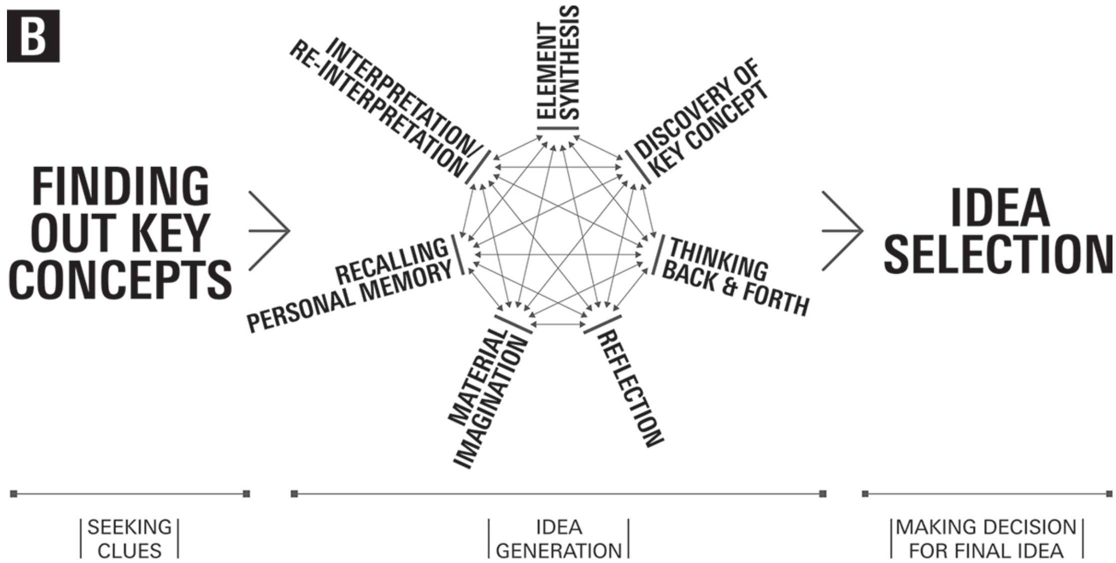



*Figure 179. The approach of Group B.*

In this group, the following seven behaviours were identified:

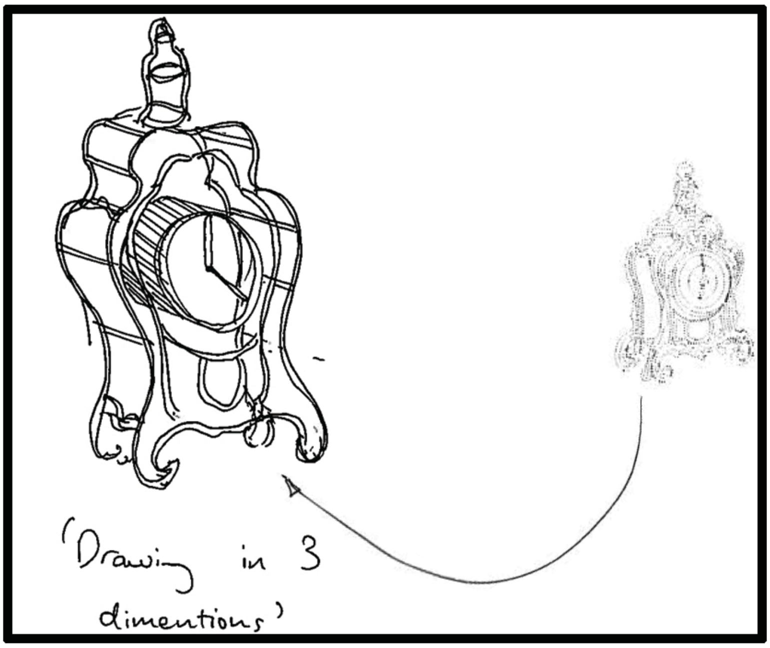
- *Discovery of key concept*
- *Interpretation/reinterpretation*
- *Thinking back and forth*
- *Elements synthesis*
- *Reflection*
- *Recalling personal memory*
- *Material imagination*

Some of the behaviours identified in Group B shared similarities with the result of Group A. Particularly, the following five behaviours were also observed within the reductive/ideation processes of Group B: “Discovery of key concept”, “Interpretation/reinterpretation”, “Thinking back and forth”, “Elements synthesis” and “reflection”. These overlapped categories can be considered as common behaviours in reductive/ideation process regardless of visual fidelity.

The behaviour of "Dismissal/focus", that was one of the element identified in the result of Group A, was not observed in Group B as the participants tended to develop their thinking avenues depending on the key concepts identified rather than through observing and extracting factors from the original prompt. On the other hand, the other two behaviours, "Recalling personal memory" and "Material imagination" were identified in the result of Group B. The examples of each category were described below:

Although the participants had a tendency to initiate the process with seeking key concepts, this behaviour, i.e. discovering key notions, was often observed throughout the process. B1, for example, discovered the key phrase, "over time–physical tangible object to nothing" through the iterative process of idea exploration (B1, 00:32:35) and this subsequently became the important perspective for the final design proposal. Or, B4 articulated the key concept, "drawing in 3 dimensions", recalling the memory of which the sculpture teacher told (B4, 00:32:35) and explored the idea of an object that is constructed with wireframe structure (Figure 180).

***Figure 180. The idea development of B4 at 00:34:52.***




The act of interpretation/reinterpretation was also essential in Group B. The key concepts or ideas discovered within the process were often interpreted in order to find a seed of another interpretation or a clue for further idea exploration. In particular, interpretation or reinterpretation seemed to be the crucial factor for the participant who conducted the reductive/ideation process through conceptual reduction mainly with words. For example, B2 explored multiple ideas, reducing the concepts one after another into relevant connotations (Figure 181). B2 generated the question, "what senses?" and interpreted this concept into multiple human senses i.e. sight, noise, touch, smell and taste. B2 then further continued the process of interpretation and conceived ideas.

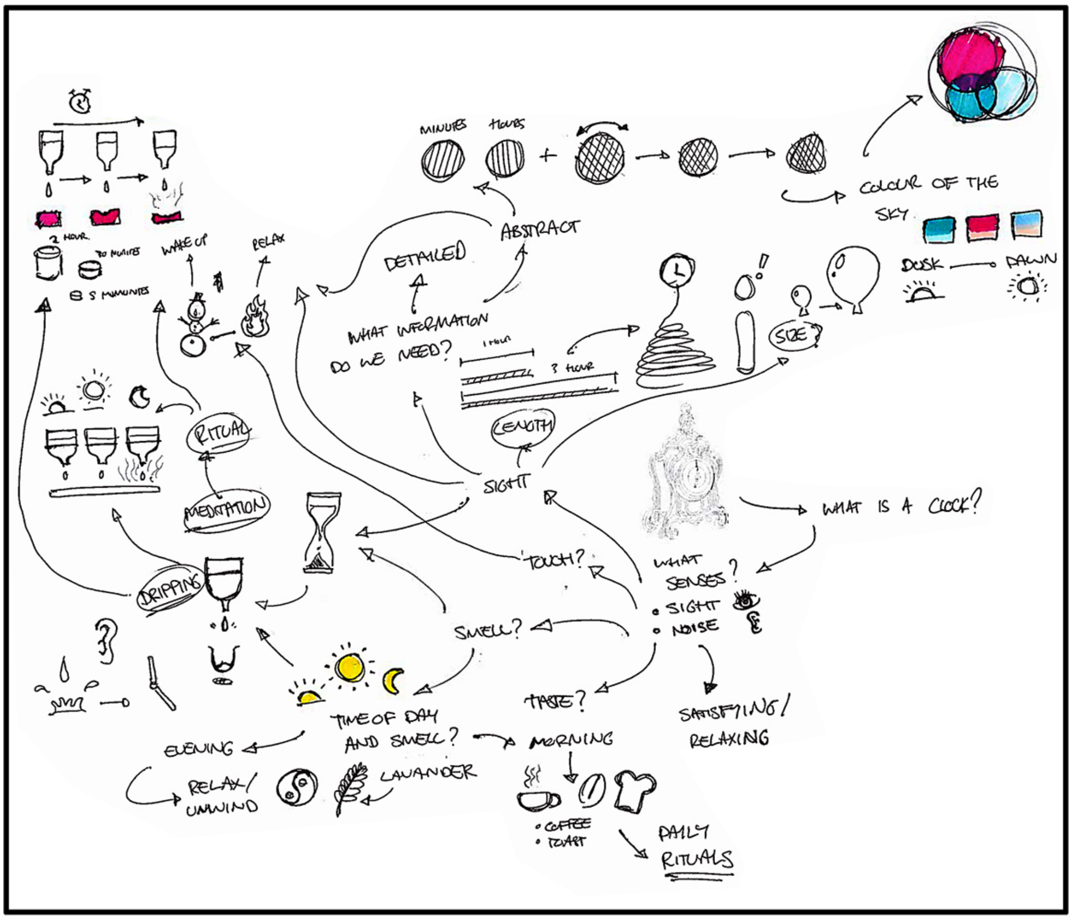



*Figure 181. The process of iterative interpretations of B2.*

Or, halfway through the process, B4 conceptually reinterpreted the two key-concepts discovered at the beginning of the process. B4 reversed the relationship between the two key-concepts ("form" and "function)" and this allowed B4 to conceive the idea of sundial that eventually became the key idea for the final design proposal:

> *"If I go back to my first thing about (…) 'form' and 'function', one argument could be the form isn't necessary. The only reason this object is there is so the people can tell the time. So, the form is where I can reduce or where I can remove. But, actually from the shape of this (original prompt), it looks like there are lots of caring more of the details and the designs. So, maybe I can do the opposite. The reductionism could be that the clock (mechanism) isn't needed and it's just an object. What about if the clock is replaced with the sundial?" (B4, 00:42:50).*

As in it was common in Group A, the behaviour of going back and forth was frequently observed in Group B. For example, B2, returned back to the previous key question, "measuring happiness?" that was suspended during the process, and continued further interpretation of its connotations (B2, 00:32:28). In B2's verbal description, B2 explained how this question was emerged as if B2 was confirming the development process of the thinking avenue. Or, B3 often moved to the thinking avenues where had previously developed as if developing multiple processes simultaneously. B3 also stressed the importance of moving around the multiple thinking avenues:

> *"I just kind of jumping around all different ones. May be if I find a little bit from that one and… that fits that one like… compensating together. And if I just look at one idea for too long you'll just kind of get bored of it. If you can mixed it up with a few other ideas and just keep it like… spending half a minute on this, half a minute on this, half a minute on this. (…) I think it's a bit better than just staying on one idea for whole time" (B3, 00:38:16).*

The behaviour of "Element synthesis" was also constant in Group B. The multiple ideas developed within the thinking avenues were often integrated. The results appeared to suggest that combining ideas or concepts were essential and it enabled the participants to organise the thoughts and/or to conceive ideas. For example, B1 attempted to integrate the two key concepts, "movement" and "process" in relation to the focus on the changes of material state (B1, 00:16:20). B1's focus, at that moment, was on how a quality of material can change into another state over time (B1, 00:15:45). Within this pursuit, B1 organised the thoughts by writing down the relevant notions of each key concept (Figure 182).

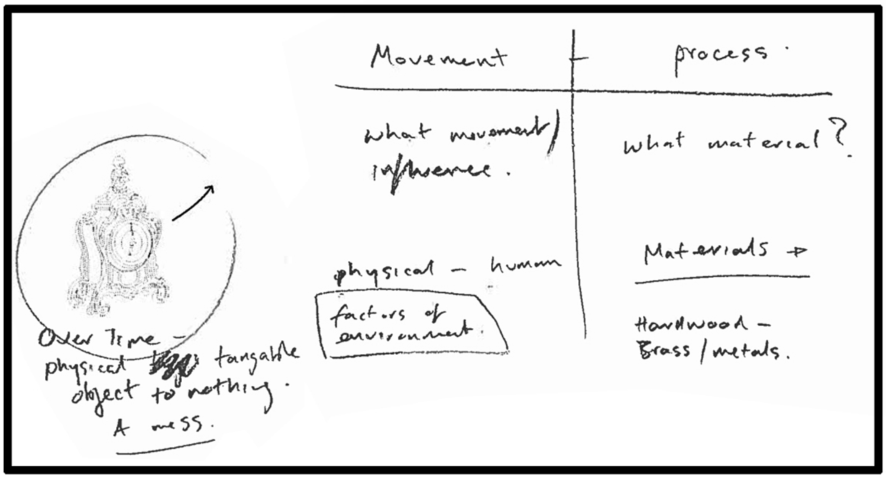



*Figure 182. The sketch where the elements were jotted down by B1.*

Or, B3 developed the idea of a time telling device, where a characterful robot tells the time by walking around the clock display placed on the ground, by combining two different keywords: "legs" and "movement" (Figure 183). B3 generated the key concept, "movement of time" by this combination and literally interpreted it into an idea (B3, 00:43:40).

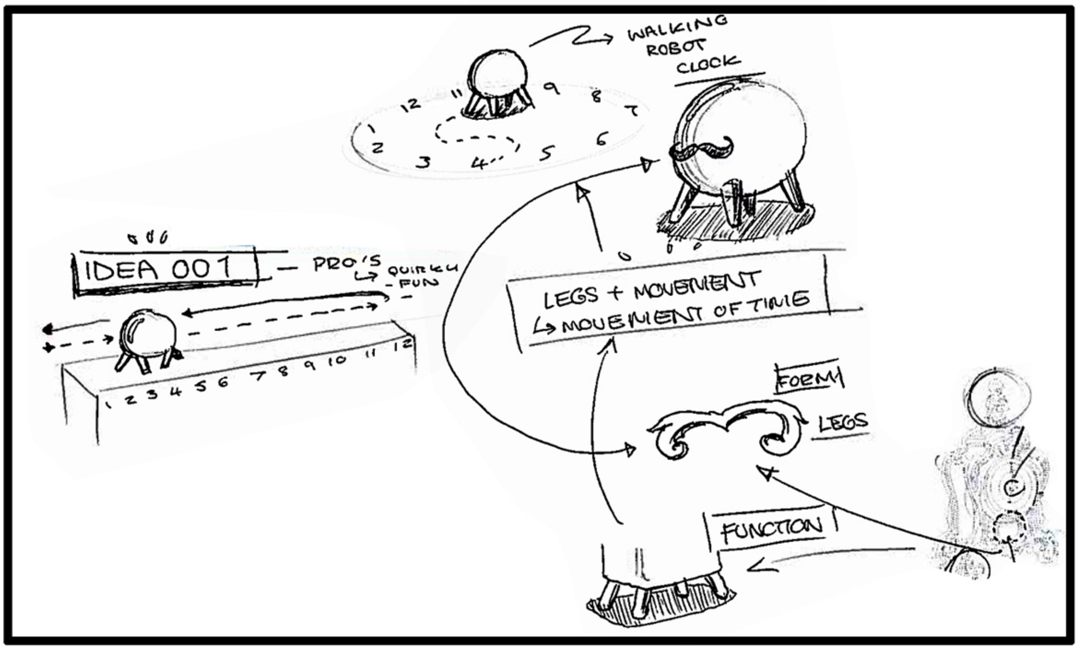



*Figure 183. The process of B3 at 00:43:40.*

"Reflection" was common behaviour in Group B. B1, for example, looking over all the processes developed, and summarising the ideas, jotted down key elements on the sheet (B1, 00:57:37). Or, B3 numbered the prominent ideas, and wrote down their pros and cons in order to classify B1's thoughts (B3, 01:01:37).

Other than the behaviours that were commonly observed in both Group A and B, additional two actions were identified only in Group B. One of the two behaviours was "recalling episodic memory". The participants recalled their episodic memories (Tulving, 1972) within the process, such as a conversation with a specialist or a particular experience they had with an object. For example, B1 recalled B1's previous project and the conversation with a traditional clockmaker at the very beginning of the reductive/ideation process. This seemed to dictate B1's thinking process:

> *"For my exploration, before the major project, sort of touched on it a little bit but it was really intriguing to go down sort of traditional route. Actually, I had really good conversation with a traditional clockmaker so some nice things are inspired by him" (B1, 00:00:46).*

B1 also remembered the familiar object placed in B1's grandparents' house and recalled its surface finish. B1 then discovered a key concept out of the memory: *"Almost like grandfather's piece. Grandmother's house has really nice traditional clock in it. It does almost seem to be polished itself over time. Actually, it's nice phrase 'polished itself over time'" (B1, 00:03:03).* B2 explored ideas of the ways of telling time by means of our senses, reflecting B2's personal experience.

> *"I find kind of relaxing listening to my watch or… it's just the mechanics of it. I find I quite like it so that I was wondering if the (sense of) 'noise' is a quite big part of time telling. What if you can do it in the other way combining with… maybe 'smell'? So the dripping of something (…) may be you control the dripping every minute or five minutes (…)" (B2, 00:39:29).*

Or, B4 recalled the words told from B4's former teacher at a sculpture class. This memory was used as a key concept for idea development:

> *"(…) my teacher used the phrase saying 'you are drawing in 3D' (…) that phrase 'drawing in 3D' I think it could be a good one to think about. (…) if it was a wireframe that represents all of the dotted lines… with represented by a wireframe. It could be 3D printed or wire bent (…)" (B4 00:30:52).*

The behaviour of recalling personal memories or experiences was seen within the process of conceptual reductions. This fact appeared to suggest that the reductive process of concepts prompted by the limited visual fidelity provided more opportunities for the participants to reflect their personal contexts. In fact, the two participants (A3 and A4) recalled their episodic memories within the process in Group A. All the participants, however, recalled their episodic memories in Group B.

The other behaviour was “Material imagination”. The imagination regarding materiality of object seemed to be encouraged in Group B. The image of the low-fidelity prompt where the object is represented with dotted lines does not include information regarding its materiality. It appeared that the lack of material information stimulated the participants’ curiosity and prompted their focuses on materiality. In particular, the two participants seemed to be encouraged to envisage the materiality of the original prompt. The materials imagined by the participants were not necessarily the same ones used in the actual object. However, they used their material knowledge as clue for their idea development. This characteristic was not observed in the group of high-fidelity prompt. B1, for example, envisaged a type of timber from the image of the prompt: *“I saw nice antique timber material (in the original prompt) so you are going to have… let’s say the nice timber of mahogany” (B1, 00:01:40).* B1 then continued reasoning about its surface finishing and this allowed B1 to discover the key concept “polished itself over time” (B1, 00:03:03). B1 even described that B1 could imagine as if B1 was actually touching the material envisaged through imagining its surface finish:

> *“I guess on the timber it always seems to really be polished up (…). Or, even something like black charcoal or something I imagined like that so when you are touching it, it’s almost giving something off. It’s may be sort of antique stuff. It would be like a darker colour. I can almost imagine like really touching it rather than actual visual presence sort of what’s the feedbacks from the clock” (B1, 00:01:49).*

Or, B4 inferred the cultural context of the material assumed. B1 then considered whether B1 can reduce the quality of the wood assumed by changing it to the lower quality veneer:

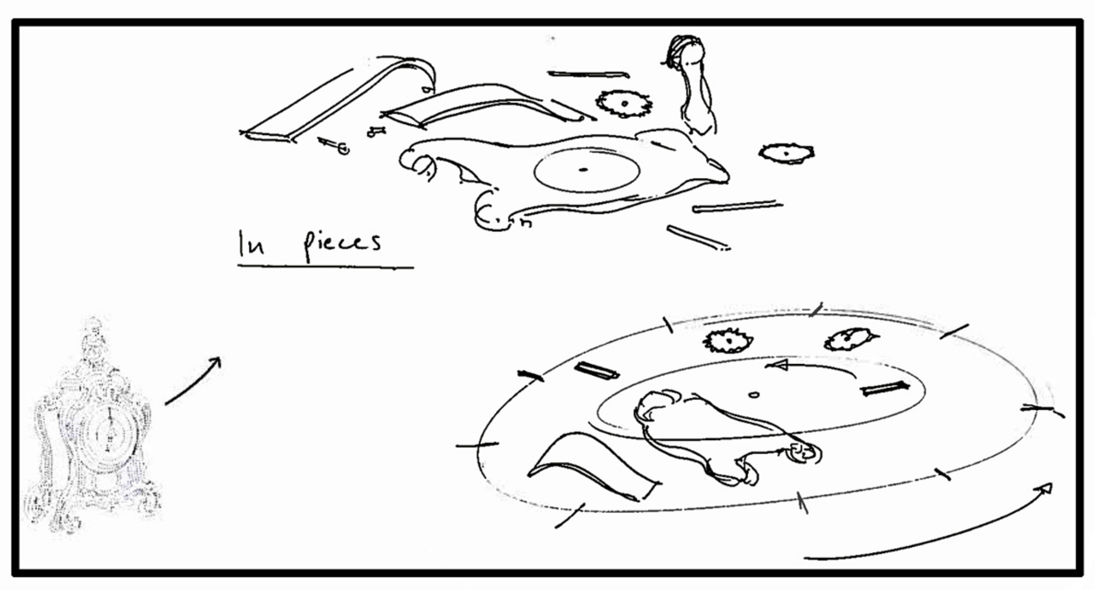
> *“What material is this? It seems it’s made of wood (…) because it looks old. (…) kind of like 17th century? (…) The fact that it’s got the figure on the top suggesting classical something. If I imagine if it’s made from wood, I think about reducing that wood, so I take wood veneer (B4 00:18:01).”*

Also, uncertainty of materiality allowed B4 to conceive the idea of dismantling all the components on a table. B4 attempted to understand what types of materials are possibly used through dismantling the pieces and placing the images of them on the same place (Figure 184).

This action subsequently provided B4 the opportunity to develop the idea of a clock where the dismantled and randomly placed components tell time by rotational movement:

> *"I'm thinking originally this (the original prompt) was made from one carved… looks like it's been carved from one piece of wood. (…) But, if I was wrong, actually it's lots of different pieces of wood and metal on its own construction. Maybe it's forged or cast metal. It seems likely could be a Victorian clock… could be a piece of die-cast metal. (…) I'm just doing like all the different parts that are made from… full laying out on the table… dismantled but what I would be interested in is if it looks deconstructed bit it still functions" (B4, 00:49:59).*

***Figure 184. The process of B4 at 00:49:59***



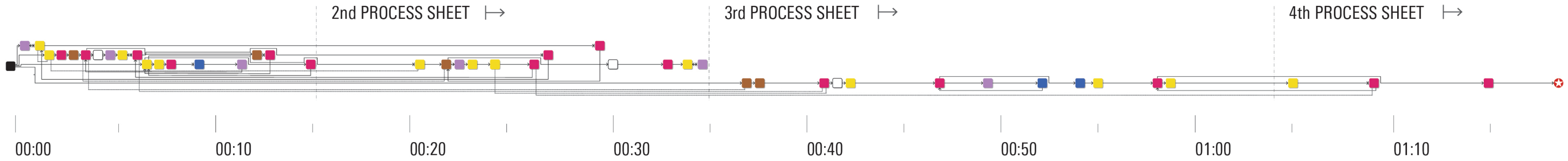

It appeared that the limited visual fidelity prompted the material imagination of the participants. Even the inference of the material of the original prompt is not accurately the same as the one is used in the original object, the misinterpreted assumptions can act as inspiration for design imagination in a variety of ways.

#### 4.7.4.2.2 Characteristics in Detail

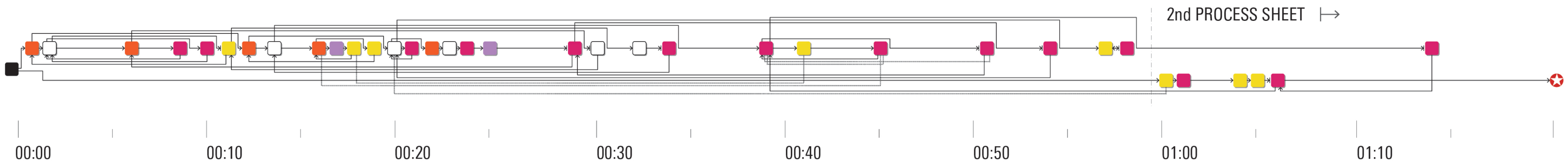
As it was shown in the section 3.3.2, the mapping that represents the processes of Group B was made, following the same rules as it was applied to Group A (Figure 185). Additionally, the nine themes shown in the table 2 (observing original prompt, discovering key concept, generating idea, recalling memory, reflective action, imagination about materials, imagination about structure or manufacturing, generating question and other actions) were also applicable to this group. The examples of Group B are presented (Table 16).

# PROCESS MAPPING GROUP B (1/2)

## B1



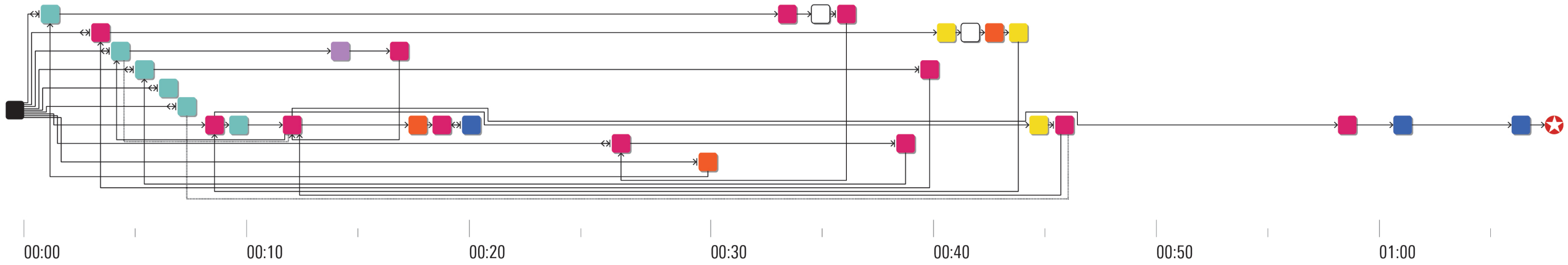

## B2



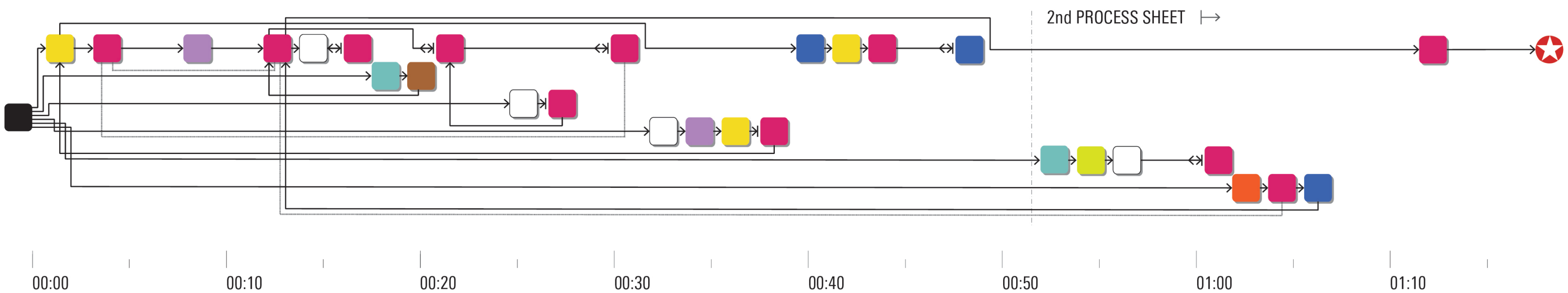

STARTING POINT / ORIGINAL PROMPT
DECISION FOR FINAL PROPOSAL
OBSERVATION
KEY CONCEPT
IDEA GENERATION
RECALLING MEMORY
REFLECTION
IMAGINING MATERIAL
IMAGINING STRUCTURE
GENERATING QUESTION
OTHER ACTIONS

# PROCESS MAPPING GROUP B (2/2)

## B3




## B4




STARTING POINT / ORIGINAL PROMPT
DECISION FOR FINAL PROPOSAL
OBSERVATION
KEY CONCEPT
IDEA GENERATION
RECALLING MEMORY
REFLECTION
IMAGINING MATERIAL
IMAGINING STRUCTURE
GENERATING QUESTION
OTHER ACTIONS

***Table 16.*** *The description about the 9 themes identified and examples of Group B.*

| | THEME | DEFINITION | EXAMPLE (GROUP–B) |
|---|---|---|---|
| 1 | Observing original prompt | The actions in which the participant observed the original prompt. | "(…) looking at the clock face, the clock hands, the pendulum and just pulling other sides and some other elements are a bit more abstract (…) (B3, 00:06:52)." |
| 2 | Discovering key concept | The actions in which the participant discovered keywords and/or key concepts. | "(…) I wanna go with the 'process'. Time essentially as process of something moving or progressing towards something (B1, 00:01:10)." |
| 3 | Generating idea | The actions in which the participant generated and depicted ideas. | "The object is getting tired as well through time so it falls over and you wake it up (B2, 01:04:30)." |
| 4 | Recalling memory | The utterances regarding personal memories. | "Grandmother's house has really nice traditional clock in it (B1 00:03:03)." |
| 5 | Reflective action | The actions in which the participant looked over the process already developed. | "I guess I'm summarising it up. Go with coal or charcoal (…) (B1, 00:53:29)." |
| 6 | Imagination about materials | The actions regarding materiality. | "What material is this? It seems it's made of wood (…) (B4, 00:18:01)." |
| 7 | Imagination about structure or manufacturing | The actions regarding structural or manufacturing matters of objects. | "(…) looks like it's been carved from one piece of wood. (…) But, if I was wrong, actually it's lots of different pieces of wood and metal on its own construction. (B4, 01:50:05)." |
| 8 | Generating question | The actions in which the participant generated key-questions. | "What if people knew that they are going to die? I wonder if people live differently? (B2, 00:07:06)" |
| 9 | Other actions | The actions other than the themes listed above. | |

All themes were observed in Group B. All of the themes, except for "imagination about materials" and "generating question" were considered as the common behaviour within reductive/ideation process regardless of the fidelity levels. However, these two themes that were not observed in Group A were identified. This fact appears to suggest that these behaviours were the prominent features of the group where the participants were given the image of the low-fidelity prompt.

Two features were identified through the analysis of the mapping of Group B. The first feature was the way in which the participants developed their reductive/ideation processes. As per the way in which the participants of Group A developed, the processes of Group B were not completely linear either. The processes of this group, however, seemed to have a primal thinking avenue that critically dictated their final design proposal. Although the participants were moving back and forth among multiple thinking avenues throughout the process, they had a tendency to stick to the key thinking avenue. For example, the process of B1 became relatively linear after moving to the third *Process Sheet*. B1 was focusing on the aspect of material quality from the early phase and this interest continued until the end of the process. The processes developed were, therefore, somewhat relevant among each other. Consequently, B1 developed relatively less thinking avenues and focused on the same path after moving to the third *Process Sheet* where B1 became more aware of the direction. The reductive/ideation process of B2 was conducted mainly by logical deduction of concepts. The concepts derived from the primal questions, i.e. "what is time?" or "what is a clock?", were interpreted and relevant concepts were generated one after the other. The process, consequently, became relatively linear until the end of the first *Process Sheet*. Although B2 started the thinking avenue from the original prompt when B2 moved to the second *Process Sheet*, the focus was still relevant to the one developed in the first *Process Sheet*. Although B3's development process was somewhat similar to the characteristic of Group A, B3 developed the process, focussing on the thinking avenue where the key idea of the tetrapod structure was generated, near the end of the process. Or, B4's interest was mainly in the thinking avenue originated from the key themes identified in the first place: "ornament" and "clock". The centre of B4's focus within the process was on the relationship between the form/ornament and functionality as a clock and on how the object can be represented with insubstantial attributes. This continued focus seemed to develop the primal thinking avenue and to encourage B4 to stick with it. Consequently, the result appears to suggest that the participants of Group B had a tendency to stay in the primal thinking avenue and to deepen their thought within the idea exploration. On the other hand, this characteristic was not prominent in Group A. The participants of the high-fidelity group focused more on the physical aspects in a variety of ways. This characteristic seemed to encourage the participants of Group A to observe the original prompt from multiple angles, and this attitude consequently became one of the factors why Group A had the breadth of focuses in its process, rather than concentrating on the primal thinking avenue.

Another feature was the pattern in which the participants generated ideas. All the participants of Group B, except for B3, often generated ideas right after discovering key concepts and/or questions. While the participant B3 only generated ideas based on the observation of the original prompt at the beginning, as the process progressed, the ideas were also generated using a key concept or a question discovered as a clue. The participants of Group

B naturally generated key concepts/questions as clue for idea generation throughout the process whereas understanding of the original prompt played an important role for Group A. For example, B1 generated the idea of a clock where its clock hands that have nails scratches the clock face to change its appearance over time (B1, 00:03:19). This idea was generated right after the discovery of the key concept: "polished itself over time" (Figure 186).

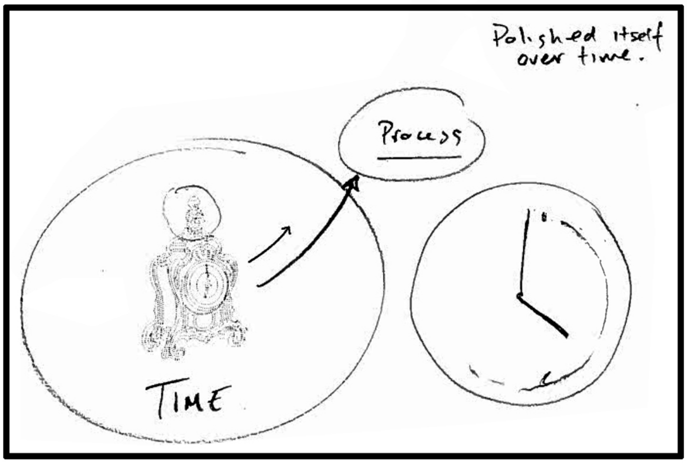



*Figure 186. The process of B1 at 00:05:17.*

B2 developed the idea of a timepiece that behaves like a tired person based on the key concept "rigidity" (B2, 01:01:32). B2 was thinking of how time passage can be visually represented by the object itself. First, B2 developed the idea of a clock whose opacity of the clock face changes as time proceeds. As the time passes by, the visibility of the clock face decreases. Within this ideation process, B2 discovered the key concept of "rigidity" in which object shows the time passage by changing its posture. This key concept allowed B2 to conceive the idea of a timepiece that behaves like a tired person (Figure 187):

> *"(...) as we get tired gradually in the day, so the clock doesn't give off. The information is not as clear… I don't know how useful it would be (wrote down the word 'rigidity'). It's kind of a different variation of this (opacity gradation). The object is getting tired as well through time. So it falls over and you wake it up. Actually, that could work because that could be a visual and then it could be another level of detail if you want to interact with it"(B2, 01:01:29).*

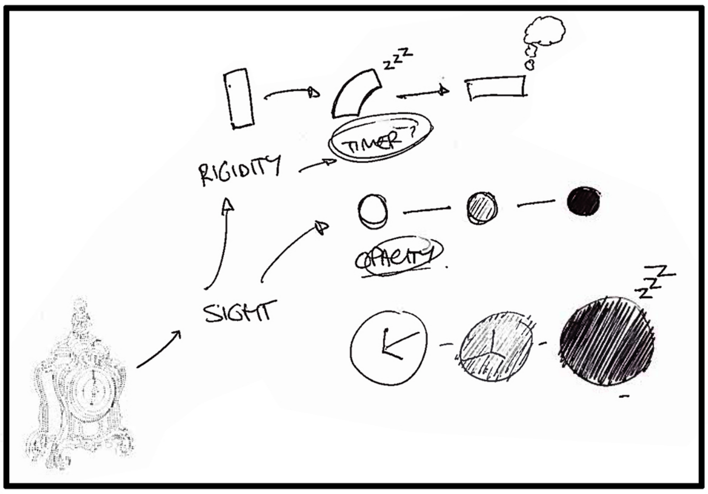
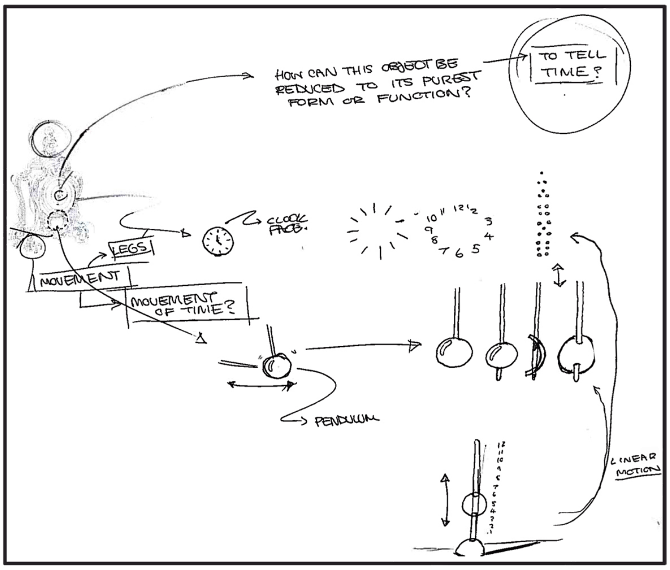



***Figure 187. The process of B2 at 01:01:29.***

B3 generated the questions, “how can this object be reduced to its purest form or function?” and “to tell time?” halfway through the process (B3, 00:29:35). B3 described their thinking in considering what the purest form of a clock should look like when all the attributes of the original prompt are removed (B3, 00:27:23). Based on this perspective, B3 returned back to the thinking avenue that focused on the clock face, and developed multiple ideas of a dial plate whose visual elements were reduced. B3 then invented an alternative clock display style where indicates the time with vertical motion, combining two different thinking avenues (Figure 188).

***Figure 188. The process of B3 at 00:33:31.***




B4 also generated the question “what if I miniaturise it?” at the later phase of the process (B4, 00:53:42). B4 imagined how the reduced size of the object impacts upon the interaction between the user and the object when the volume of the original clock is shrunk to a miniature scale.

This attempt allowed B4 to envisage an idea of how to interact with the clock using a magnifying glass. This approach subsequently led B4 to the other ideas of perceiving objects or clocks through virtual reality (Figure 189).

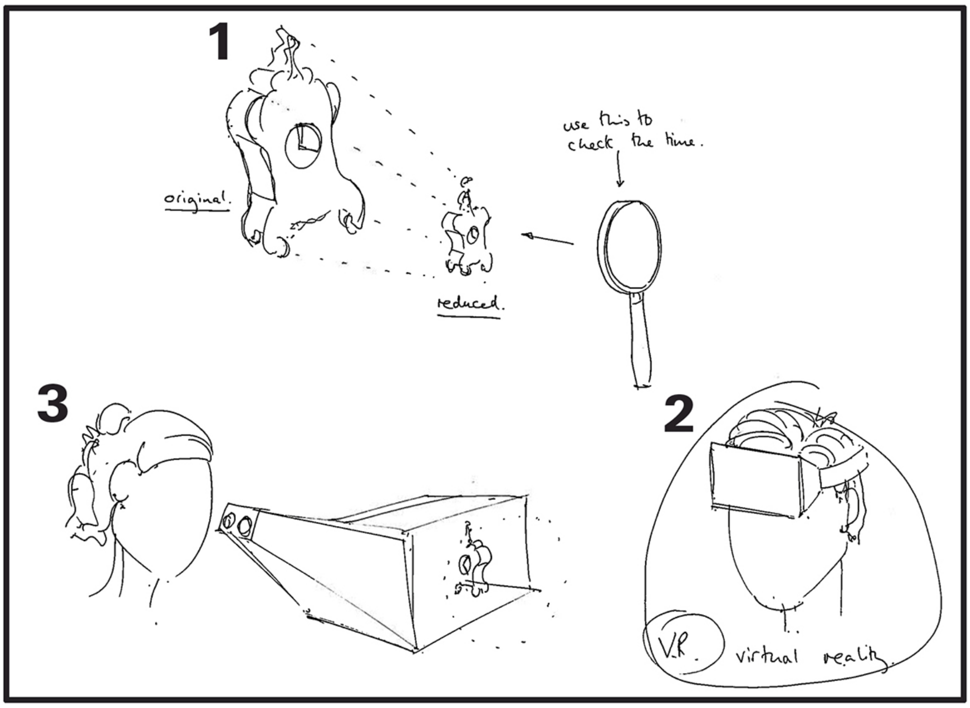



*Figure 189. The ideation process of B4.*

Thus, the participants of Group B generated ideas from the key concepts and/or questions. The reduction of the concepts that discovered, generated another concept and this became the opportunity for the participants' idea exploration. Also, by generating questions the participants sought clues for exploring possibilities of further ideas or concepts. This characteristic was not observed in Group B.

### 4.7.4.3 Summary of Findings

The participants of both groups managed to create design proposals as an outcome through the proposed deconstructive process. The deconstructive approach certainly encouraged the industrial design students to establish an in-depth dialogue with the prompts provided during the process. The deconstructive process was developed through the actions identified such as discovering key concepts, interpreting/re-interpreting, synthesising elements, returning back to the previous thinking avenues and reflecting the processes.

Along with these similar characteristics, however, significant differences were also identified between the two groups in the outcomes and the processes they developed. Most of the participants that were given the high-fidelity visual prompt (Group A) conceived timepieces as outcomes, thus maintaining the same typology of the object as the original prompt. It appeared that the participants purposefully maintained the relevance to the original object as a clock within the reductive/deconstructive process and this attitude was also represented in their outcomes. The participant A3 designed an object in a different category from a clock: a speaker unit. However, its physical features i.e. the composition and the proportion were taken over from the original Rococo clock. Also, the participants of Group A had a tendency to develop reductive/ideation process by closely scrutinising the physical aspects of the object. The participants gained detailed information from the original object, such as structure, functionality, design intention and so on, and these were used as clue for further development of the process. The reductive/deconstructive process being provided with high-fidelity prompt potentially offers the design practitioners an opportunity to discover/re-discover the aspects of existing objects that they have not considered, and use the awareness for exploring new design concepts.

On the other hand, the participants that were given the low-fidelity visual prompt (Group B) also created time-related objects. However, its design concepts became even more radical comparing to the Group A. Instead of designing a “clock”, the participants of this group considered the “time-related” objects in a variety of ways. Most of the objects do not function just as a clock but suggest the user an alternative interaction with time. Although the participant B1 redesigned an existing game, its focus was rather on the “time passage” underpinned by the relationship between usage and changes of the material state. In other words, this participant redesigned an object, interpreting the concept of time into a physical characteristic. Additionally, the participants of Group B tended to develop reductive/deconstructive process by deducing conceptual aspects that the original prompt includes and by generating questions. Most of the participants deepened the understanding of the concepts by repeatedly interpreting the notions or questions generated. The outcomes and the approach of this group suggest that the participants engaged the more conceptual design approach, comparing to Group A, where allows the designers to *address the design situation in* *multiple angles* (Lawson & Dorst, 2009). Further, the results also appeared to suggest that the participants of Group B were encouraged self-reflective thinking approaches during the process. They reflected their personal memories or experiences within the interpretative process of the concepts. The reductive/deconstructive process being provided with low-fidelity prompt potentially offers the design practitioners an opportunity to interpret/reinterpret conceptual aspects that the original prompt represents from multiple angles. The gained insights or awareness were then used as a clue for generating unexpected or radical ideas.

In conclusion, the act of deconstructing elements of an existing object clearly impacted on the design students' imagination in a variety of ways. The researcher believes that if the prompt is carefully selected and if the level of fidelity is properly controlled (depending on the anticipated purpose), this approach has the potential to become an effective way in encouraging the designer's imagination through creating an in-depth conversation with the object. What the researcher believes is that the technique of *autonomous reduction* has generated a high level and rapid concept ideation period for the industrial design student participants. This disruption appears to add new values to the industrial design students' creative thought process within concept development phase.

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# 4.8— MAIN STUDY 2: AUTONOMOUS REDUCTION VERSION 2.0— EVALUATION BY PROFESSIONALS

## 4.8.1 Introduction

The previous study revealed certain patterns and characteristics when the industrial design students engaged the proposed reductive process. The autonomous reductive-process allowed the design students to have an in-depth dialogue with the object provided as a prompt and they all could develop the design proposals in their own ways. This proposed reductive approach appeared to encourage particular engagement in the participants' design reasoning and the original ideas were generated based on the act of reduction. This fact appeared to suggest the potential of applicability of the proposed approach to the actual design process. Then, the researcher further considered how this reductive approach could play a role in the reasoning process of experienced designers. In order to investigate the impact of autonomous reduction upon the professional designer's design reasoning, the final study was conducted using the same Rococo bracket clock but in the different conditions. The six professional participants were invited to challenge the reductive technique within thirty minutes. Additionally, they were not required to complete the *Idea Sheet* where the idea is finalised. Also, only the high-fidelity image of the original prompt was provided to the participants. The researcher visited four product design enterprises in both England and the Netherlands in order to ask the mature industrial designers to challenge and evaluate the proposed reductive technique. The research questions in this study were: 1) how does the autonomous reduction impact on the design imagination of mature industrial designers? and 2) how can this approach potentially play a role within the industrial design process on a professional level?

## 4.8.2 Company Visit

The studio visits were carried out from August to September 2016 (Figure 190). The researcher contacted each company by email and phone beforehand, and the date of visits was carefully planned in accordance with the schedules of the participants. All the participants were supportive and warmly welcomed the researcher into their offices, and participated in the study in their spare time. All the necessary materials for the study were brought by the researcher so that the participants were not required to prepare anything for the participation. The researcher visited four companies located in Amsterdam, London and Cambridge.

*Figure 190. The offices where the study was taken place.*

The first company FA was a product design studio based in Amsterdam owned by two Italian co-founders/design directors. The studio was established in 2009, and has been engaged a number of both self-initiated and commissioned projects. Their design approach was characterised by experimental material investigations and consistent interests in the relationship between objects and socio-cultural issues. The studio has worked with broad global brands and many of their works were kept in the museums' permanent collections all around the world.

The second company CL was a London based multi-disciplinary design consultancy, owned by the German design director, with a diverse output across product, furniture and spatial design. The company was established in 2002, and caters to broad clients working on bespoke commissions and installations with global brands, galleries, interior designers, architects and private customers. As well as commissioned projects, the company also has been designing a number of consumer products under license for the respective collections of manufacturers.

The third company SC was a design consultancy based in Cambridge established in 2004. The company has been working across a range of sectors, including consumer products, healthcare and sport with global brands/clients. The company's business covers full-range of product design services, including opportunity exploration, concept creation, proof-of-principle testing, technology development, product design and development, as well as transfer to manufacture. Their design has an established reputation for excellent engineering expertise and successful outcomes with a clear vision.

The fourth company ML was an award-winning product and interior design studio based in London. The studio was established in 2006 and has been engaging a number of experimental design projects ever since. Their experimental approach was characterised by the innovative manufacturing process using a diverse range of natural materials. Their commissioned works were exhibited in all over the world and were acquired for the museums and the institutes internationally. The participants were selected within these companies.

### 4.8.3 Methodology—Main Study 2

Although the image of the Rococo clock as a provided prompt and the *Process Sheet* was the same with the ones given to the student participants, the conditions of the study for the professional participants were different. The participants were asked to reduce/deconstruct the elements of the original prompt by themselves on the *Process Sheet* provided following the same instruction and the procedure. They were also asked to discover ideas/design concepts by sketching within the reductive process, thinking aloud throughout the task. However, there are five different conditions applied in this study: 1) time limitation, 2) selection of the participants, 3) use of the only one fidelity level, 4) exemption of the *Idea Sheet* and 5) being informed the context of the project.

First, the participants were required to complete the reductive task within thirty minutes. The study was carried out in the office where the participants belong during their business hours. The participants participated in the study on a voluntary basis and each professional designer took part in the event, suspending their own work. Accordingly, in total forty-five minutes (including the fifteen minutes interview) were the maximum time the researcher could ask the professional participants for the study.

Second, the results of the four participants were analysed and described in this chapter. The researcher has conducted this study with in total nine professional designers for the data collection. In this study, however, the four participants who hold the design director position at the company were selected within the nine cases. One of the reasons why this selection was made was due to its large amount of transcript data. For the sake of the limitation of the thesis, the researcher decided to only select the participants who are well experienced and empowered to make decisions in the company.

Third, the high-fidelity image of the prompt was only used in this study. The focus of this study was on observing how the professional designers approach and behave towards the autonomous reduction. Due to the small number of samples, the researcher considered that it is better to conduct the study under the same conditions. Therefore, the researcher decided to use only the high-fidelity image prompt for the study.

Forth, the *Idea Sheet* was not included in the study. As aforementioned, the time that the professional participants could spend for the study was very limited. Additionally, as also aforementioned, this study focuses on the event that happens within the reductive process rather than the conclusion. Accordingly, the participants were only given the *Process Sheet*.

Fifth, the participants were given a short presentation that describes the summary of the research before the commencement of the task. One of the significant aims of conducting this study with the professional designers was asking them not only to try the task but also to evaluate the proposed reductive process from the professional point of view. Therefore, it was important to ask them to participate in the task with understanding the context of the research project rather through providing a random exercise. Thus, the summary of the amendment applied in this study is the following:

- *The participants were required to complete the process within 30 minutes.*
- *The four design directors were selected as the professional participants.*
- *The only high-fidelity image was used as a prompt.*
- *The participants were invited to challenge the task only with the Process Sheet.*
- *The participants were informed regarding the context of this research before the commencement of the task.*

The details of the methodology applied in this study are described in the following sections.

#### 4.8.3.1 Participants

In total four participants were involved in this study. The only participant P1 comprised of two members as they have always engaged and developed their design projects together since they established their design studio FA. Accordingly, these two designers were considered as one participant and the task was conducted as a team. All participants have minimum seven years of acquisition of experiences in the industrial design industry. All the participants were the founder/design directors of the companies where the researcher visited.

#### 4.8.3.2 Study Environment

The study was individually conducted using a small space available in the office of the participants' companies. Just like the previous study, the video camera and the sound recording device were set next to the participant, and the researcher as instructor sat on an adjacent seat to them (Figure 191).

*Figure 191. The study environment at the participant P4.*

#### 4.8.3.3 Procedure

The study was initiated with giving a short presentation that describes the summary of this research project. This means that the participants engaged the task, being aware of the scope and the aims of this research. The participants were then asked to try the proposed reductive process within thirty minutes. The *Process Sheet* and the image of the prompt object printed in A4 size was prepared and provided during the task. As aforementioned, they were not required to deliver the final design proposal at the end of the process in this study. The semi-structured interviews were conducted after the completion of the task. The detailed description of the procedure is as follows;

1. The participant was given a short presentation (5 minutes) regarding the research project by the instructor (the researcher).
2. The *Process Sheet* and the image of a prompt object were provided
3. The participant was asked to explore new design concepts, reducing/deconstructing the elements of the original prompt within 30 minutes.

They were also required to think aloud throughout the reductive/deconstructive process.

4. The participants were interviewed after completion of the task.

#### 4.8.3.4 Questions Asked During the Interview

The interview focused particularly on their reasoning processes since the participants were not required to produce the final design proposal. Additionally, the questions were designed, aiming to ask the professional participants to review the potential value and the applicability of the proposed reductive technique to their own design practices.

- *Please explain your reductive processes.*
- *What kind of elements of the original object did you eliminate or leave?*
- *How did you conceive new concepts/ideas in each reductive process?*
- *Were the ideas you conceived "unexpected" (were you surprised)?*
- *What elements were important in conceiving your ideas?*
- *In your opinion, explain the meaningful values you have found using the approach "reductive technique".*
- *On the other hand, what are the limitations of the approach "reductive technique?"*
- *How can the technique potentially be deployed in the product design process?*
- *How might the reductive technique be improved to facilitate the designer's idea exploration?*
- *How do you feel about groups of designers using the technique in the idea exploration stage?*

### 4.8.4 Results

This section describes the results of the professional participants. All the data were collected through the following media: the contents of the *Process Sheet*, the verbal description captured during the task, and the semi-structured interview conducted. The process of each participant was shown, focusing on how the professional designers engaged the autonomous reductive process and how the ideas were explored within the process. The process mapping that illustrates the entire process was also produced based on the data.

#### 4.8.4.1 The Participant P1

The participant P1 is composed of two Italian designers, in their mid-thirties, from the product design studio FA. Both are also the co-founders and the design directors of their own design enterprise. Both designers have more than seven years of professional experiences in product design and have engaged more than forty design projects.

They have been engaging their design practices always together since they started their studio. Therefore, this design duo was considered as a single participant in this study (one of the members is shown as P1-F and the other is mentioned as P1-T when needed). The reductive/deconstructive process was developed through their dialogue. This interactive approach appeared to allow them to avoid the flow of their reductive process being stagnant. One brought an idea or a theme as a cue into the conversation and the other responded to it. The process was developed discovering many keywords relevant to the notion of time and the ideas were generated at the same time.

The process of P1 initiated by seeking the aspects in which the participant can work with. P1 identified the two aspects of "form/shape of object" and "time/signalling time" (P1, 00:00:17) and prepared two *Process Sheet*s in order to develop the reductive process separately. P1 then found the new theme, "material reduction". Here, P1 stated that the sheet titled "shape" will no longer be used since the form of the object is naturally reduced following the reductive process on the other themes: *"I actually really don't like the 'shape reduction'. (...) I would just go for the "time" and "material" reduction and then the form will reduce by itself." (P1-F, 00:01:40).* P1 started the process on the *Process Sheet* focused on the theme of "time/signalling time" by drawing the simple square clock with the clock hands. P1 then focused on the clock face and conceived the idea of a clock in which the numbers rotate to indicate the time instead of moving of the clock hands (Figure 192). P1 stopped this thinking avenue at this point and developed a new thinking avenue.

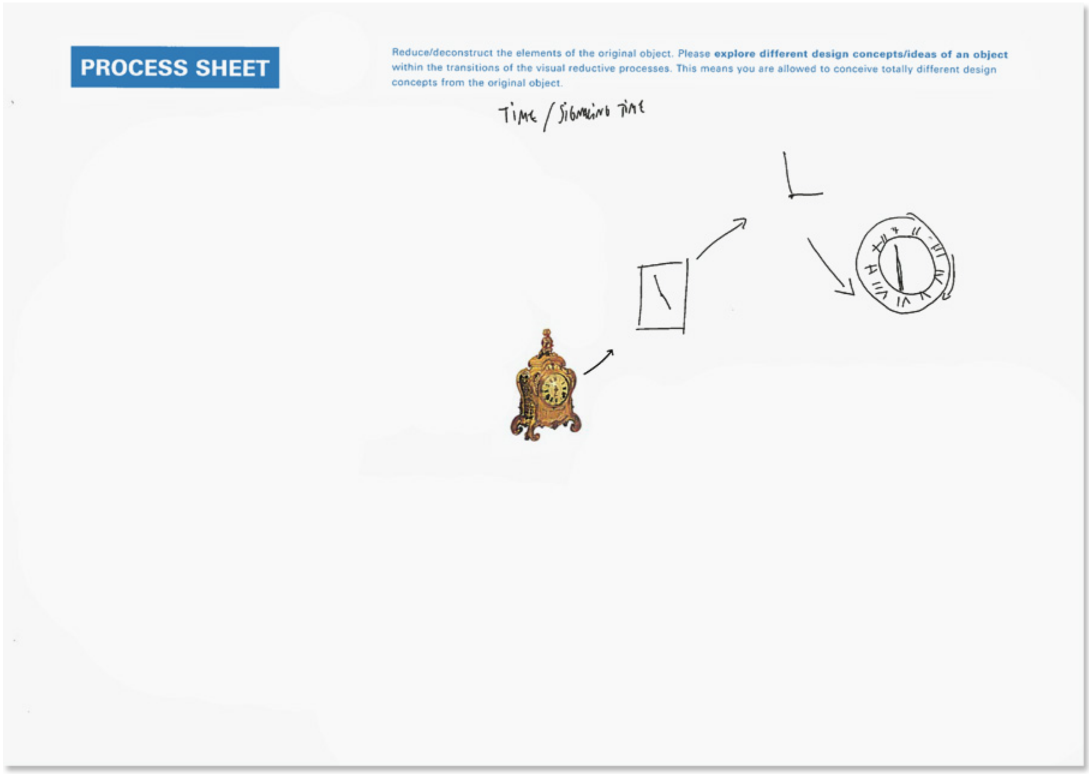



*Figure 192. The process of P1 at 00:03:52.*

P1 then came up with a new concept "historical reduction". This concept implies that the technological regression is regarded as a way of reduction: *"And then there is "historical" reduction and then you go where implies, for instance, using less technology and involving a sundial (...) you just don't use any mechanics (within the sundial) so it's sort of reduction." (P1-F, 00:03:58).* This approach allowed P1's to consider primitive clocks e.g. a sundial or a sand clock. P1's process continued and other concepts "body time" and "aging" were found. The key concepts identified were also reinterpreted into other relevant notions such as sleeping and waking or a cock bird crows in the morning (Figure 193).

At this point, P1 reflected the processes that had been developed and stressed the difference between "reducing" and "removing" (P1-T, 00:06:35). P1 considered that the first thinking avenue where the original clock was reduced to the simplified form was the act of "removing" the elements. However, in the following thinking avenue where P1 focused on the aspect of "signalling time", P1 was "reducing" the elements of the object. It appears that P1 found that the act of reduction means not just getting rid of physical components of the original prompt but rather reducing the concepts that the object implies into more primitive or essential notions.

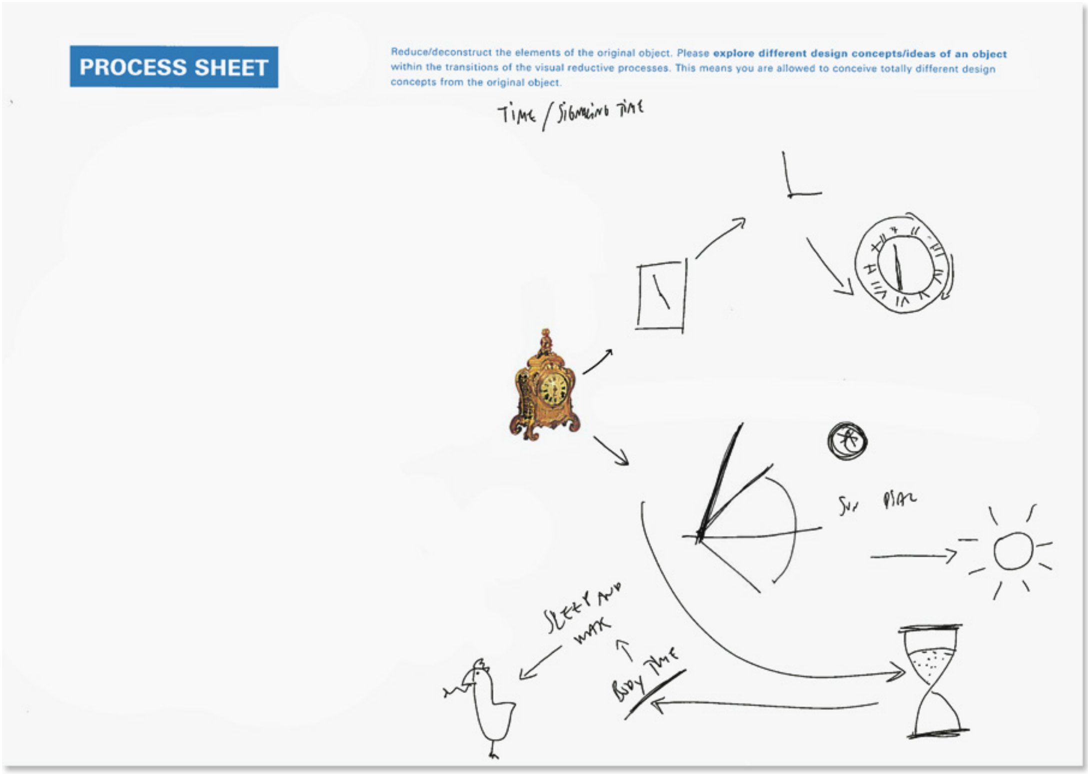



*Figure 193. The process of P1 at 00:06:31.*

P1 then envisaged an annual growth ring by combining the two key concepts: “materials” and “signalling time”. This reasoning process also allowed P1 to discover another concept “the materials that change over time”. P1 further conceived the technique of “oxidizing” based on the concept discovered. At this point, P1 found that what P1 had been doing so far was examining the conceptual aspects that the original object involves rather than designing its form:

> *“I think it’s interesting when you do this (reductive process on the sheet), you also understand how you work. It’s not about designing process. When we started examining things like time, we are not interested in formalization of it (the aspect of form of the object). But I think I am more interested in the idea behind. The concept of time” (P1-T, 00:08:13).*

P1 further described that what P1 regards the most important was the functionality of the object so that all the ornamental elements immediately became the target for the reduction (P1-F, 00:09:11). Therefore, P1 naturally conceived the state of the object whose elements were ultimately reduced. P1’s focus was shifted to the conceptual aspects of the object when the most essential elements, i.e. the clock hands and the mechanism, were eliminated (P1-T, 00:09:45).

At this phase, P1 decided to shift their focus onto the aspect of materiality. P1 then split the space of the *Process Sheet* into two areas by drawing a line (Figure 194).

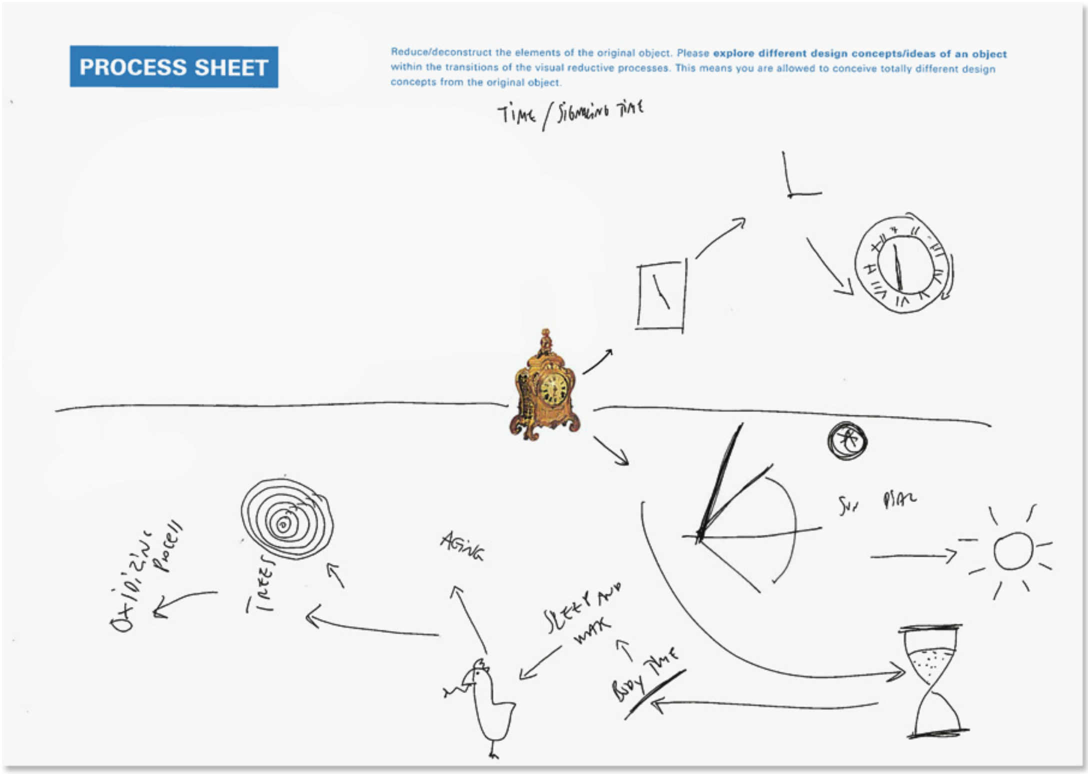



***Figure 194. The process of P1 at 00:10:18.***

P1 then reflected the processes that had been developed again. In it, P1 described the importance of questioning about the object itself by abstracting the meaning of the clock:

> *"(...) here (the first thinking avenue) we are reducing the object. Here (the subsequent thinking avenue where the sundial was depicted) we are thinking about time. So here we are not questioning about this object. We just accept that it is a clock and here we are thinking about time. It's the abstraction of the clock. If I can reduce this (original clock), then I can just have two clock hands on the wall with the box for the mechanism. That will be enough but maybe that's not the reduction I like. So, maybe there can be other different kinds of reductions" (P1-F, 00:10:25).*

This appears to suggest that P1 quickly predicted the limitation of reducing physical aspects of the object at the early stage of the process. Additionally, questioning the meaning of the prompt object on an abstract level allowed P1 to explore various kinds of reductive approaches. P1 continued the process with generating a question based on this thought*: "The ultimate reduction* *of the object as physical is the hands and the mechanism. Then, if you start taking off things what could it become?" (P1-T, 00:11:42)*. Then, P1 focused on the transparent cover shaped convex lens for the clock hands of the original object, and developed their design reasoning with it. P1 conceived the idea where the time is shown by means of the phenomenon of burning lens.

P1 previously dismissed the physical aspect of the original object. However, P1 changed their mind and decided to reinvestigate the physical aspect of the object here (P1, 00:13:24). P1 focused particularly on the "heaviness" of the object. This interest in the impression that P1 perceive from the original object led P1 to the idea of a clock tower. P1 drew a sketch of a clock tower and inferred the relevant concepts:

> *"(…) But, in away I kind of like it so heavy. So for instance it would be nice to make very… heavy object" (P1-F, 00:13:26). "May be we should create more… like a (clock) tower" (P1-T, 00:13:35). "Yes, if you think about… in the public space… that's interesting observation. (drew a clock tower) in the public space, you have a gigantic tower which is that a clock and a bell which signal time. Of course it's for ritual but it's interesting if it's for something abstract this time you make it even in an architecture." (P1-F, 00:13:43).*

This reasoning process allowed P1 to conceive the idea of "a room for time" (Figure 195). In this idea, the space is designed only for telling time with the gigantic clock hands. The key concept of "public time" discovered within the reasoning process seemed to be important for P1. In fact, this key concept was used in the new *Process Sheet* as a theme.

At this phase, P1 moved to the new *Process Sheet*. The process was started with the theme "public time" and several important keywords that had been discovered in the previous *Process Sheet* were written around the original object. It appeared that P1 was organising the key concepts/keywords found and built a new thinking avenues on them with the new theme: public time. P1 then sought routine events happened in P1's daily life. P1 attempted to consider these events that regularly happen as an abstract representation of time: *"There are also, certain kind of things that are again abstract. Certain things, for example, when the shop opens everyday at the same time, or certain noises on the street. For me, they are signalling of passing of time" (P1-T, 00:18:13).* This focus on the daily events also allowed P1 to consider the sensory aspect of human beings e.g. smell and hearing. P1 further continued recalling memories regarding the moment when P1 can feel time: *"think about when you are in Paris or in Italy during the breakfast, you know, coffee in the morning… yeah, there is this kind of a smell that tells you it's time" (P1-T, 00:18:43).* P1 considered this phenomenon where a person perceives time through senses as an ultimate reduction of a clock.

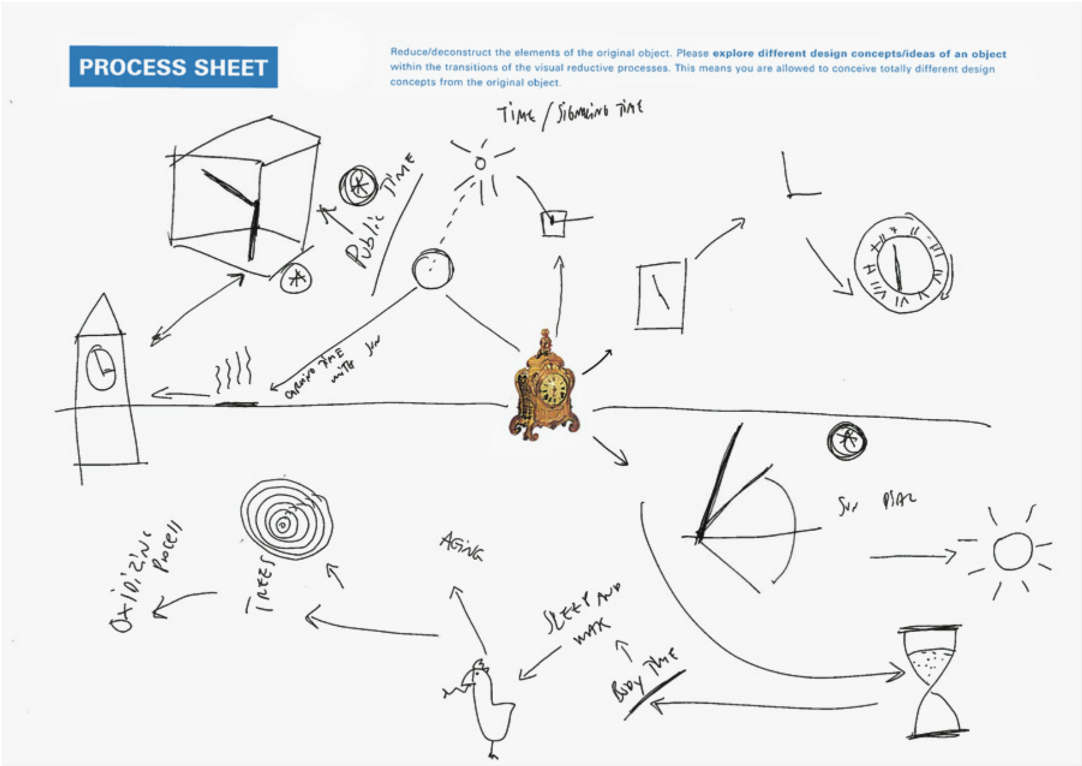



*Figure 195. The process of P1 at 00:16:01.*

Based on this thinking approach, P1 discovered the key concept "using the senses to understand time" and wrote it down on the *Process Sheet*. P1 also referred to the experiences that P1 had at home: *"Well, here, the architectures help us a lot because that (sunlight) help us to wake up in the morning because it comes from the top" (P1-F, 00:20:23). "Yeah, and there are some birds like all the time screaming at the same time" (P1-T, 00:20:35).* Following this, P1 discovered the keywords "sunlight/architecture" and "sound". P1 then realised that these keywords are relevant to the key concept "body time" that had been discovered before. P1 listed these key concepts on the *Process Sheet* (Figure 196).

P1 returned back to the original prompt and developed a new thinking avenue, focusing on the keyword "sound". P1 associated with a classic cuckoo clock in the first place and conceived the idea in which a cuckoo generates different sounds every half an hour. Then, the keywords "sound clock" was discovered. This idea was polished within the dialogue of the participants:

*"Maybe it will be sound clock then. It's like the old cuckoo (...)" (P1-T, 00:21:36). "Maybe that would be nice. Instead of singing only at 12 o'clock, we can have different sounds throughout all the day. That's nice. Every half an hour you have half sound (...)"(P1-F, 00:21:50). "It's a sound amplifier…"(P1-T, 00:22:24). "Could be an amplifier but you can also translate it just in sound. Instead of having… a reading the clock, you just get information coming" (P1-F, 00:22:30).*

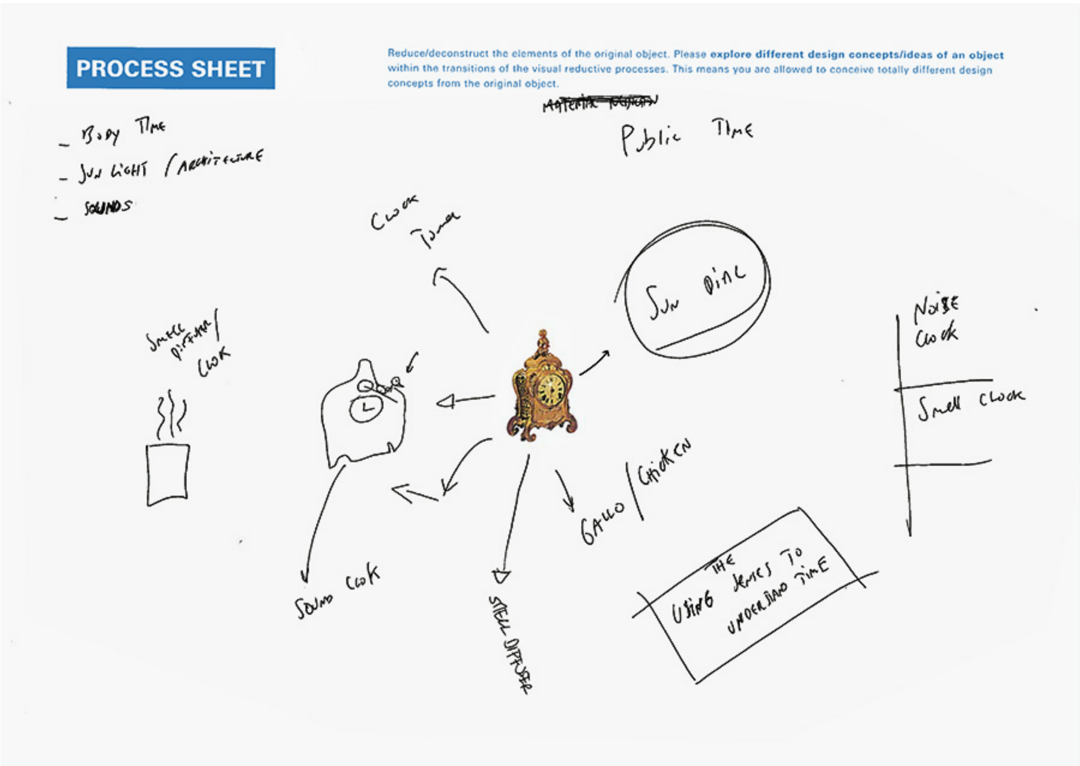



***Figure 196. The process of P1 at 00:24:39.***

At this point, P1 returned back to the concept that P1 discovered within the reminiscence; *"the smells that suggests the time during the day."* Again, P1 remembered the moments when P1 smells something that suggests a particular period of time during the day. Recalling those memories led P1 to realise the fact that the factor of smell can play a role of indicating the time:

*"(...) the smell is even better to understand that (time). In the morning, there is like a… the smell of like sweet stuff and coffee. (...) in the morning there is like a smell of more fruity one and coffee again. And then, there is… during lunch, you have certain salty stuff. (...) you know before going to sleep, there is a tea or camomile smell that are indicating you the passing of time. It would*

*almost be like a smell diffuser. (...) again, the "ultimate reduction" is almost like a smell diffuser" (P1-T, 00:22:55).*

P1 jotted down the two keywords "sound" and "smell" on the *Process Sheet*.

Then, P1 returned back to the thinking avenue where P1 focused on the materiality and moved to the new *Process Sheet*. This interest in the aspect of materiality encouraged P1 to look into the original prompt. P1 attempted to understand what elements were included within the original prompt by drawing the original clock. P1 particularly focused on the materials that are possibly used in the original prompt. Within the process, P1 imagined how a classic object made of metal such as bronze is oxidised over time and considered it as a sort of reduction (P1-F, 00:25:58). P1 also considered the time taken to naturally change the state of materials and the time informed by a clock separately: *"(...) it's the time of the material. It's not our time. (...) this is human time (pointed out the clock face)... right? Because we decided what it is. This is our (social) code. But which is the 'time of the material'? " (P1-T, 00:25:41).* This focus allowed P1 to conceive the idea of a bronze clock whose surface visually represents the oxidising process of the material:

*"(...) a block of bronze with a time. Here, (clock face) you read the time. Maybe you have here (the side surface of the object)... different stages... oxidising processes..." (P1-F, 00:26:52). "They show the passing time of the material..." (P1-T, 00:27:09). "Yeah, I wonder if they could... here you could have sort of a legend of the colour that changes over time. So, if a clock changes from this colour..." (P1-F, 00:27:12). "That means it's been done..." (P1-T, 00:27:22). "Yeah it's 30 years or 20 years. That's nice" (P1-F, 00:27:24). "Something that is signalling how the time passed... not for us but for it (the object)" (P1-T, 00:27:29).*

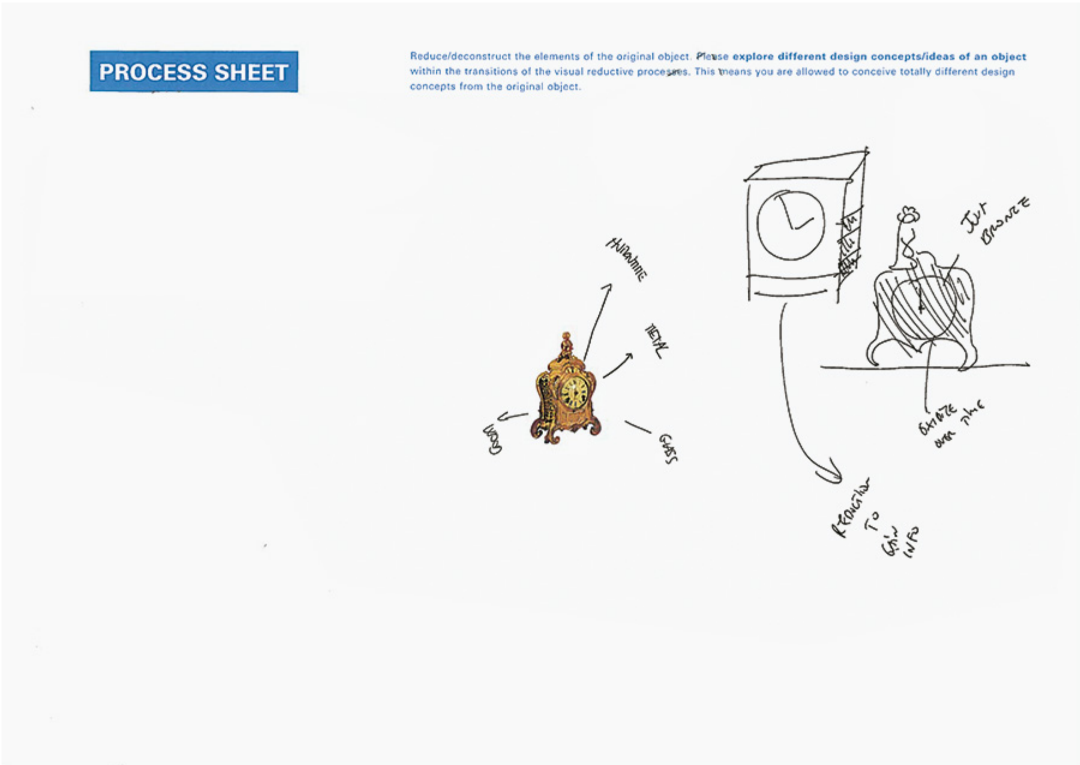
Within the ideation process, P1 discovered the key concept "you have a reduction in form but actually you have more information" and wrote down "reduction to gain information" on the sheet (Figure 197). P1 further described that the corrosion process of the material as reduction increases the information that the object includes:

*"To have reduction to gain more information. Physically reduced. It can also be just a plate of bronze... and because the plate has been oxidised in time if you would have different samples of tones of colour that is corresponding to the passing time of the bronze. Let's say you could read more information in*

*this object (the bronze with colour tones) than in that one (the original)" (P1-F, 00:27:58).*

This thought also made P1 realise the fact that the way the "style" that the original prompt represents (Rococo style in this case) is perceived at the era when the object was produced is transformed into something different at the present day. This fact implies that objects essentially updates and varies its attribute information across the ages. P1 then wrote down the key concept "style as time signal".

*Figure 197. The process of P1 at 00:27:59.*




At this point, P1 reflected the processes and decided to select one of the directions in order to further continue the process and the key concept "signalling time through the material" was chosen. P1 then continued considering the relationship between changes of time and natural materials. The materials such as marble and limestone were conceived as well as natural phenomena e.g. sedimentation. P1 stated that this relationship can be found in any natural materials and it enables the viewer to visually perceive time in itself:

*"we are just more thinking of the materials where the element of time is already there… in the material itself. For instance, in wood, if you had a tree you can read the passing of time, you can read it in the oxidizing of metals, you can read it in sedimentation of rocks. You can read time… and what else? Of course*

*I guess, on a scientific level, you can read it (time) almost everywhere. But definitely those ones (wood, stones etc.) are visually readable" (P1-F, 00:31:35).*

P1 then finished the process (Figure 198).

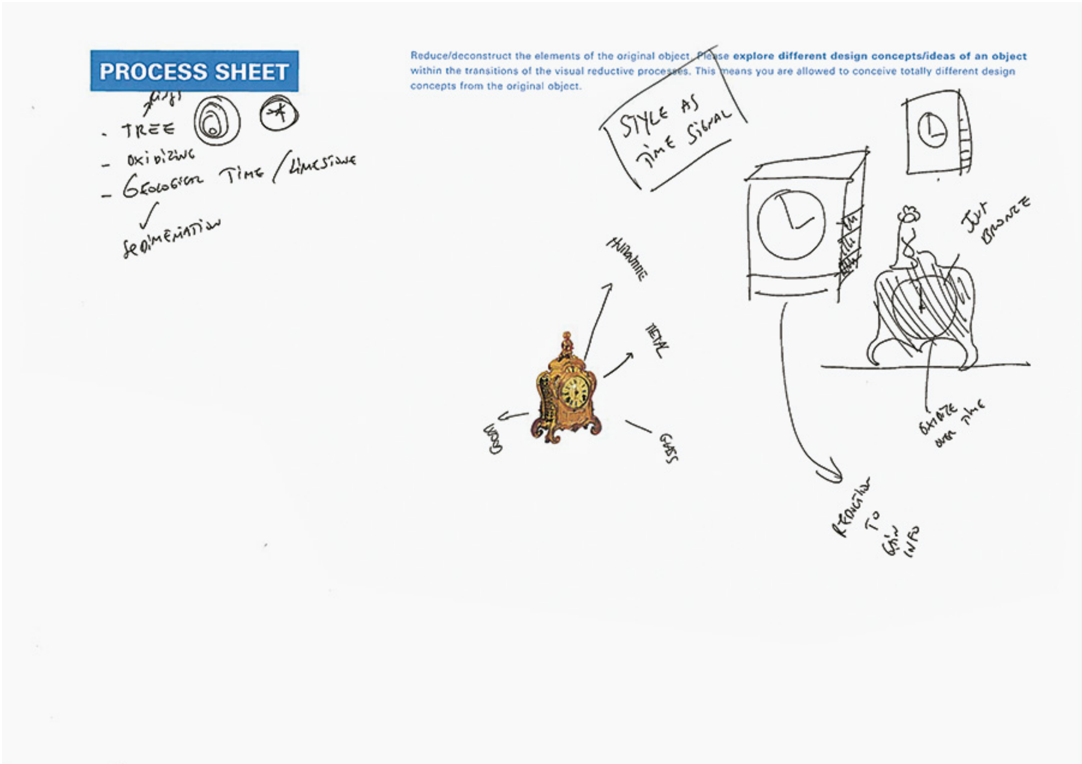



*Figure 198. The process of P1 at 00:33:34.*

## 4.8.4.2 The Participant P1 Summary

One of the prominent characteristics of this participant was the way in which P1 initiated the process (Figure 199). Instead of addressing the original prompt immediately, P1 sought the themes for reduction to begin with. In the interview conducted after the task, P1 described that it was important to consider what the reduction means for P1 in the first place (Interview, P1-F, 00:01:30). Therefore, P1 prepared the multiple sheets that have different themes respectively i.e. "material reduction", "shape reduction" or "time/signalling time". P1 also stressed that setting up the themes as sub-category at the beginning of the process encourages the user of the *Process Sheet* to conceive different reductive approaches:

*"maybe if you notice something since the beginning… (...) staring with the categories could help (...) I think a lot of people, very very very traditional designers would probably go down with 'form reduction'. So, maybe starting with categories it could help people to develop different way of approaching towards reduction. Not only reduction as in form but as in technology or in materiality that would have never been considered before" (P1-F, 00:14:40).*

This fact appeared to suggest that it was important to be aware of which aspects of the original prompt should be addressed for reduction from the beginning. Setting up themes helped P1 to keep the thinking avenues consistent to some extent and the process was developed within the scope of P1's interest.

The reductive process of P1 was summarised mainly in the act of abstraction of the notion of time. Even though the P1's first approach was reducing the physical elements of the original prompt, P1 quickly shifted the focus to the conceptual aspects that the original object implies. Focusing on the conceptual aspects of the prompt allowed P1 to consider what the essence of the object is (P1-F, 00:02:33). P1 stressed that P1 attempted to consider not the "clock" as an object but rather the "time" as a concept (P1-F, 00:07:11). Reducing the conceptual elements, that are involved in the original prompt, by abstraction provided P1 more freedom in interpretation. P1 described this abstraction as the "process of cleaning up" where P1 got rid of preconceived ideas about the original prompt (P1-F, 00:08:24). The act of abstraction of the meanings of the original prompt led P1 to consider how to design a clock differently. This process of abstraction allowed P1 to discover several keywords and/or key concepts such as "body time", "using the senses to understand time" or "reduction to gain information", generating ideas simultaneously. These concepts subsequently prompted P1 to recall personal memories as a cue.

In conclusion, P1's reductive process was considering the essential factors of the original prompt by conceptual abstraction. Also, the conceptual abstraction provided P1 a freedom in interpreting the meaning of the original prompt and envisage ideas in a variety of ways.

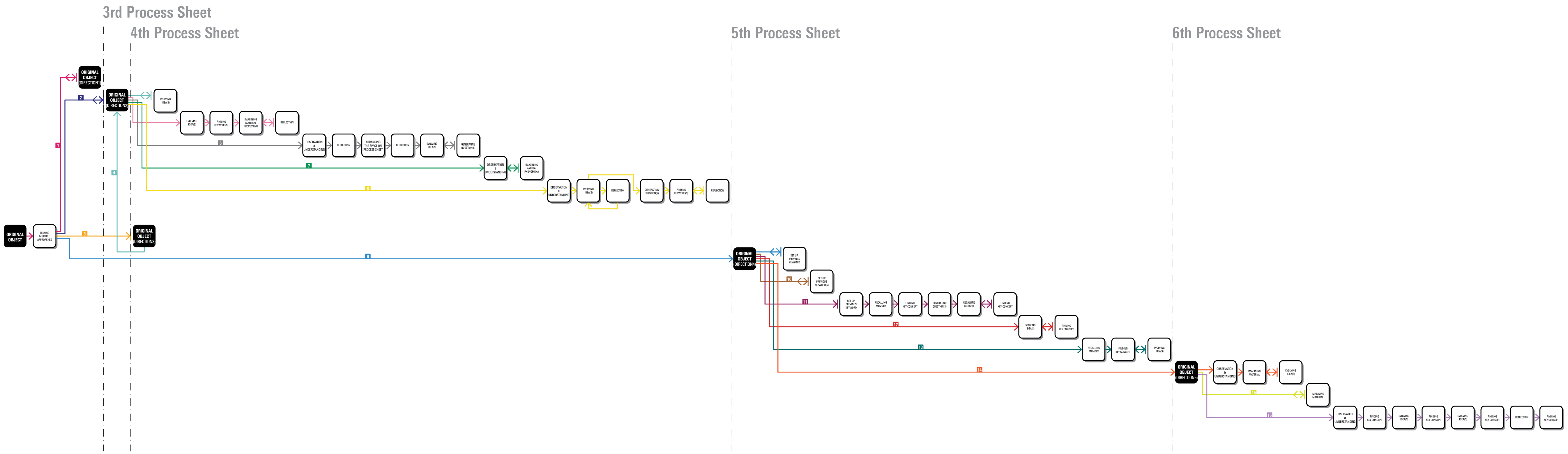



*Figure 199. The diagram that represents P1's reductive process.*

### 4.8.4.3 The Participant P2

The participant P2 was a mature German industrial designer in their late thirties. P2 was also the founder/the design director of their own design consultancy. P2 studied product design in their bachelor degree. P2 has fourteen years of professional experiences in industrial and interior design, and has engaged in more than hundred design projects.

The process of P2 started by drawing a softened and simplified silhouette of the shape of the prompt. Then, P2 developed a new thinking avenue where the individual components were featured. Within the process, each component was depicted separately, assuming manufacturing technique: *"(...) what I've seen is maybe one casting here (pointed the finger at the part underneath the clock face) or is actually made of different components… so they are more kind of solid elements I suppose (P2, 00:02:09)."* Following this, P2 develop the idea in which the individual components were further simplified and exploded. P2 then returned back to the previous thinking avenue and continued developing another idea in which the form of the clock is vertically stretched. P2 further developed the idea of a chest of drawers based on the shape of the stretched clock. Then, P2 returned back to the previous thinking avenue where the components were exploded, and continued developing further idea development, simplifying the form (Figure 200).

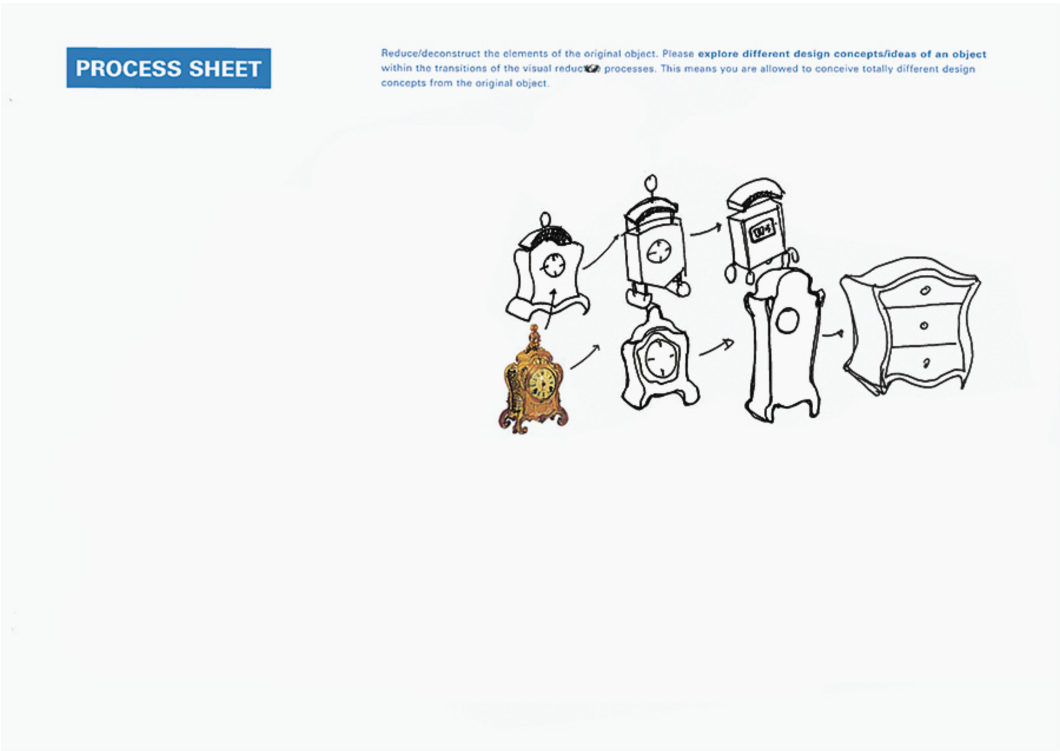



*Figure 200. The process of P2 at 00:06:36.*

P2 returned back to the original prompt and observed the feature of the form of the original prompt. In so doing, P2 focused on a part of the original prompt and interpreted into a cartoonish figure:

> *"I'm kind of looking at it (the original prompt) and thinking that it almost looks like ears. I'm kind of exaggerating it. It's got a curve on the outside (...) the appearance is becoming more of a person that it's got ears and maybe becoming like a hairstyle. It's got ears, hairs and it's got a face being a clock (P2, 00:06:52)."*

Following this, P2 further continued the reductive process. P2 remembered the cartoon character "Mr. Potato Head" based on the previous idea of the cartoonish clock and sketched the figure out on the *Process Sheet*.

P2 returned back to the original prompt again and continued developing the process. P2 attempted to simplify the decorative form into a minimal form. Within the process of simplification of forms, P2 conceived the idea of a container/pot by looking at the form created as a different object. P2 described that the idea of a container/pot was discovered within the process of deconstructing the components: *"The deconstruction feels that you can take the components off, looking at the image. It feels like 'you can lift' that is actually a lid that's how you would get into your clock (P2, 00:12:01)."*

P2 developed a new thinking avenue, returning back to the original prompt. P2 then developed an idea where the object has double functions: a clock and a container. In this idea, the user can use it as a clock but also can store or hide valuables or money inside of the object. Apparently, this idea was relevant to the last idea.

P2 again returned back to the original prompt and stared at it. P2 then described that the typology of the original prompt reminded P2 of a musical box that shares the similar features (P2, 00:13:40) and depicted the idea of the idea (Figure 201). P2 seemed to still be keen on the idea of "secondary function" within an object. P2 also described that the ideas were developed, being inspired by the top figurine (P2, 00:16:16).

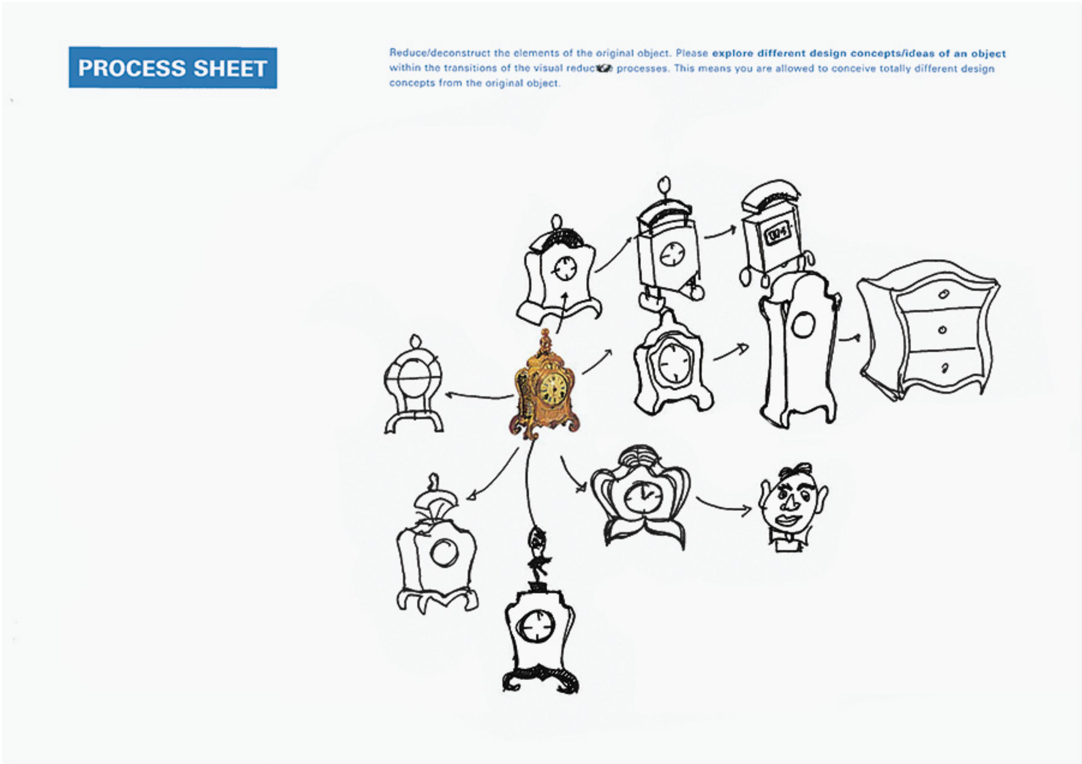



*Figure 201. The process of P2 at 00:16:16.*

P2 returned back to the original prompt here and developed a new thinking avenue. In this avenue, the side texture of the original prompt was focused and P2 associated with an animal pattern. Based on the association, P2 developed a digital clock whose surface has an animal pattern print.

At this point, P2 stated that the most favourite avenue is the first one where the components were simplified geometrically (P2, 00:19:45) and developed further idea based on one of the ideas that had been developed. P2 developed the idea of a clock that has a void inside of the silhouette of the original prompt and the clock part is suspended from the top of the structure. P2 then returned back to the one of the ideas developed on the same thinking avenue and conceived a classic dial telephone. P2 then returned back to the previous idea and developed another idea where the form was even more simplified. P2 described that P2 attempted to focus on reducing the elements rather than conceiving different category of object i.e. the classic dial telephone (Figure 202): *"I'm just reducing it (previous idea) to it. It's quite opposite to this one (the dial telephone) where it reminded me of a completely different product. I'm just making sure I'm reducing it to its simplest form (P2, 00:22:54)."* P2 suspended this thinking avenue at this point.

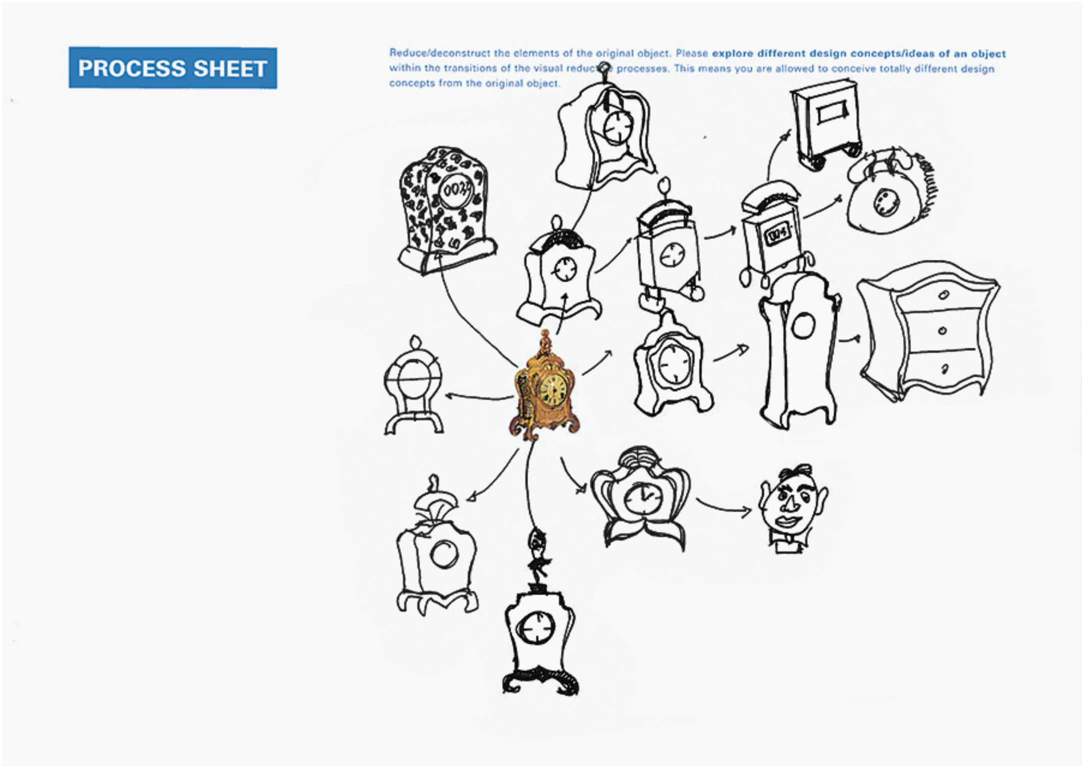



*Figure 202. The process of P2 at 00:23:18.*

The focus of P2 moved to one of the previous thinking avenues in which P2 found the idea of "secondary function" and continued further idea development. In this process, the form of the object became even more simplified and lost its characteristics of the original shape: *"Suddenly it loses its… extruded shape turned into be more spinning I guess… which is much softer (P2, 00:23:51)."* It appeared that P2 developed the idea of a storage into much simpler form.

At this point, P2 stated that P2 re-focused on the initial thinking avenue where P2 conceived the idea of a chest of drawers through the process of form simplification (P2, 00:24:55). P2 then developed an idea, focusing on the part of clock face of the original prompt. In this idea, the part of clock face was emphasised by extruding the form and that image encouraged P2 to further conceive an idea of a vending machine for chewing gum. Although the form of the vending machine was completely altered, some decorative features, such as the top figurine or the detail underneath the clock face, were kept and turned into the functional components in its design. The process of reduction further continued within this thinking avenue. P2 conceived a sphere shape with a dial on the top. It seemed the idea of this object had been conceived as it had no particular functionality. P2 then developed the idea of a stopwatch with a chain based on this sphere object. P2 finished the process here (Figure 203).

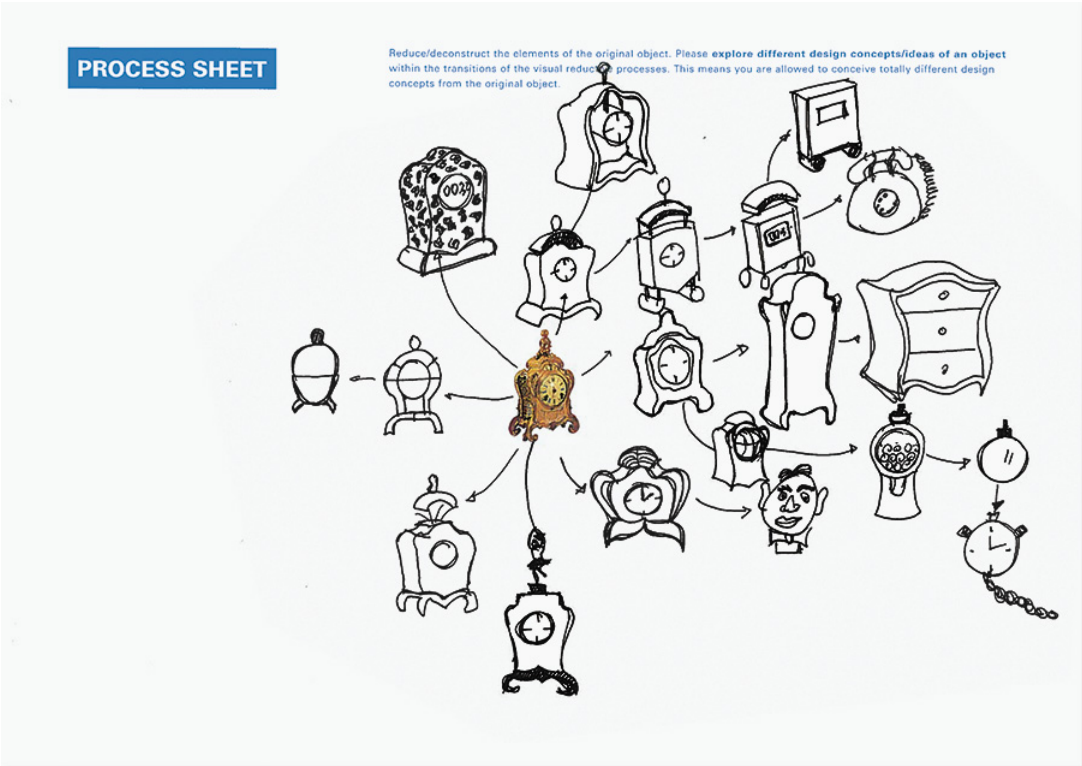



*Figure 203. The process of P2 at 00:30:54.*

### 4.8.4.4 The Participant P2 Summary

The reductive process of P2 was form oriented. Most of the thinking avenues were initiated with observing the features of form of the original prompt (Figure 204). The act of observation allowed P2 to consider physical aspects of the original object such as manufacturing, composition of the components and/or the texture on the surface of the original clock. The focuses derived from the observation were then used as a clue for subsequent ideation. The ideas were generated within the reductive process where the forms of the components were minimised, softened and reinterpreted (P2, Interview, 00:00:05). P2 also stated that the ideas were generated through the re-evaluation of what P2 drew: *"(the ideas were generated) by drawing or duplicating the shape and re-evaluating the shape where new ideas were formed from drawing it… you know, being reminded something else or being having references to other objects (P2, Interview, 00:01:30)."* It appeared that the ideas were generated within the sequence of reductive drawings where focused on the forms. P2 further described that the exercise of form reduction encouraged P2 to explore unexpected ideas:

> *"I didn't think I would derive certain elements to think of… coming from a clock to a toy or a chewing gum dispenser. (…) I was trying to get away from*

*thinking of what it is and mostly deconstructing it into whatever the shape might be or whatever it could turn into (P2, Interview, 00:03:30)."*

The ideas were developed by seeing the forms P2 produced another object. This act of "seeing as" encouraged P2 to conceive unexpected ideas that P2 have never conceived.

Another prominent characteristic was the fact that P2 often returned back to the previous thinking avenues that had already been developed and continued further idea exploration. P2 described the importance of suspending idea development and returning back to it later on: *"Probably looking at it (the ideas that has been developed) differently after a little bit of time and kind of... seeing something else in it to then take it further (P2, Interview, 00:03:00)."* Accordingly, the process of P2 became cyclical.

In conclusion, the reductive process of P2 was carried out through the exercise of form reduction based on the focuses derived from observation of the original prompt. The ideas were then generated through reinterpretation of the meaning of forms conceived through the act of "seeing as." Also, suspending idea development for a while within the process was the key to rediscover the elements as a clue that P2 had never considered.

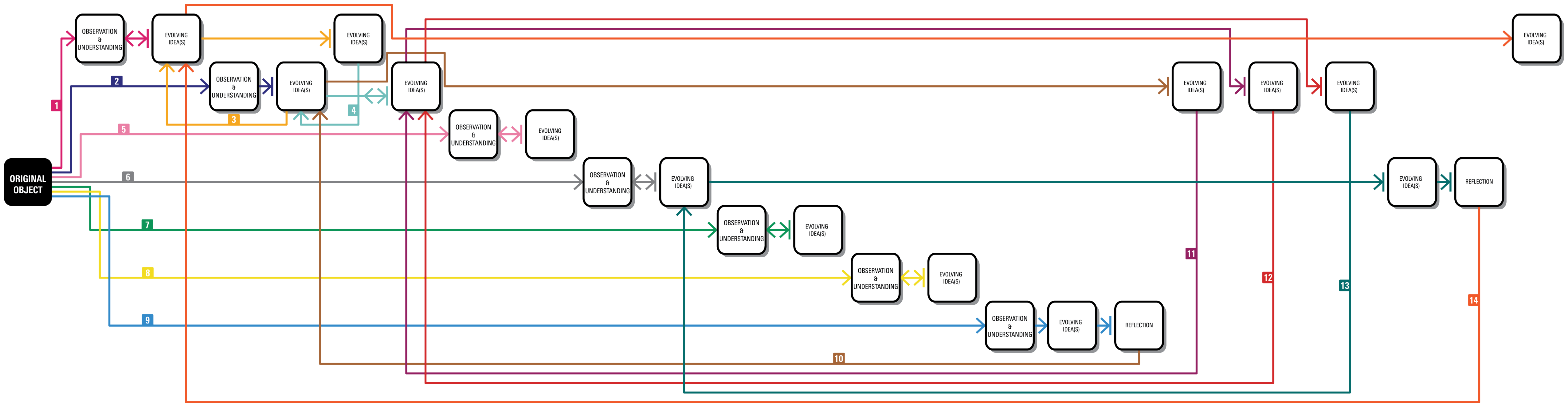



*Figure 204. The diagram that represents P2's reductive process.*

### 4.8.4.5 The Participant P3

The participant P3 was a mature British industrial designer in their mid-forties. P3 was also the founder and the managing design director of their own product design consultancy SC. P3 studied design and technology in their bachelor and industrial engineering design in the master degree. P3 has twenty-five years of professional experiences in industrial design and has engaged more than 100 design projects.

P3 initiated the process with extracting eight keywords ("purpose/function," "benefit," "implication," "construction," "make," "intention," "literal," and "value") from the original prompt in order to discover various ways of approaching. It appeared that P4 attempted to seek clues to develop thinking avenues by finding out the keywords: *"(...) the function, implication of what's doing, the way it's made, the construction… lots of different things how you interact with it. How it's being literal about deconstructing it and then you go from there (P3, 00:00:42)."* P3 then returned back to one of the keywords identified, "benefit" and continue to reduce the meaning of the word. The two notions, "telling the time" and "decoration" were identified through the process. Following this, P3 developed a couple of ideas of figuring based on the keyword "decoration." P3 conceived the idea of figurine that was composed of separate multiple figurines and this led to the idea of looking at the original clock, detaching the components (Figure 205).

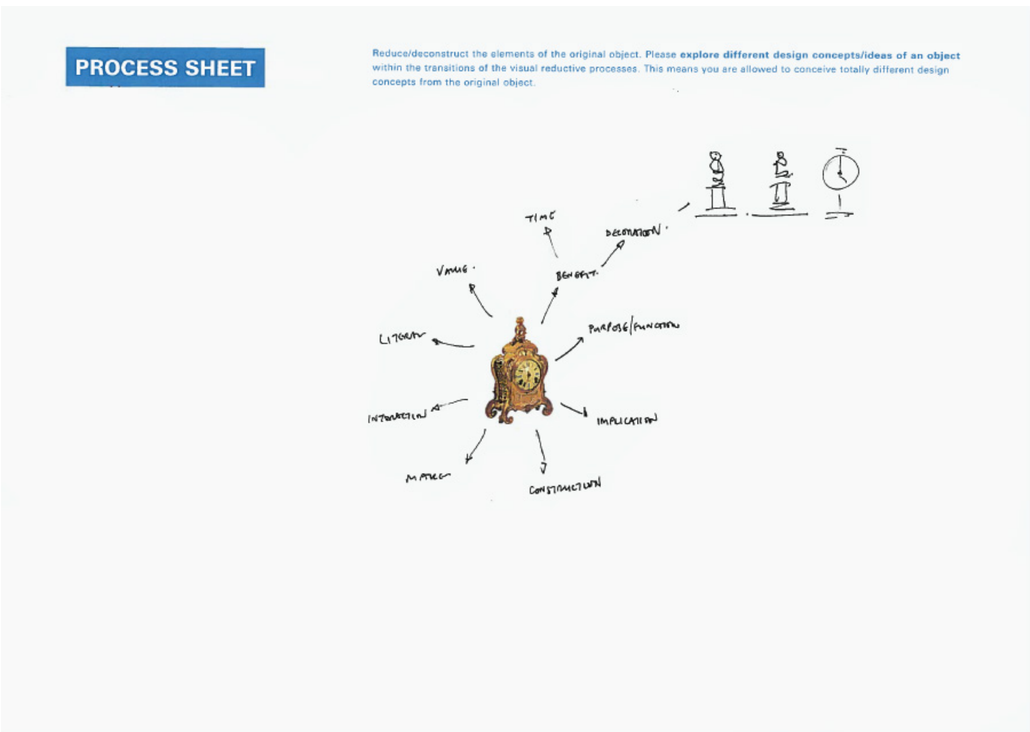



*Figure 205. The process of P3 at 00:02:13.*

P3 then returned back to the previous keyword "time," and conceived ideas in which the clock was simplified, observing the image of the original prompt. Following this, P3 also developed the idea of an object in which the decorative elements were reinterpreted and integrated into the modernised clock form:

> *"(...) I have it being very simply just the time and reinterpreted some of the decorative elements that's being more graphical so I just create those 2 dimensional, graphical elements within them. So, the decoration doesn't become part of the structure. It just becomes part of the face (P3, 00:03:01)."*

The focus on the idea of representing a clock also encouraged P3 to conceive a couple of ideas in which the time is displayed by a projector or is indicated by an audio device. Further, P3 also conceived the idea of a clock that is presented on a mobile phone display. P3 then extracted a keyword "centralising function" from the idea of a clock indicated on a mobile phone display. The process development was continued and considered another idea that a decorative clock was shown on a mobile phone screen.

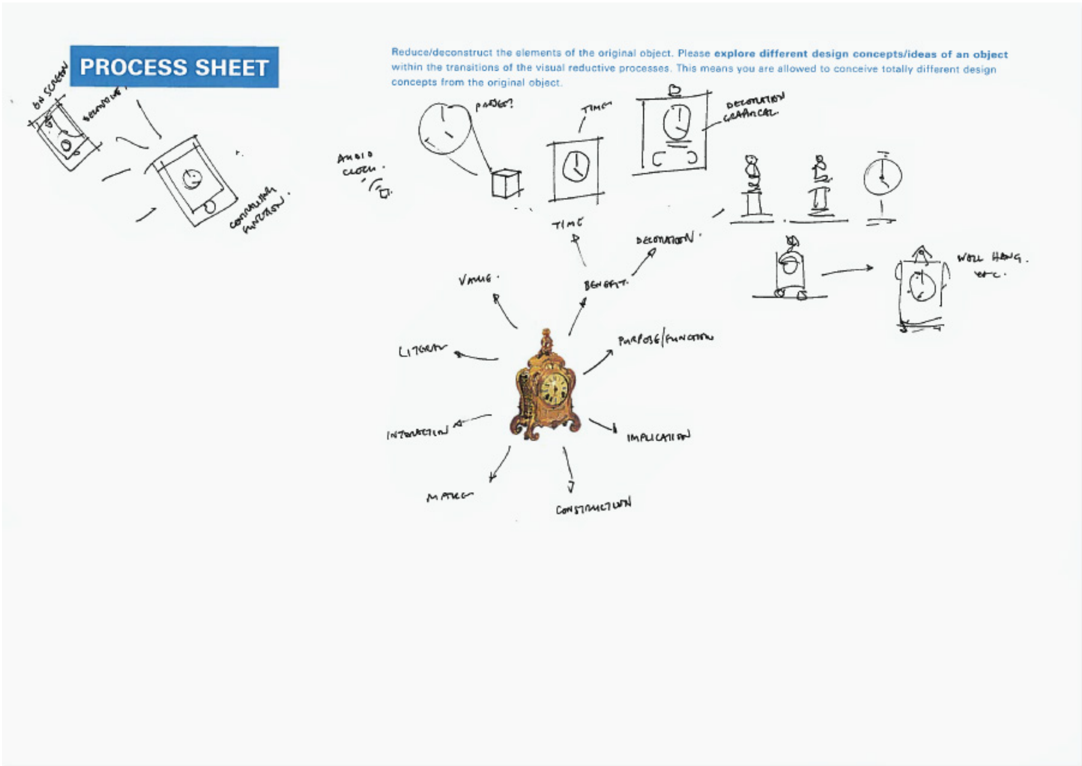
P3 then observed the ornamental aspect of the original prompt, returning back to the keyword "decoration," and considered *"how the decorations were used at that moment (when the object was produced) (P3, 00:05:20)."* Within this consideration, P3 envisaged an alternative way to place the original clock instead of standing on the surface with legs. P3 then conceived the idea of a clock that is hung up on the wall (Figure 206).

At this point, P3's focus shifted to the keyword "value" that was previously identified and continued reducing the concept. Within the attempt to simplify the concept of "value" of the original prompt, P3 specifically focused on the materiality of the object. P3 then conceived the idea of "removing non-precious elements other than gold material." The decorative elements were then removed and a simple clock that kept a few ornaments (i.e. the top figurine, the face and the legs) was developed.

A3 moved back to the keyword "literal" and developed an idea, observing the characteristics of the original prompt. P3 conceived a clock that consists of two flat surfaces bridged by pillars. Then P3 iteratively developed some ideas of form based on the same concept and linked one of the ideas with the keyword "make". This process also allowed P3 to consider manufacturing methods (Figure 207):

*"Some of that are about simplifying the way it's made. (...) think about... changing the materials so it could make... for example we could mould it or... if we mould or cast it, it goes to make it more of a one-piece and that is going to be different materials that are plastics and cast metals (P3, 00:09:23)."*

***Figure 206. The process of P3 at 00:06:08.***




P3's reductive process of form continued and conceived another idea that the surface of the front face of the clock is made by laser cutting. P3 suspended this thinking avenue at this point.

P3 then returned back to the original prompt and observed the ornamental details. P3 sketched out the graphical components on the clock face in order to understand the composition, and then developed another idea, reducing the elements: *"There are lots of details. (...) the details could also be... you can just take one element. At the moment, you've got seconds, hours... some scripts, some circles and you've got two winding mechanisms (...) take that (graphical elements) down to the steps (P3, 00:11:45)."*

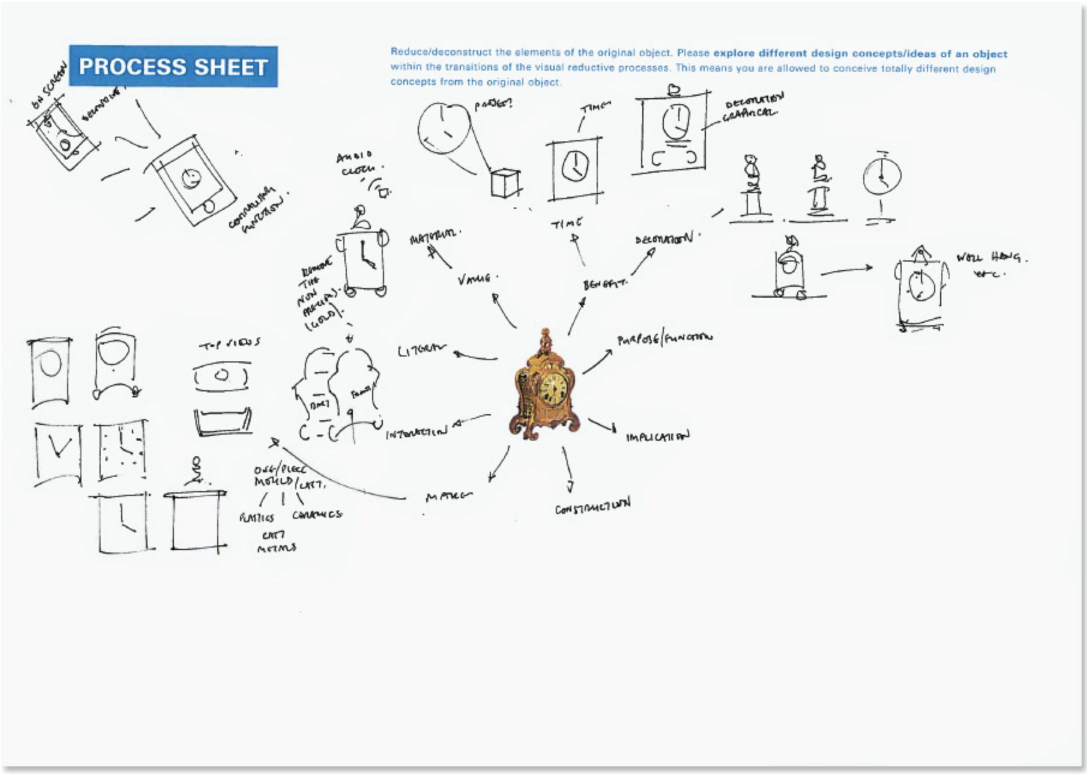



*Figure 207. The process of P3 at 00:10:10.*

P3 returned back to the original prompt again, and conceived a new keyword "aesthetic" after observing the object. P3 particularly focused on the form for reduction in this avenue. In this implementation, P3 sought and picked up the forms as a key element for reduction:

> *"you could simplify its form which is a bit of a challenge because it's quite complicated form as a role. We could say what we want to do is to look what the key elements are… into one thing you might say the key elements are… the figurine and the clock so we could simplify things like that (…) (P3, 00:12:30)."*

P3 conceived an idea of a clock that kept only the stand, the clock-face and the figurine. P3 further continued the reduction and developed a couple of other ideas (Figure 208). This iterative reduction was implemented, reducing the "numbers" of elements identified that constitutes the object: *"those elements could be simplified by looking at… that takes 1, 2, 3, 4, 5. If we are really talking about those 2 elements, we could just crop it and (…) reduces it down to the 2 elements (P3, 00:13:25)."*

P3 then returned back to the keyword "purpose/function" that was identified in the first place and conceived the idea of a simple digital clock. P3 moved to another keyword "implication" that was also identified before and continued the process. P3, however, stated that this process was still relevant to the keyword "purpose/function" (P3, 00:15:03). The concept of "implication" was further reduced and the notion of "gift" was conceived. P3 developed an idea of pocket watch by reducing the decorative elements, making the object more personal (P3, 00:15:37). Following this idea, P3 refined the idea of pocket watch, making the elements disintegrated, in which the figurine and the watch were separated. P3 described that this idea adds some values on the object, keeping the essential function as a watch (P3, 00:06:07). P3 further continued generating another idea within this thinking avenue and conceived a couple of ideas of a pocket watch with engravings that allows the user to add personal meanings to the object.

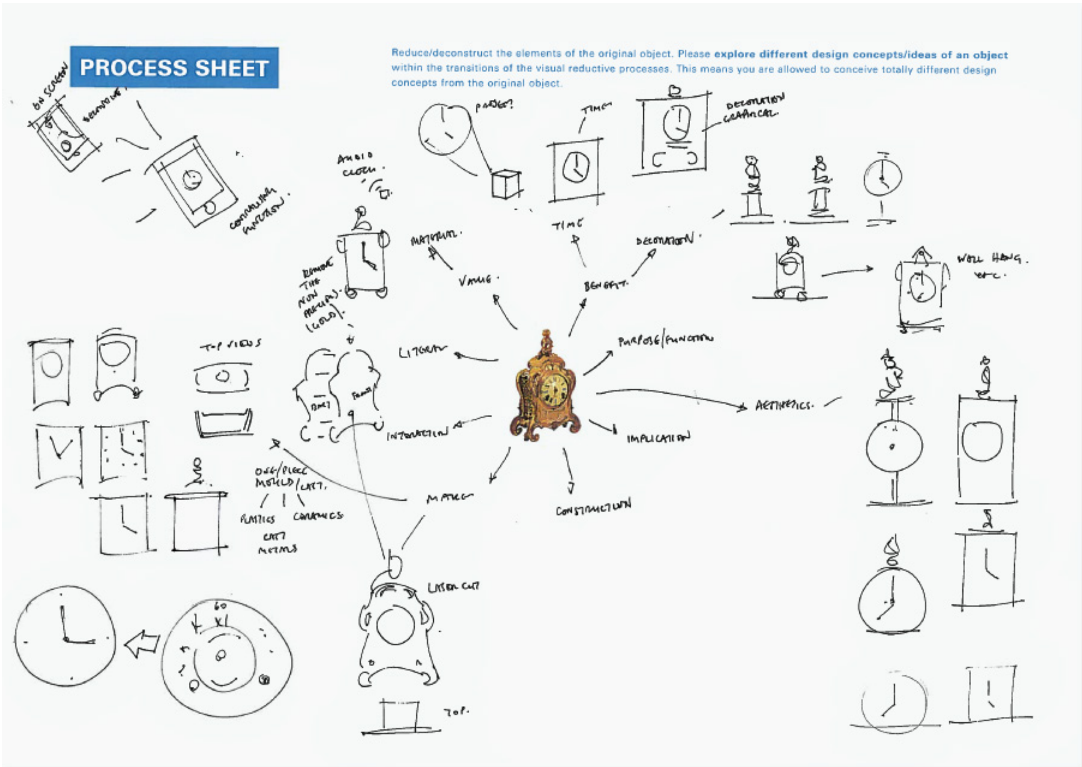



*Figure 208. The process of P3 at 00:14:29.*

P3 changed the focus to the mechanical aspect of the clock here. P3 identified that the original clock is a wind-up clock through observing and finding out the holes for winding keys on the clock face. P3 considered that technological evolution makes the object simpler (P3, 00:17:25) and then conceived a battery-powered clock. The idea of changing the mechanism allowed P3 to consider other technologies such as the sensors using sound or light (Figure 210).

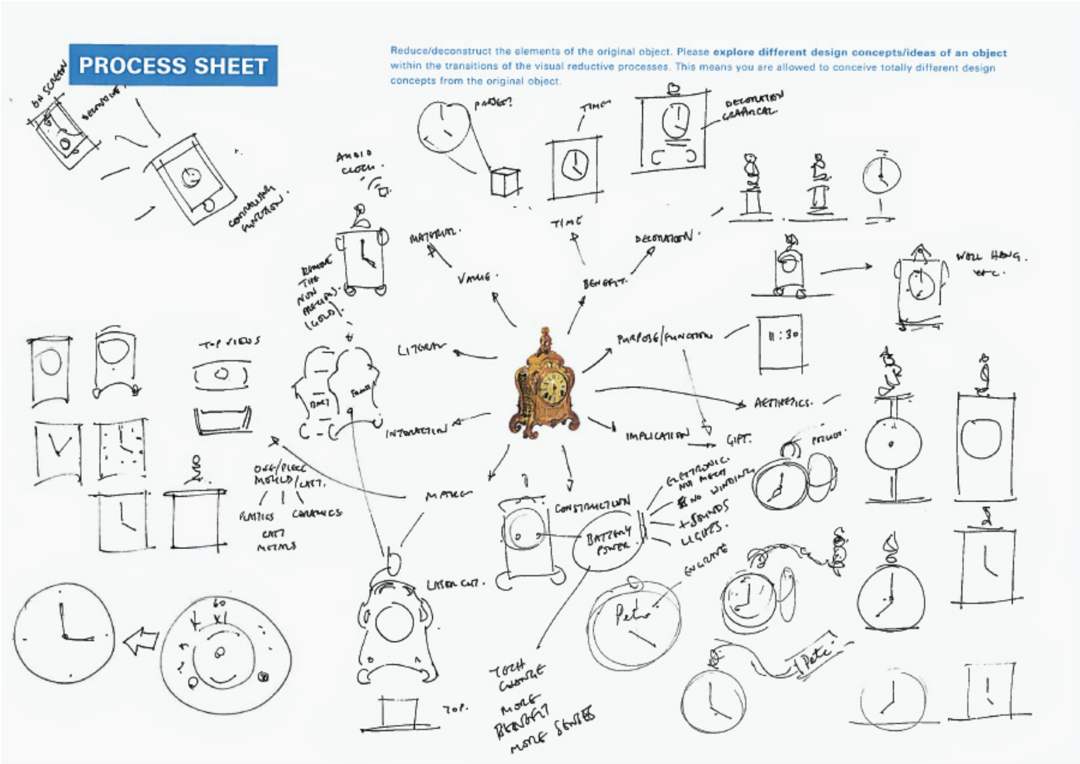



*Figure 209. The process of P3 at 00:18:56.*

P3 moved to the second *Process Sheet* at this point. P3 then conceived the keyword "decoration." P3 stated that the original prompt reminded P3 of an existing decoration and conceived the idea where the clock function is integrated with another object:

> *"This reminds me of, on the decoration side, particular kinds of decoration so you could start to say this could be (...) wall pater plus clock. It's got a roll of wall paper and that wall paper has got a decoration on it and that creates a pattern. You could also supply a clock separately. The purpose of this clock is to link art movement or design period. (...) that could be Rococo but (...) that you could offer Art deco, Art nouveau, Gothic (...) whatever that decoration might be, you can choose again to link the decoration to a period (P3, 00:18:55)"*

Following this, P3 discovered another keyword "buy" where the relationship between the consumer and the object conceived (a wall paper with a clock) was considered. P3 quickly associated with relevant and practical ideas when it is actually sold such as how it is produced, ordered, customised and so on (Figure 210).

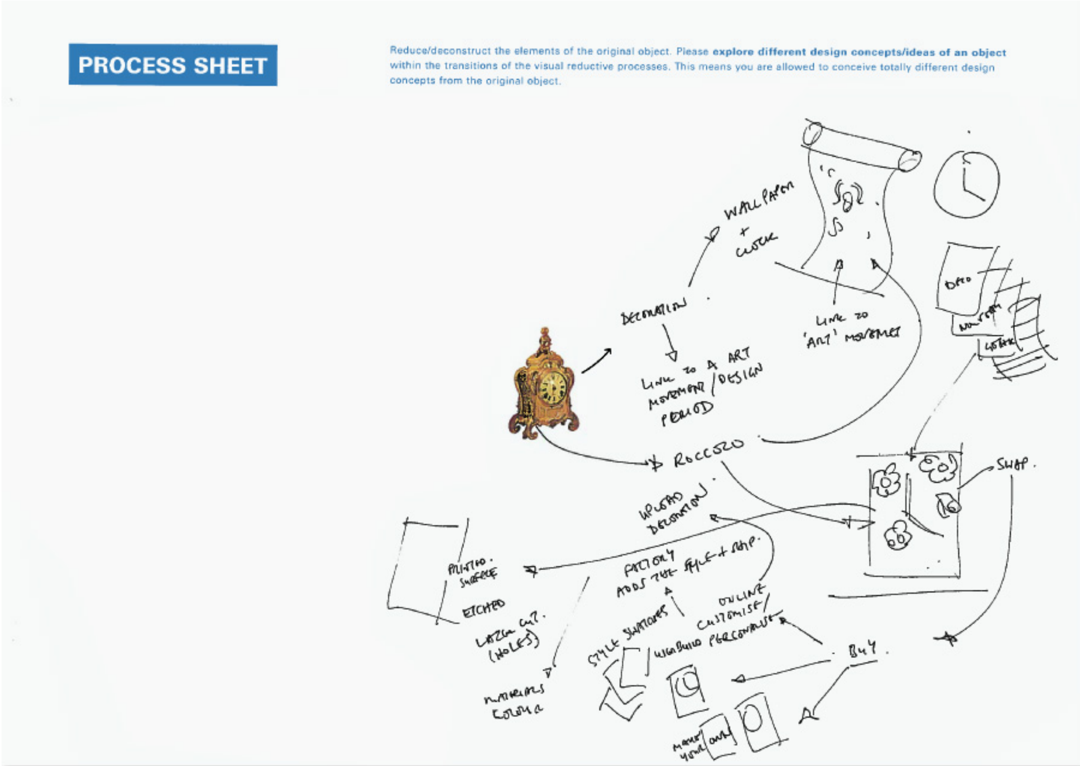



*Figure 210. The process of P3 at 00:23:41 on the second Process Sheet.*

P3 returned back and observed the original prompt again and stated that the object is not about the functionality but the decorations (P3, 00:23:50). P3 then wrote down the phrase "time telling vs decoration." It appeared that P3 considered the functionality and the ornament of the original prompt separately as the dichotomy. This thinking approach encouraged P3 to conceive the idea where the object can be customised with a variety of different parts. P3 called this idea as "Mr Potato Head" (P3, 00:24:42) which is the famous American toy consisting of a plastic model of a potato which can be decorated with a variety of plastic parts that can attach to the main body (Wikipedia). In this idea, the object consisted of several separate components and the user builds the decoration by attaching the parts. P3 stated that this knockdown system realises the cost reduction and visual consistency of the product at the same time (P3, 00:25:58).

P3 then return back to the original prompt again and observed it. P3 considered how to improve the original prompt by making good use of the "complexity" of the object rather than modernising the elements by simplification:

> *"Generally, I don't like the idea that, in order for design to become progressive, it always has to be simplified and made into a modern piece. The purpose of this (original prompt) is partly (...) in its complexity so one of the things to*

*think about is to keep the complexity and improve the efficiency of construction (P3, 00:26:22).”*

P3 continued to reduce the key concept “keep complexity improve the efficiency of construction” and conceived the other keywords “offshore manufacturing.” This thinking approach encouraged P3 to think about the practical issues regarding manufacturing such as how and where the object is produced, who makes it or how to increase the production volume.

P3 returned back to one of the thinking avenue where focused on the manufacturing methods and materials on the first *Process Sheet* and added some other processing techniques i.e. spraying, coating or moulding.

P3 then returned back to the original prompt and observed it. The keywords “change scale” was conceived. Following this, P3 quickly moved to another thinking avenue where the ideas were developed based on the keyword “aesthetic” on the first *Process Sheet*. P3 then developed an idea of a clock by changing the scale of some elements: *“In making it simple, you can also change the scale of it. (...) you can change the scale of the timepiece so it keeps its overall size but scale up some elements (P3, 00:28:47).”*

Again, P3 observed the object, returning back to the original prompt. P3 assumed that the original prompt has the clock faces on the both front and back sides. This assumption encouraged P3 to conceive the idea of a clock that has multiple clock faces (Figure 211). P3 stopped the task at this point.

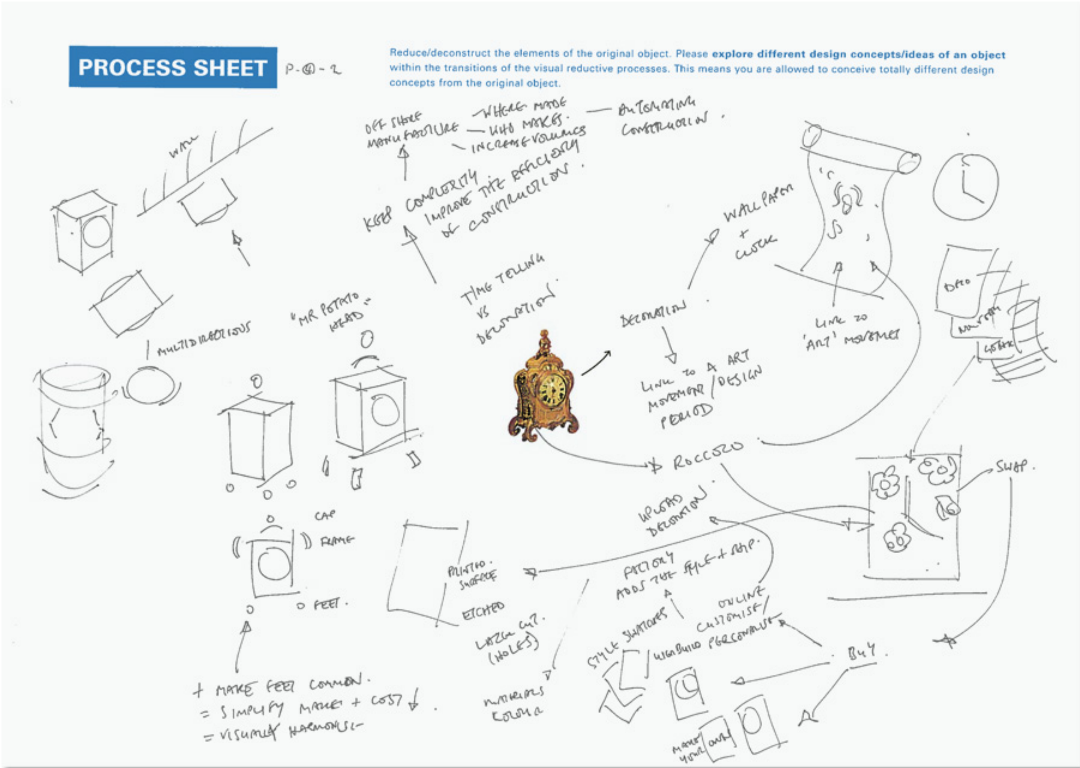



*Figure 211. The process of P3 at 00:30:37 on the second Process Sheet.*

## 4.8.4.6 The Participant P3 Summary

The prominent characteristic of this participant was that P3 developed the reductive process by finding out keywords/key concepts and observing the original prompt simultaneously. P3 extracted the relevant notions regarding the original prompt as a key concept at the very beginning of the process. P3 sought the ways to approach the concept of reduction through this action:

> *"I think I was started thinking about… starting off for what could be reduced and also what it was for so I tried to think a little bit about just different ways of thinking about it. So, thinking literally what it is, thinking about how we interact with it, thinking about what it is for, the benefit and then went on to thinking about the way it's sold the way it's made (P3, Interview, 00:10:05)."*

The keywords or key concepts discovered defined P3's focus for reduction and they were then used for further observation of the prompts or idea generation. For example, P3 focused on the mechanical aspect of the original prompt based on the keyword "construction" and conceived the idea of a battery-powered clock, identifying the winding mechanism of the original object through observation. This characteristic was observed throughout the process. Thus, P3 developed each thinking avenue based on the keyword/key concept discovered and the focus changed after exploring the particular thinking path up to a point. The process was developed going back and forth among thinking avenues where focused on different aspects of the original prompt (Figure 212).

Additionally, P3 often observed the original prompt. The observation was conducted right after finding keywords. Or, keywords were discovered through observation. The original prompt was closely observed from multiple angles not only focused on the physical properties but also on the semantic attributes of the object. The meaning of "reduction," for P3, was not merely taking elements away from the original prompt but rather reducing the complexity of the object, taking advantages of its charm:

> *"I think part of the purpose of that clock is to be of the style and so I wanted to increase something that maintained the idea of being decorative because it was about reducing and deconstructing the elements. Maintaining the appeal of something is complex and decorative and that's part of the appeal of it. As soon as you take away some of the context of that, it stops being what it is which is a Rococo decorative clock. So you are loosing it (P3, Interview, 00:01:57)."*

P3 further described that the original object is not just a device for telling time. Accordingly, just conceiving the idea of a clock, dismissing the attributes of the original prompt loses the essence of it: *"The reason of this clock exists is not just tell the time. So, to reduce it down to just a timepiece misses the point of what this was about (P3, Interview, 00:05:00)."* Hence, it was important to engage the reduction, being aware of the essential characteristics of the original prompt within the process.

Further, the observation also prompted P3's imagination regarding the socio-cultural background behind the era in which the object was produced.

> *"It made me think about the role of man and woman. This is coming from the pointing time when women looked after their home and men had to work so the idea of this (Rococo clock) partly comes a pride in a home and men designed machines and women decorated their house and there's a clash of machine and decoration (...) There's a masculine history of inventing a clock. There is then feminised by men in the way it's been designed. (...) if you want to explore things around that, you also have to think about creating things that dictated*

*by the way where they were made because if you would have this today, it would be very different and the difference would be social and cultural as well as technical (P3, Interview, 00:15:05).”*

The cultural attribute that the original prompt implies allowed P3 to consider the role of object in a wider perspective, referencing different states of society.

In conclusion, the reductive process of P3 was keyword/key concept driven approach through identifying the essential factors regarding the original prompts. Also, the in-depth observation about the original prompt from diverse angles including socio-cultural or physical properties was also the key for finding out key concepts and also for generating ideas within the reductive process.

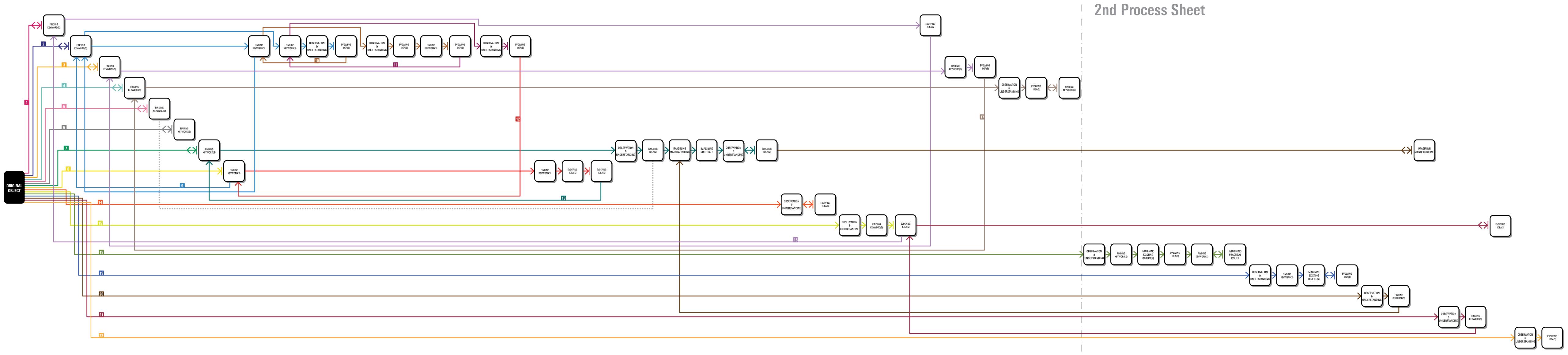



*Figure 212. The diagram that represents P3's reductive process.*

#### 4.8.4.7 The Participant P4

The participant P4 was a mature British industrial designer in their mid-thirties. P4 was also the founder and the design director of their own product design enterprise ML. P4 studied product design in his both bachelor and master degree. P4 has more than ten years of professional experiences in industrial and interior design and has engaged more than 250 design projects.

The process of P4 initiated with identifying what the original prompt is. P4 regarded the original prompt as a mantel clock and assumed it is made of gold or gilded surface. The observation further continued and P4 focused on several features of the original prompt: *"(...) roman numerals and a cherub on top. It's very very decorative… baroque (P4, 00:00:38)."* P4 stated that P4 was overwhelmed by the excessive amount of information attached on the surface of the object (P4, 00:00:52). P4 then conceived an idea focusing on a particular part of the original object. This ideation was also part of P4's understanding process of the original prompt:

> *"All I wanted to do is that I'm trying to understand what's these panels (the side decoration of the original prompt) are. It's kind of a pierced shape. So, obviously you can see a symbolic… representing something but I don't really know… I guess probably floral (P4, 00:01:46)."*

P4 then interpreted the original pattern of the side ornament into simplified patterns. P4 quickly shifted their focus from the side ornament to the top figurine of the original prompt and conceived another idea. In this idea, the top figurine was reinterpreted as a handle of a clock (Figure 213). At this point, P4 realised that the time was wrongly indicated on the clock face of the original prompt. Despite the minute hand of the original clock was standing straight up, the hour hand pointed to the area in between 6 and 7. It seemed that P4 was scrutinising the details of the object thoroughly.

At this point, P4 described the attitude towards P4's design practices:

> *"If I think about my practices of design what I do and how I design… I begin with understanding or focusing on the function. Do I want to design a clock?*

*Or, do I want to design a chair? Or, do I want to design another piece of furniture? So, I immediately focus on the primal function (P4, 00:03:46)."*

Following this, P4 started drawing an analogue clock face. Then, P4 reduced the graphical elements of time on the clock face from twelve to four (12, 3, 6, and 9). This reductive process further continued and conceived another idea of a clock face without time indications. P4 stated that the series of the drawings of a clock face represent the essence of a clock as a time-telling device in a two-dimensional way (P4, 00:05:35). This thinking approach encouraged P4 to consider the relationship between the current digital devices as a physical object and the clock face that visually indicates the time: *"It's interesting you know with digital technology which is on the computer or on a phone we have time-telling devices that are completely two-dimensional yet the two-dimensional within the three-dimensional objects (P4, 00:05:54)"*

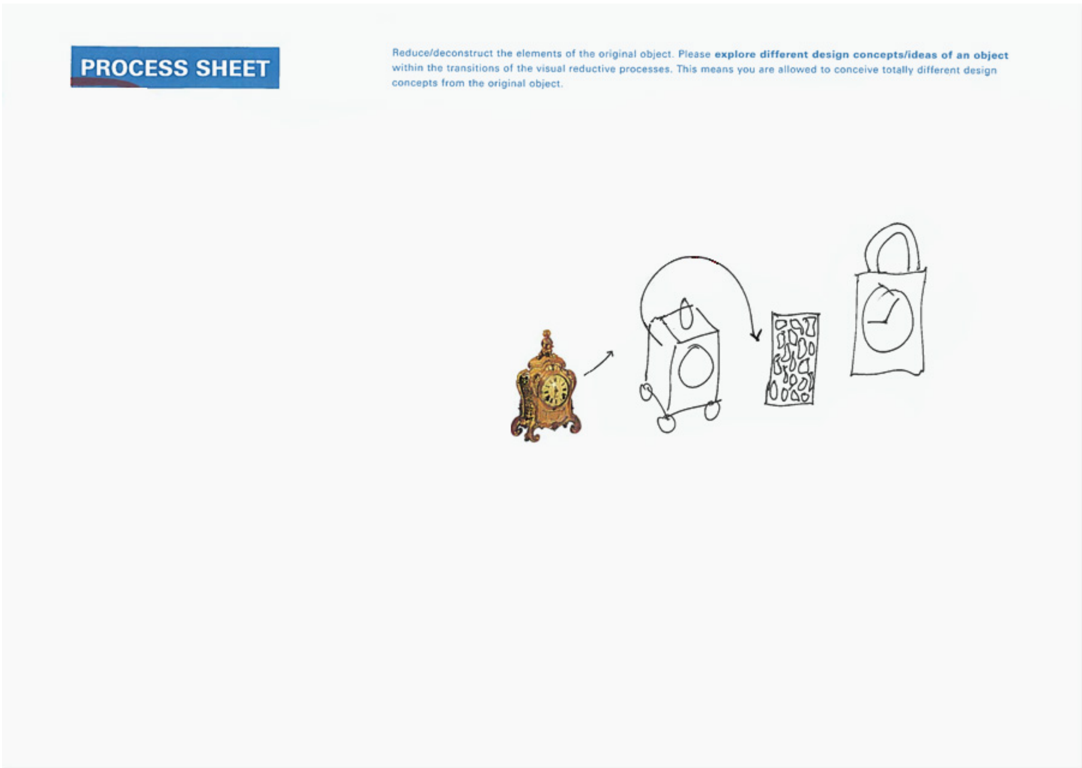



*Figure 213. The process of P4 at 00:03:43.*

P4 returned back to the original prompt with the notion of this relationship between two-dimensional and three-dimension and continued further process. P4 seemed to scrutiny the composition of the components of the clock by sketching the elements out on the *Process Sheet*:

> *"(...) one of the faces round, and yet this one is sitting in this rectangular. It is rectangular partly because it is mechanical and it is of this scale because of the technology of the time and the engineering and the craftsmanship that was required to make this object function… to make it work. And most of the cogs and dials would all have been made by hand yet now, it's complete digitalisation so mechanical aspect of this is essentially superfluous (P4, 00:06:35)."*

P4 then envisaged the ultimate state of reduction of this object. P4 assumed that the ultimate reduction of a clock becomes just a sheet or a surface of screen and P4 concluded that such an object does exist already (P4, 00:07:45).

Then, P4 returned back to the previous drawing that is a rectangular with a circle and continued to reduce the superfluous part around the circle until the square frame vanishes. This iteration let P4 conceive the idea of a clock face floating in space. P4 identified that what P4 is seeking here was perceiving time through senses such as vision, smell, hearing or touch (P4, 00:09:22). P4 then realised that the clock hands drawn on the previous drawing essentially represent numbers. Following this, P4 also drew the image of a clock face with numerals yet without hands. P4 then considered the numerals arranged in a circle as a flow of time that constantly revolves (P4, 00:10:24). P4's consideration about the arrangement of numerals on the clock face continued and this allowed P4 to gain an insight that a clock face as an interface essentially represents numbers even if the numerals were not shown (P4, 00:10:51). Then, P4 removed the circle around the numerals. P4 gained the understanding of the circular display system of a clock face: *"(...) it's sort of rotary. It allows for uninterrupted movement or uninterrupted cycle (P4, 00:11:14)."* This thinking approach encouraged P4 to draw a clock display arranged in a linear manner in order to compare it with the circular display. Then, P4 acknowledged that the linear display does not work as a clock face. This awareness also encouraged P4 to consider the digital display that differs from the analogue circular clock face: *"So, digital display is interesting in that the number themselves change rather than there have been individual numbers (P4, 00:12:05)."* P4 then drew a digital display and realised that it can indicate the time in 24-hour manner that the analogue clock cannot show.

At this point, P4 again interpreted the meaning of the original prompt as a timepiece and inferred how the technological progress changes how the clock interacts with the user:

> *"(...) this (the original prompt) is static. (...) an original mantel clock which is designed to sit on a mantelpiece in a room and every room might have one, so in the kitchen, living room or dining room, bedroom every room might have*

*some sort of timepiece. But you only get to see this when you are in that room but it's telling the time when you are not there and in theory, the time in that room and on that clock is the same as the time in the other room and on the other clock. But the duty of scaling down the product into something more portable is that a single timepiece can travel everywhere… which then kind of negates the need for this (the original prompt). We don't have a clock in this room right now. We've got a clock but even it doesn't work on the oven (P4, 00:13:55)."*

P4 then started playing with the digital indication of numerals and this exercise allowed P4 to be aware of the fact that the numeral is displayed with the composition of "marks": *"There is something very beautiful about digital display, in a way, because these individual numbers are broken down into marks. It's a 'mark' (P4, 00:15:47)."* Then, P4 depicted a series of drawings that show how the number can be displayed in a digital manner (Figure 214). This exercise gave P4 a hint that each unit of the seven-segment display essentially can be regarded as a pixel that composes the number. At this point, P4 brought P4's iPhone in order to compare the numerals represented with the seven-segment display with the ones shown on a modern liquid crystal display. P4 described the notions of high-tech and low-tech, focusing on the different resolution on the two display styles:

*"This (the clock on iPhone) is the digital display but it doesn't have that saying faceted low-resolution pixel… pixelated graphic because the definition of the resolution of the screen is so high. So now I'm liberated from this (the seven-segment display)… low-fi low tech yet, hi-tech considering digital. This (the seven-segment display) is still digital but we consider digital as "hi-tech" so actually this is 'low-hi-tech' (P4, 18:07)."*

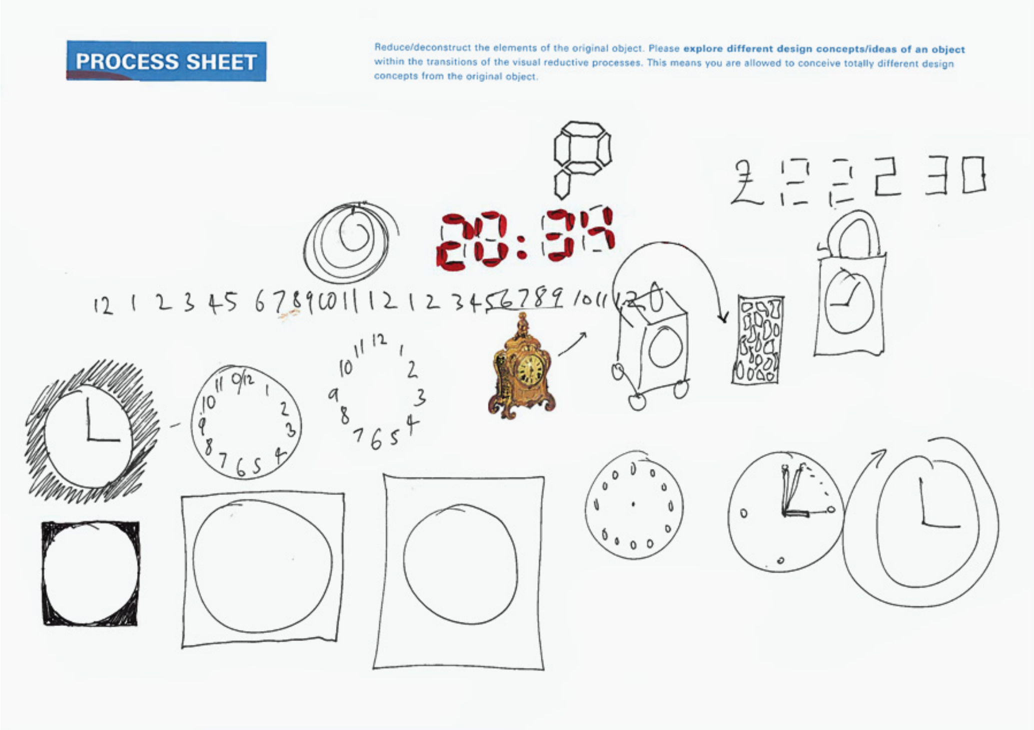



*Figure 214. The process of P4 at 00:17:20.*

This thinking process encouraged P4 to consider the aspect of pixel based digital display and took a screenshot of the clock shown with numerals on P4's iPhone screen. P4 then opened that photo image on the mobile phone and zoomed it and took another screenshot of the expanded numerals. P4 then repeated this process again and the numerals became pixelated (Figure 215).

*Figure 215. The process of P4 at 00:19:11.*

P4 stated that P4 found beauty in the pixelated image:

> *"Actually the '5' I'm looking at screen and thinking is looking like this (high resolution image) but actually, it's faceted (pixelated) which is actually very beautiful because it's not perfect. I think it's very imperfect… rendition of something that reconsider exact. When we think about a clock when it's digital we see the exact time whereas when we see read the face of an analogue clock face, a dial, more mechanical it's more of a general time telling (…) (P4, 00:19:26)."*

P4 discovered the imperfection within the high-resolution image on the mobile phone display by reducing the visual quality of the clock.

At this phase, P4's interest shifted from the notion of "digital/analogue" to "high/low resolution." P4 stated that the analogue numeric display in seven-segment manner can be regarded as "perfect low-resolution" and the pixelated digital image of a number can also be seen as "imperfect high-resolution" (P4, 00:22:15). P4 seemed to develop the thoughts identifying conceptual dichotomies at this moment. P4 then attempted to develop an idea of the way to tell time based on this thinking approach. However, P4 immediately realised that the very small clock displayed on top of iPhone is enough to tell time rather than creating a new interface of time indication. Then, P4 pressed the button of iPhone twice to activate the lock screen where the time is shown in a bigger way and described how several different sizes of time indication on the phone communicate the user: *"(…) we can still see them (the small clock on the phone). This is all you need in order to tell the time. The legibility of it is useful at that scale. This (the bigger clock displayed on the lock screen) is useful for quick… (P4, 00:24:01)."* P4 then depicted the clocks displayed in the two different scales on the same phone on the *Process Sheet* (Figure 216).

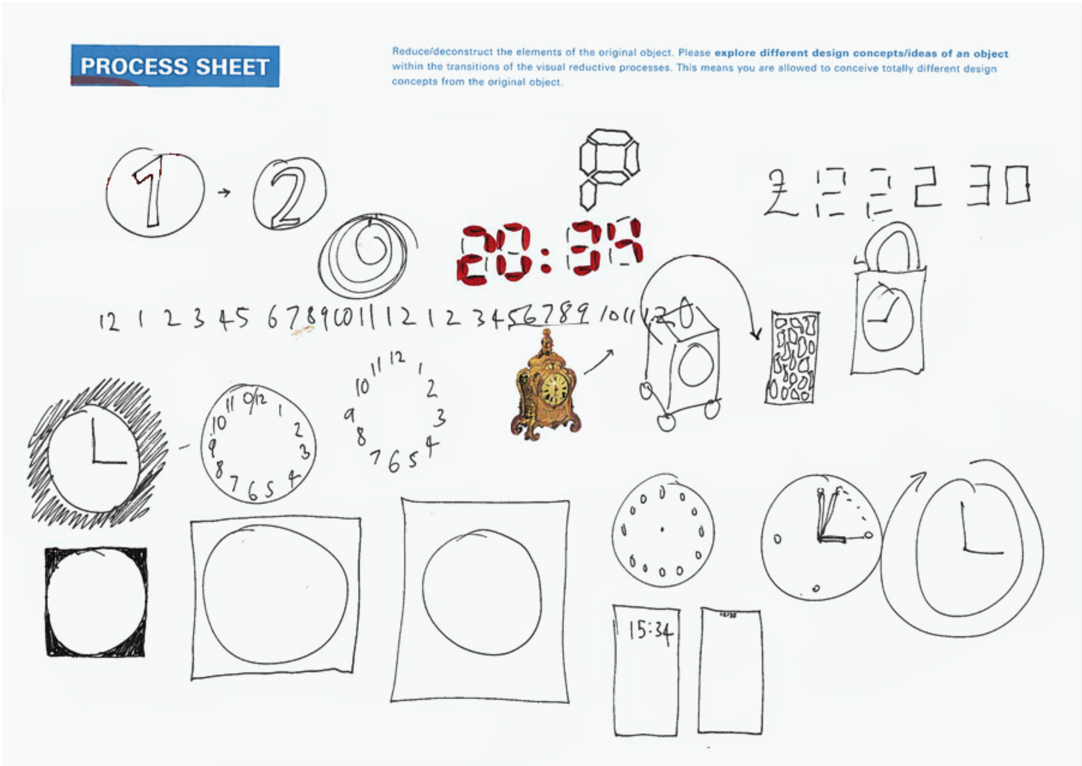



*Figure 216. The process of P4 at 00:25:14.*

At this point, P4 framed around the original prompt with a square. P4 stated that the drawings of iPhone display with a clock and the original prompt famed by a square is the same (P4, 00:25:11). Following this, P4 started focusing on the discrepancy that the original prompt printed is two-dimensional image yet P4 was considering it as a three-dimensional object as a clock. This notion encouraged P4 to take a photo of the original prompt by the mobile phone, and set the picture as the home and lock screen images on P4's iPhone (Figure 217).

*Figure 217. The process of P4 at 00:28:11.*

P4 also realised there was another small clock on iPhone. In order to magnify the image of that small clock, P4 took a screenshot of the phone screen. P4 seemed to be very intrigued by this action. The image of the original prompt used on the home screen of the phone was then shrunk by pinching with fingers in order to figure out how small the image of the clock can be legible (Figure 218).

*Figure 218. Changing the scale of the digital images of a clock on the screen.*

P4 compared the pixelated image of the clock on iPhone and the system of the seven-segment display. P4 understood the different system between the pixel and seven segment display in representing numerals through the comparison:

> *"It's (the pixelated image of the clock on iPhone) kind of close but shape of them (the numerals) are different. I think that's the point that we aren't achieving quite this kind of original digital (the numerals represented with seven-segment display). So, what it's very nice about it is, actually, it's broken down to individual pixels. They can't be a single dot. They're like a linear pixel, it's actually a line rather than dots (P4, 00:31:06)."*

P4 then attempted to develop the display system where numerals are represented with dots following the seven-segment style (Figure 219).

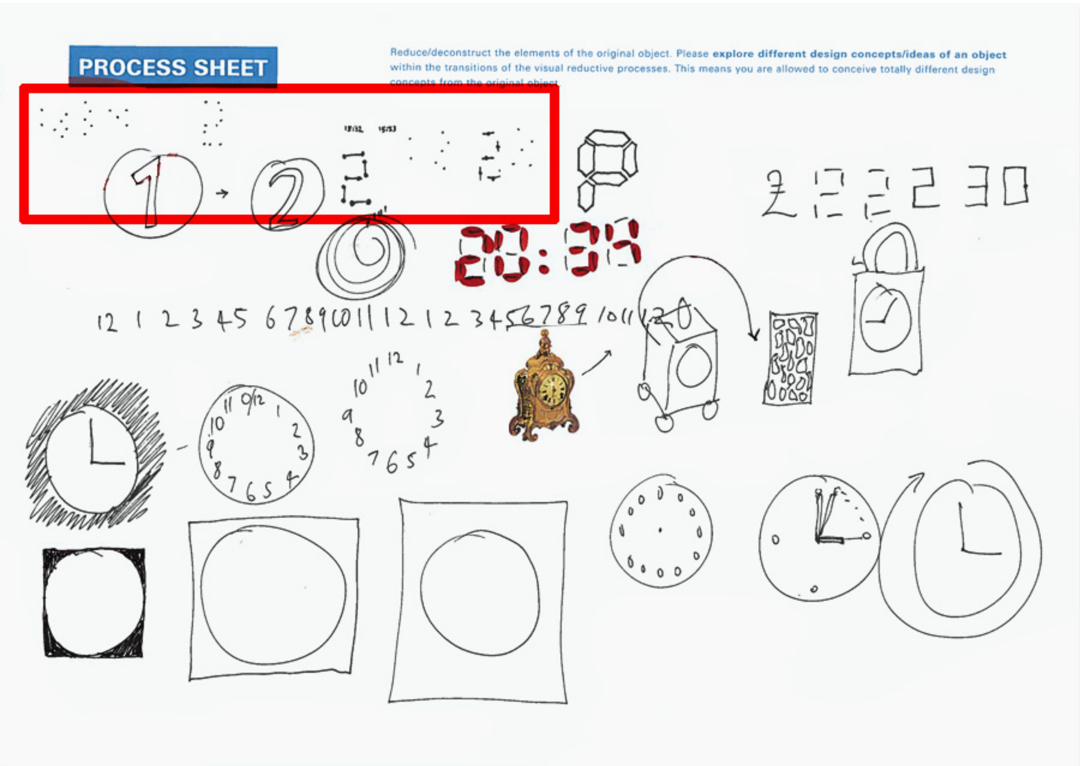



***Figure 219. The display system conceived (in the red box).***

The observation of the pixelated image of the clock on iPhone continued. The elements in the pixelated image of the clock were then sketched out:

*"And another thing is, of course, this one (the clock on iPhone) is that as you zoomed in the pixels become fuzzy. It's not black and white. It's grey in there. By being grey, you start losing that real definition. The hand is kind of nice a line made up with horizontal… and this kind of wired black dot- box thing which is the centre. And the shorter dashes are going that direction to indicate the minute (P4, 00:33:55)."*

P4 suddenly noticed the ticking sound of the researcher's wrist watch and imagined if the clock that P4 just depicted works with it. P4 then zoomed in the image of the clock on iPhone again and P4's interest was captured by the label of "clock" displayed underneath the clock icon (Figure 220). P4 regarded that this descriptive label is unnecessary (P4, 00:35:43). This awareness regarding this redundant labelling encouraged further investigation about the interface of icons on iPhone:

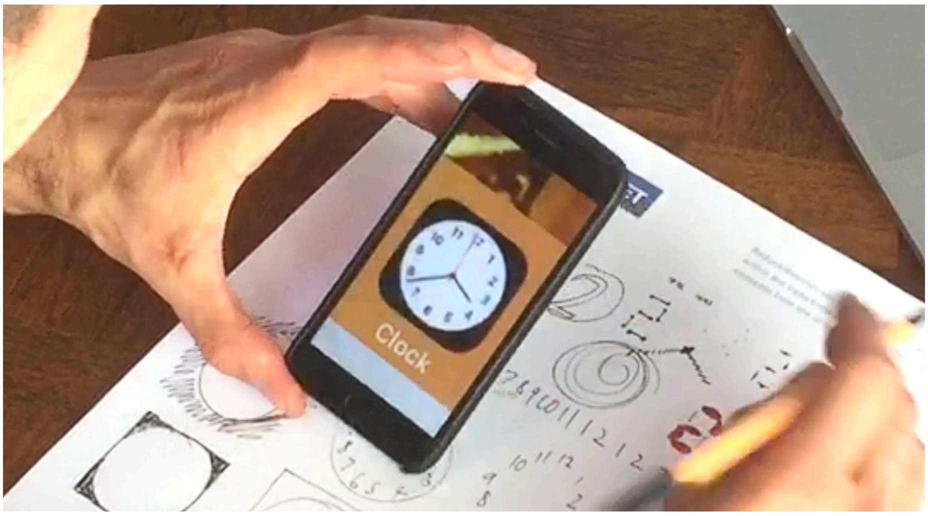



***Figure 220. The redundant labelling that P4 identified on iPhone.***

"The phone got these little names even though it's pretty obvious. Like, when you look at BBC news (icon) it's also got BBC news (label). It's just doubling up. In fact, what is doing is giving too much visual information making those icons unnecessary or confusing the icon. You don't need to draw the picture of clock and then put "clock" underneath it. You don't need to label it. (P4, 00:36:10)."

At this point, P4 stated that the display system in which numerals were represented with arranged dots are the major outcome of the reductive process (P4, 00:37:45). P4 then refined the idea. Within the refinement process, P4 ripped off a piece of paper and developed an instant template for depicting numerals based on the display system proposed (Figure 221). P4 described the idea in the following:

*"this is sort of turning them (numerals represented with seven-segment display) into pixelating them to the most minimum amount of pixels needed to tell the number. (...) the position of each of those dots is based on the original position of the dashes but we're using dots not dashes. Even when you scale it down the orientation is still the same (P4, 00:41:18)."*

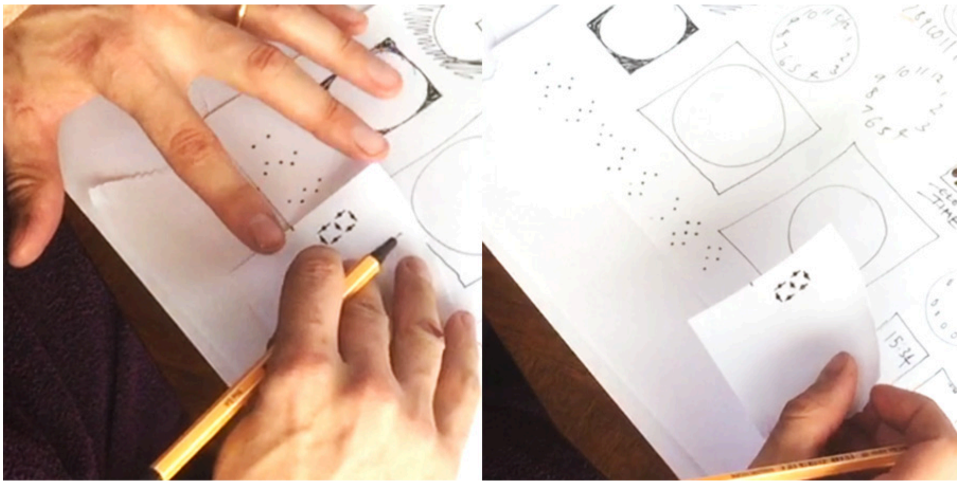


**Figure 221. Development of the numeric display system using the template.**

P4 also described that what was developed here was "a new language" or "a new set of pictures" where each figurative picture represents meanings when it is placed in a visual context (P4, 00:43:26). P4 explained this concept referring to how English words are recognised:

*"Even words… when you see the word 'clock' what it (the alphabet 'C') is a form. It's a shape. If we take the word 'clock', and then we scribble that (the word 'clock' without C: LOCK) out. That's (the alphabet 'C') just a shape. But we know because of its orientation that is the 'C'. (...) It's just shapes. It's all pictures. That's how our brain reads it (P4, 00:43:30)."*

P4 stopped the reductive process here. The completed *Process Sheet* of P4 is presented in Figure 222.

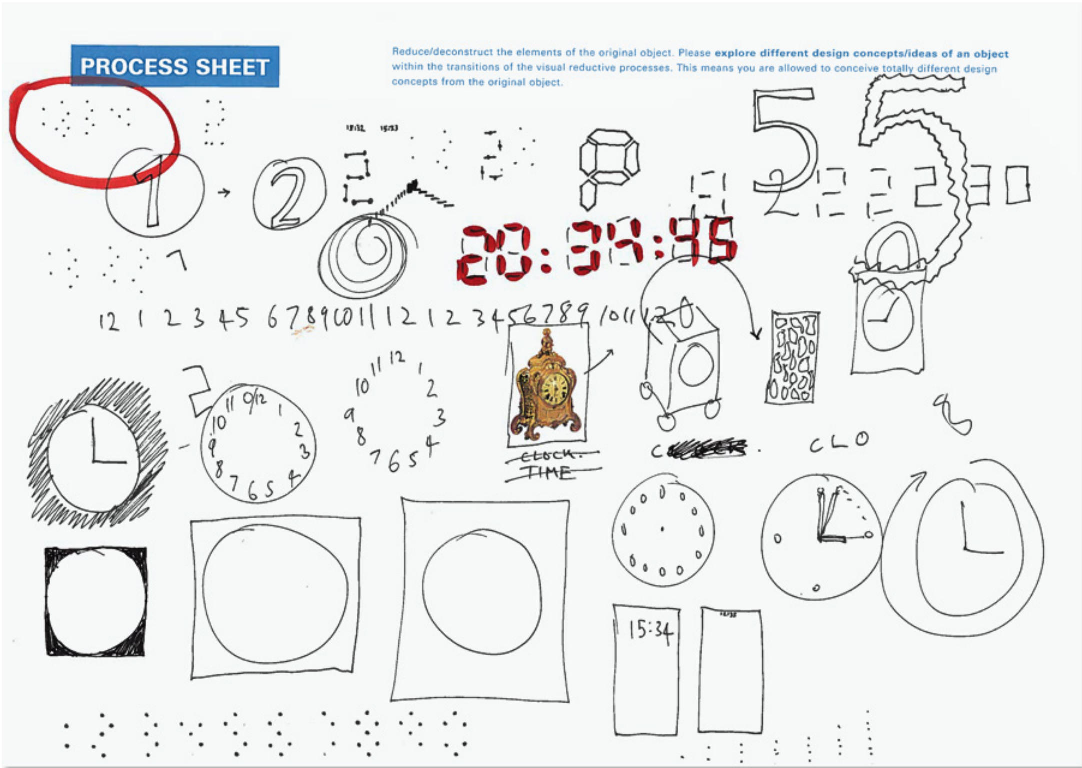



*Figure 222. The completed Process Sheet of P4.*

## 4.8.4.8 The Participant P4 Summary

The reductive process of P4 was relatively iterative and linear (Figure 223). Although P4 developed thinking avenues changing P4's focuses, P4 scarcely returned back to the original prompt to start over a new path. P4 often discovered a different viewpoint within the process of ideation and flexibly switched the focus one after the other. P4's focus was shifted halfway through the process of evolving the previous idea even if P4 had not found any conclusions about the idea. For example, P4 was focusing on the physical aspect of the original prompt. However, the focus was suddenly shifted to the display style of a clock (P4, 00:09:57). Or, P4 spontaneously found the clock application on iPhone in the middle of the process and switched the focus to the interactive aspect of the icon on the mobile phone (P4, 00:28:45). It appeared that the ideation process itself played a role as a cue for discovering a new viewpoint. P4 described that the sequences of sketching action allowed P4 to do so:

> *"The sequence. The fact is that every thought is represented by a mark (depicted objects) and each mark is permanently visible. Even when I am covering something up you can still see the history of that mark so seeing history of thought gives you an understanding of how ideas were evolved… at the same time as not being evolving ideas in the same way if you weren't*

*visualising it because thoughts are superseded by thoughts. Every thought is superseded immediately. (P4, Interview, 00:13:25)."*

Another characteristic of this participant was the fact that the development of the reductive process was based on the act of observation. Most of the ideas derived from what P4 discovered within the observation process. However, the original prompt was not only the main concern for the observation. The other objects such as the icon of application or the clock display on iPhone was also observed within the process. P4 mainly considered the conceptual aspects of the original prompt as a "time telling device" rather than a particular Rococo clock. Therefore, physical aspects of the original clock, such as the ornamentation, the patterns, the structural composition or the materiality were almost dismissed. In fact, the main focus was on the display system of time as a means of communication and ended up with the idea of new typographical system as the conclusion (P4, Interview, 00:10:13). Instead, the main concern was how to interpret the essence of the original object as a time telling device throughout the process. P4 described this approach in the following:

*"My approach of design is quite elemental. It is about (...) the essence of the product. (...) So, it (the original prompt) is a clock and a clock tells a time. Time is my focus. (...) So, 'time' will be my primal focus. (...) the purpose of this, for me, is… my interpretation of this is 'time telling device' (P4, Interview, 00:11:10)."*

In conclusion, P4's reductive process was carried out through the intensive interpretation of what and how the original prompt essentially communicates. Also, this interpretative process was not conducted through the random inference but rather through close observation about the original prompt and the other objects, focusing on the essential and conceptual aspects of them. Additionally, the reduction and ideation were conducted through discovering different viewpoints within the process, shifting the main focuses quickly and flexibly.

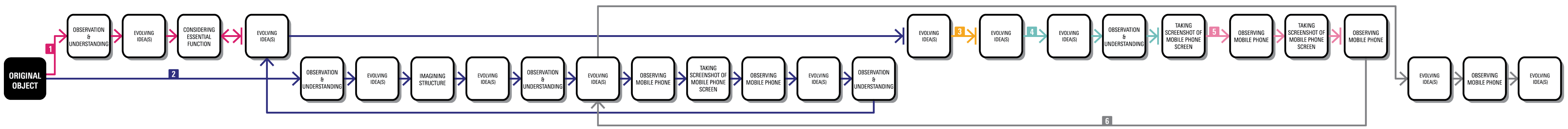



*Figure 223. The diagram that represents P4's reductive process.*

## 4.8.5 Findings

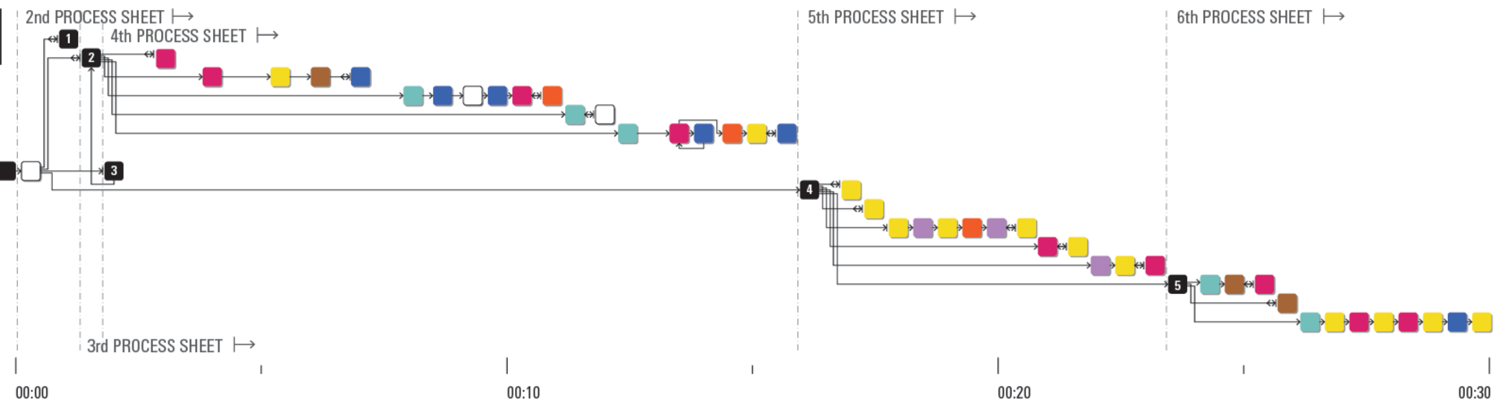
The condition of the task for the professional participants was different from the student participants. They were asked to complete the *Process Sheet* within the limitation of thirty minutes and the act of delivering the design proposal as a final conclusion was not included. In other words, the professional participants have merely challenged the proposed technique without the act of finalising their conceived ideas towards the end. Also, the professional participants were only given the high-fidelity prompt within the task. This variation provided the professional participants with the different conditions to the student participants. Therefore, the analysis that focused on the overall characteristic process, shown in the section 4.7.4.1.1 and 4.7.4.2.1 in the student participants, was not carried out within this study. Instead, the focus of the analysis was on how the professional designers considered the reductive approach and how they implemented the process of reduction and ideation.

### 4.8.5.1 Characteristics of the Professionals

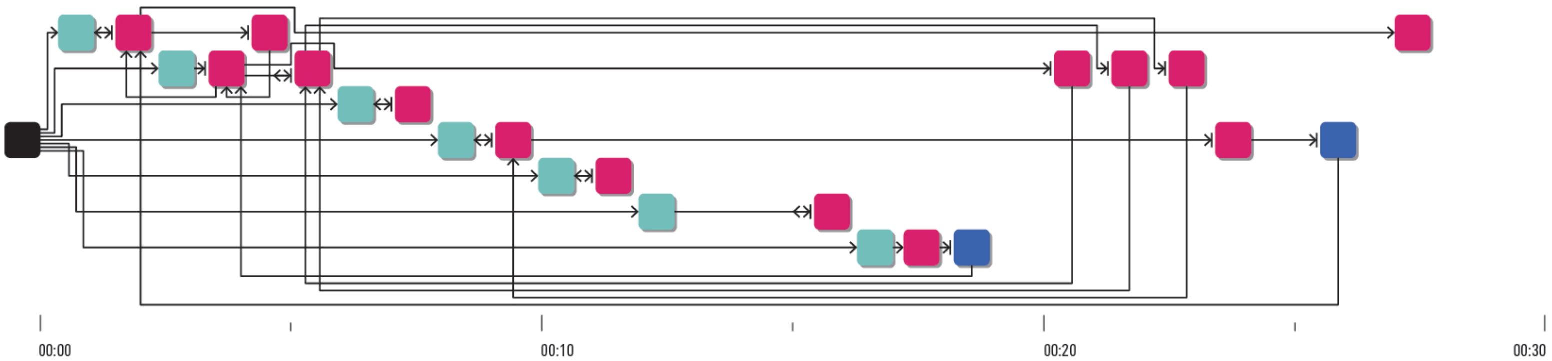
The colour-coded mappings that represent the process of the participants are presented (Figure 224). The nine colour-coding scheme used within the mapping was the same as the one employed for the student participants: observing original prompt (light blue), discovering key concept (yellow), generating idea (red), recalling memory (violet), reflective- action (blue), imagination about materials (brown), imagination about structure or manufacturing (light green), generating question (orange), other actions (white). This section describes the characteristics of each professional participant, reflecting on all the processes. The professional participants developed the reductive process in their own ways adapting them to their style of design practices within the limitation of thirty minutes. Although the elements that the participants specifically focused or the concrete approaches of each participant were idiosyncratic, the remarkable feature was the breadth of understandings or the scope of conceptual explorations through the high level of observation.

# PROCESS MAPPING PROFESSIONAL (1/2)

**P1**




**P2**




STARTING POINT / ORIGINAL PROMPT

OBSERVATION · KEY CONCEPT · IDEA GENERATION · RECALLING MEMORY · REFLECTION · IMAGINING MATERIAL · IMAGINING STRUCTURE · GENERATING QUESTION · OTHER ACTIONS

## PROCESS MAPPING PROFESSIONAL (2/2)

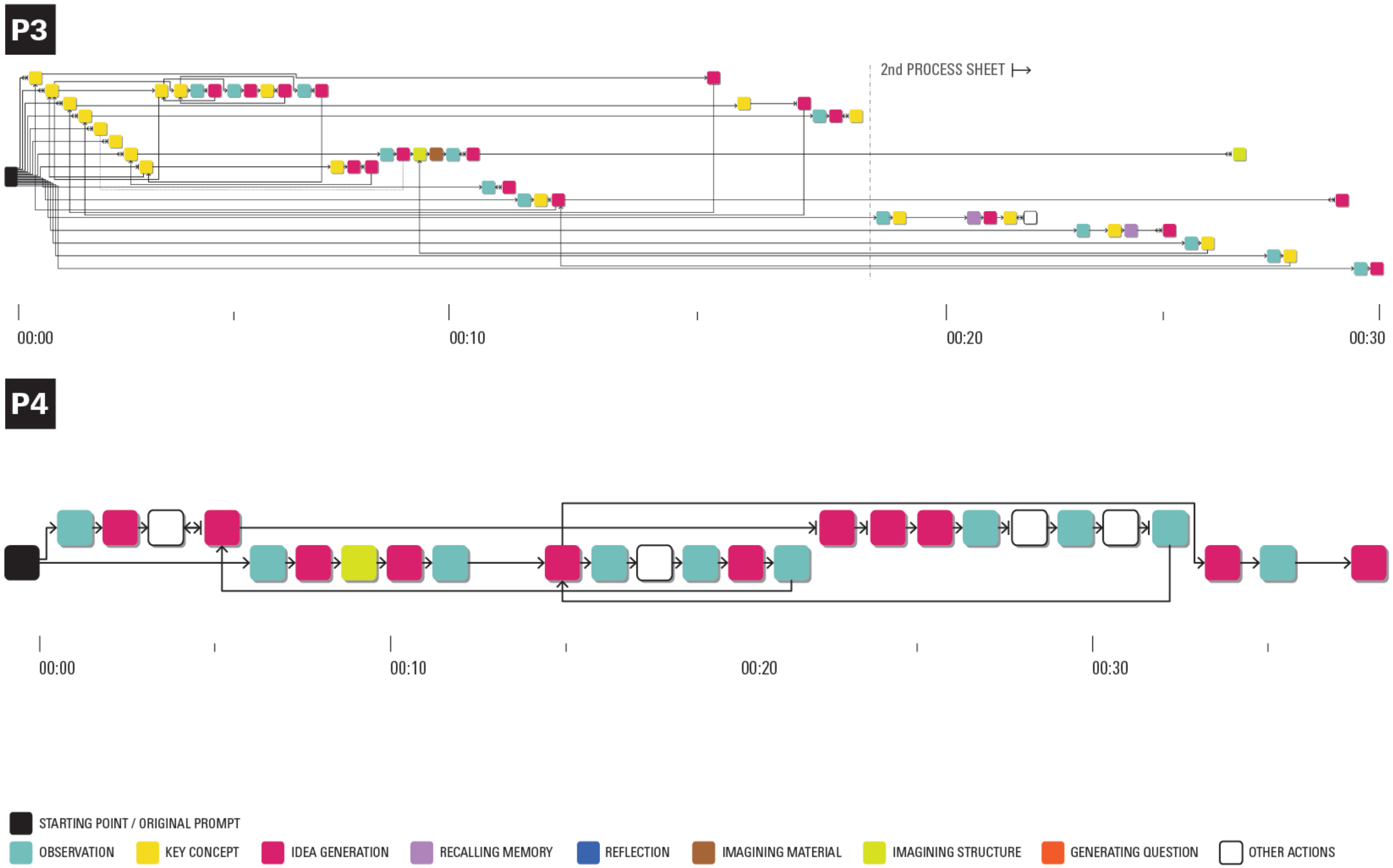



*Figure 224. The mapping describes all the processes of professional participants.*

The participant P1 prepared multiple *Process Sheet*s depending on the themes they identified at the very beginning of the process, including the ones that were never used: the first *Process Sheet* untitled and the one titled “shape.” Further, P1 also set up other new *Process Sheet*s that focused on the particular themes, i.e. “public time” and “material,” discovered within the process at the later stage and then continued to develop the processes from them. P1’s reductive process was totally conceptual driven, considering what the “core” of the object is (P1-F, Interview, 00:02:27). In so doing, setting up the themes as sub-category on each *Process Sheet* helped them to encounter the ideas that they have never considered before (P1-F, Interview, 00:14:40). P1 stressed that taking a conceptual approach towards design as a common practice for them: *“(...) most of the time we don’t confront ourselves with what is in front of us but we try to go beyond what is there (P1-T, Interview, 00:04:04).”* Even though, however, P4’s approach was conceptual driven, P4 elicited insights for ideas from the original prompt through observation. P4 developed ideas or extracted keywords, observing the particular elements, the impressions, and the materiality of the original prompt.

Additionally, the actions identified within their reductive process were not consistent. Although P1’s actions seemed to be somewhat random until the midpoint, as soon as they moved to the 5th Process Sheet, P1 developed the process finding multiple keywords/key concepts. Thus, the reductive process of P1 was conceptual driven based on the sub-categories established as a conceptual framework as well as the key concepts identified within the process. Also, within the reductive process, the act of observation played a role in understanding the object and gaining clues for idea generation.

On the other hand, P2 focused on the aspect of form of the object throughout the process. The ideas were generated within the iterative process of simplification and interpretation of form. P2 often suspended the thinking avenues that had been developed and continued further reductive/idea exploration, returning back to the ideas generated at the later stage. Additionally, close observation of the details of the original prompt was important and allowed P2 to gain a clue for developing the reductive processes. Accordingly, the process of P2 was observation driven and the ideas were often generated after looking into the original prompt.

In the case of P3, they rapidly explored multiple conceptual frameworks regarding the original prompt, discovering key concepts at the early phase of the process. P3 then focused on particular key concepts and deepened the thoughts. However, even though P3 initiated the thinking avenues with exploring key concepts at the very beginning, P3 also closely observed the original prompt within the process. The ideas or the key concepts were often developed right after the observation. P4 conducted the close observation and the reduction of the elements for the sake of in-depth understanding of the original prompt. The essential factors identified through the observation/reduction were then reflected upon the ideas. This characteristic was observed until the end of the process. Thus, the approach of P3 appeared that the process was developed based on the discoveries of key concepts in P3's pursuit of the essence of the object. In so doing, the act of understanding derived from observation played an important role in the reductive process.

Or, P4's process was relatively linear. P4 developed the thinking avenues by iterative inferences, focusing on the primal theme "time telling device" from the beginning of the process (P4, Interview, 00:56:36). Therefore, the reductive process was developed through the iterative interpretations where the idea discovered encouraged P4 to conceive another understanding or idea. In this respect, P4 developed the process focusing on the conceptual aspect of the original prompt apart from its physical attributes. However, the act of observation played an important role within the process. P4 often observed not only the original prompt but also other spontaneous objects, i.e. the clock display or the clock application on iPhone. Also, P4 used the torn piece of the spare Process Sheet to create a template in order to depict the idea. Thus, P4's reductive process was conceptual driven where the understandings and ideas were explored through iterative inferences. Additionally, the act of observation allowed P4 to gain insights for generating ideas.

In conclusion, the analysis revealed two characteristics of the participants' reasoning with regards to their reductionist approaches:

- *The first approach towards reduction*
- *The entire approach.*

The first characteristic was observed in their different initial approaches. The participants P1 and P3 took a *"conceptual driven"* initial approach. Their reductionist process often started by generating relevant keywords or questions. These key concepts were used as a clue to explore further problem spaces. This approach allowed the participants to consistently develop their reductionist processes, using these concepts as an anchor for exploring thinking avenues. The participants P2 and P4, on the other hand, started their processes by closely observing the attributes of the original artefact. The insights gained through the observation were then used as a clue for idea exploration. This *"observation driven"* initial approach allowed the participants to develop their reductionist process, utilising the information available within the original artefact at the beginning of the task.

The second characteristic was the difference observed within the entire approaches the participants developed. All of the participants, except for P2, developed their reductionist processes without returning back to the original artefact. They developed their thinking avenues without reconsidering or reflecting on the attributes of the original artefact but rather using the keywords or insights that they discovered as an impetus for idea exploration. This suggests that most of the professional design participants had a tendency to rely on what they interpreted or discovered within the original artefact as a clue for developing their design reasoning. The participant P2, on the other hand, relied heavily on the attributes of the original artefact. P2 consistently focused on the physical aspects of the original artefact throughout the process. The researcher concludes that this difference occurred because of the different interests, styles or specialisms existing within the professional design practices.

Moreover, another prominent characteristic identified was that some participants used the *Process Sheet*, modifying the sheets to suit their own ways. P1 prepared multiple sheets, attaching different themes on each *Process Sheet* before starting the process development. Or, P4 spontaneously created an instant drawing template in order to depict a numeric display system that P4 developed, ripping off a piece of *Process Sheet*. These unique usages of the sheet were unexpected and never observed within the group of student participants. These spontaneous usages of *Process Sheet* suggest the professional participants' flexibility in engaging with the technique of *autonomous reduction*.

Although these characteristics were identified through the analysis, the sample size of this study was too small to draw a conclusion about the reasoning processes of the professional participants. The conclusive evidence will be expected to obtain in further post-doctoral research.

#### 4.8.5.2 Critical Evaluation by Professionals

The professional participants were also asked to critically review the proposed technique of the *autonomous reduction* within the interview conducted after the task. The criticisms were gathered and described in this section, focusing particularly on the following five themes: 1) values, 2) limitations, 3) improvement, 4) deployment within the design practice and 5) effectiveness as a group session.

#### 4.8.5.2.1 Values

The values of reductive approach that the professional designers consider are mainly the following three aspects:

> 1) *Reductive process provides the designer with an opportunity to consider/reconsider the essential meaning of the prompt object in a wide range of focuses.*
> 2) *Reductive process unveils the designer's fixed thinking and enables him/her to take off from the fixation in idea generation.*
> 3) *The abstract information derived from the reduction allows the designer to interpret the subject in a variety of ways.*

The first characteristic that the professional participants regarded as valuable was that the proposed reductive technique encourages the designers to consider/reconsider or better understand the meanings of the original prompt. The participant P1 developed the reductive process within the pursuit of understanding the "core" of the ideas (P1-F, Interview, 00:02:27). P1 described that the reductive approach can help the designer to "unpack" the meaning of the prompt object, providing him/her with a question: "what is this about?" (P1-F, Interview, 00:11:00). P3 also initiated with scrutinising the original prompt as a clock by generating multiple questions in order to be aware of what the object is and even why P3 engages with the reduction:

> *"I tried to think about why I'm reducing it as a starting point. (...) and think about why somebody or I want a clock, what the clock is doing beyond telling the time and then thinking about some of the challenges around making and designing a clock like that (...). It had to take away some of the challenges (...). Some of the challenges are about how you make it, some of the challenges are… it's very specific in its style so it wouldn't be appealing to everyone so how I can make it more flexible" (P3, Interview, 00:00:10).*

P3 considered regarding the original prompt by breaking it down to the multiple different elements until when P3 reached the "pure concept" in which P3 became aware of what and why P3 is deconstructing the object (P3, Interview, 00:17:41). Or, P4 also described that the act of reduction prompts the designer to understand the "essence" of the object by generating multiple questions: *"(...) reducing something in itself is perhaps a good exercise when trying to understand the essence of an object. What it does and how it does it and why it does it" (P4, Interview, 00:17:08).* Thus, the reductive approach appeared to offer an opportunity to consider or reconsider the essential factors about the prompt object provided externally. The participants P1, P3 and P4 also mentioned this approach is somewhat similar to the way in which they consider about things in their design practice.

The second characteristic that the professional participants considered as valuable was that the reductive process unveils the designer's fixed thinking or preconceived ideas regarding the object. P1 stressed the importance of getting rid of their fixed ideas regarding the prompt object within their reductive process (P1-F, Interview, 00:08:27). P1 explained this process as "cleaning up what they know." This process of "cleaning up" led P1 to different considerations of how to design a clock (P1-F, Interview, 00:08:55). P2 also described that the highlight of the reductive process was the fact that P2 explored ideas apart from P2's preconceived ideas about the object as a clock (P2, Interview, 00:06:00). This allowed P2 to explore ideas, focusing not only on the aspect of form but also on the different typology of objects at the same time. Being apart from the preconceived idea of what a clock is consequently encouraged P2 to conceive the unexpected category of ideas i.e. the toy and the chewing gum dispenser (P2, Interview, 00:03:30). P3 considered that the reductive approach helps to reveal the process of how the designer's mind works and this consequently describes the designer's preconception: *"(...) for this (reductive process), it's a very good way of exposing the way that the designer's mind works because you're giving a blank canvas for them to show what their preconceptions of the opportunity are" (P3, Interview, 00:20:22).*

The third beneficial feature of the reductive technique identified by the professional participants was that the abstract information derived from the reductive process allowed the designers to interpret its meanings in a variety of ways. P1 stressed that the iterative abstraction of meanings gave a freedom in interpretations during the idea generation process: *"(conceived ideas) by abstraction I think. We didn't set a "clock" but set "time." So, we abstracted even more and then when you abstract it you are more free to come up with different interpretations" (P1, 00:07:05).* P4 also stressed that the user of the reductive technique needs to be equipped with the flexible mind-set in interpreting the notion of reduction in a variety of ways in order to successfully exploit the technique: *"The idea of reduction or the word reduction is very specific. I think in order for the process of the technique to be truly useful, you would have to be able to interpret the idea or the word in multiple ways" (P4, Interview, 00:16:03).*

It appeared that the reductive process encouraged the professional designers to consider the essential factors of the original prompt through a critical scrutiny. The gained insights were then used for their idea generation. The professional designers also regarded that the act of reduction helped them to remove their preconceptions about the prompt object and that allows them to get clear of fixed thinking in their idea exploration. Further, the professional designers considered the abstract thinking happened within the reductive process diversified their interpretations regarding the concepts that the original prompt implies.

#### 4.8.5.2.2 Limitations

Several limitations of the proposed technique were identified by the professional designers. P1 pointed out that the rules in the use of the *Process Sheet* are the limitation. P1 stressed that the design method that requires the designer to follow a specific manner is not omnipotent for idea generation (P1-T, Interview, 00:11:45). P1 does not start the design process with sketching in their design practice. The act of sketching is usually conducted at the later stage of the design process when the research activities were completed. Accordingly, the reductive technique where the designer is required developing the process through sketching did not fit their design approach. P1 also stressed that there is no need to have a specific structure where designers follow within the design processes (P1-F, Interview, 00:13:38). P1 considered that the design process should allow the designer to approach in diverse ways. Instead, however, P1 mentioned that this reductive technique could be exploited as a prompt for conversation among multiple designers when they brainstorm within a group (P1-F, Interview, 00:13:50).

P2 considered the two issues as the potential limitation of the reductive process: 1) the influence of the selection of the original prompt on the designer's reductive process and 2) the *Process Sheet* is not suitable to expose and share with others who are not close to the designer.

First, P2 pointed out that the selection of the original prompt dictates the performance of the designer within the reductive process. P2 described that one of the limitations is the discontinuity between the original object as a prompt and the outcomes conceived within the process (P2, Interview, 00:06:29). This is also what P2 counted as one of the advantages of the technique. P2 considered that the selection of the original object critically dictates the consequences. If the original object selected as a prompt is too irrelevant to the scope for design ideas in which the designer wants to explore, the result might be undesirable. On contrary, if the prompt is too close to what the designer expects beforehand, the result might also be conventional. In this case, the reductive approach does not effectively perform for the designer's imagination. Therefore, P2 considers that the selection criteria for the prompt object should be made depending on the design brief the designer received:

> *"I think if we want to use it (the proposed technique), I'm thinking how would we chose what it (the original prompt) would be. (…) that pretty much depends on the brief. I think it's interesting in a way that what you would chose the item*

*when you're trying to design is similar or you would chose the item when you're trying to design is completely different" (P2, Interview, 00:07:18).*

Although P2 mentioned the importance of the proximity between the original prompt and the targeted scope for the outcomes, P2 concluded that randomly selecting an unrelated object can be helpful to stimulate the designer's imagination: *"I think that it will probably be more interesting to almost pick something completely random, that's completely unrelated to what the brief might be. It's just sort of the thinking outside the box to explore different typology of form" (P2, Interview, 00:08:24).*

The second issue P2 mentioned was the difference between the sketch that is produced for the designer's own sake and the drawing depicted for communicating with others (P2, Interview, 00:12:08). If the *Process Sheet* is produced to show and share the contents with another person, the designer as the user of the sheet needs to consciously develop the contents as the medium of communication. The difference of these conditions dictates the contents of the reductive process and, therefore, P2 considered that the designer should explore the ideas for their own sake dismissing the aspect of communicability in the use of the sheet. P2, however, mentioned that this reductive technique is useful for working within a group (P2, Interview, 00:14:00). This appeared to imply that the drawings produced within the reductive process should be personal but they can communicate with the person/designer who is close enough to be able to read and interpret them.

P3 deemed the two issues as the potential limitation within the reductive process: 1) the risk of which the participant only addresses their familiar subjects and 2) a lack of purposes.

First, P3 pointed out the risk that the designer lapses into the behaviour where they address their familiar and comfortable subjects within the reductive process:

> *"I think the limitation is you tend to deconstruct in the way that you are comfortable and familiar way. By not specifying or guiding how to deconstruct or reduce, it takes you into your "lazy thinking." You do it in the way you know what you expect" (P3, Interview, 00:19:10).*

In order to avoid this "lazy thinking," P3 suggested that the user of the reductive technique needs to carry out the reductive process with self-awareness of what, how and why they are reducing/deconstructing (P3, Interview, 00:21:33).

The second limitation P3 mentioned was that this task was conducted without any specific purposes (P3, Interview, 00:12:41). The task P3 conducted was exploring different objects from the original prompt without certain aims. P3 described that the unexpectedness or surprise in ideas can only be verified within the comparison between what the designer initially tried to achieve as an objective and what came out as a consequence. Accordingly, it was difficult for P3 to judge how good the ideas conceived unless it has particular aims.

P4 pointed out the three issues as the limitation of the reductive process: 1) two dimensionality of the *Process Sheet*, 2) engaging with the reductive process as a fake task and 3) the *Process Sheet* is not suitable for communicating with someone who is not close to the designer.

First, P4 deemed that the two-dimensionality of the *Process Sheet* is the limitation (P4, Interview, 00:15:05). It is important for P4 to have freedom in approaches towards generating ideas. Even if a good idea is conceived, it is difficult to represent it in three-dimensional media: *"The limitation is that I have no idea what I'm doing yet. I don't know what… physical manifestation is going to be. I don't know whether or not it's going to be 2 dimensional or 3 dimensional. And, if it's going to remain 2 dimensional, how does it become real?" (P4, Interview, 00:15:11).*

The second issue P4 mentioned was the fact that P4 engaged with the reductive process, knowing that the task was a challenge but not the real design project (P4, Interview, 00:20:24). P4's design process starts based on the design brief where specific requirements were indicated (Figure 225) whereas the proposed reductive task does not include such a practical information. P4 presumed that P4 will possibly find difficulties in making a bridge between the "hypothetical thinking" derived from the proposed reductive technique and the requirement in the real world:

> *"I think, as a general exercise, it's a good way of visually brain storming and testing the thinking processes. But, ultimately comes down to how that thinking process and that brainstorming can be applied to a real-world situation or a real live brief… this (the reductive process) is still very much hypothetical and the difficulty of this research project is we all know that it is hypothetical. So, the way I'm thinking during the hypothetical exercise is very different if you tricked me by pretending to be a client, a Japanese producer and inviting me to design a clock for you. (…) then I would approach in a very different manner (…) and I know I would come up with a final conclusion but you also would*

*give me a lot more information, you didn't. So, the difficulty of that is I know that it's fake" (P4, 00:20:36).*

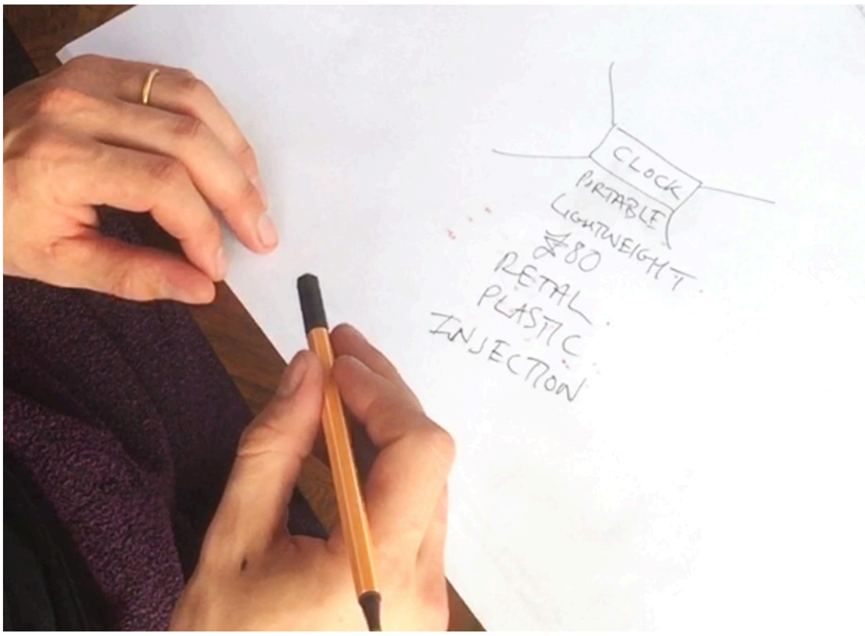



***Figure 225. The typical requirements in a real-world for designing a product that P4 explained.***

This criticism appears to suggest that it is not easy to directly apply this reductive technique into P4's design process. However, as P4 mentioned, this technique rather fits into more of the designer's brainstorming exercise that is conducted individually.

The third issue P4 mentioned was that the contents depicted on the *Process Sheet* are not easy to communicate and share particularly with another person who is not close to the user of the *Process Sheet* (P4, Interview, 00:15:35). P2 also mentioned the similar issue in the interview. The ideas developed are not necessarily depicted explicitly on the *Process Sheet*. Therefore, even though the depicted elements are meaningful for the designer, it is not always useful for sharing the contents with others who does not work with such as the client.

#### 4.8.5.2.3 Improvement

The feedback of the professional participants suggested several ideas for the improvements of the proposed technique. The participant P1 suggested setting up the sub-categories for each *Process Sheet* at the initial stage of the process:

*"(…) if you notice something since the beginning, we tried to make categories. So, maybe the subcategories could help. (…) Subcategories could help to develop different ways of approaching reduction, not only reduction as in*

*'form' but the reduction as in 'technology'… 'materiality' that maybe the designers have never considered before. I think the categorisation is good to go beyond what you know" (P1, Interview, 00:14:40).*

In so doing, P1 further suggested that it is helpful to set up the sub-categories that are not directly relevant to the original prompt:

*"They can also be helpful if they are more slightly absurd categories. You know, they don't immediately apply but maybe they can help triggering… you could argue (for example) 'technology reduction' and maybe you have 'leather.' And you said, well there aren't a lot of technologies there, but maybe you can still be triggered for imagination" (P1, Interview, 00:15:38).*

This feedback appeared to suggest that the designer's imagination can further be stimulated by setting up the sub-categories that are conceptually far from the original prompt.

P2 suggested that the designer as the user of the reductive technique needs to make sure that they should not think too much of how the depicted contents on the *Process Sheet* are reviewed by others. This is what referred to in the section of limitation as well:

*"One thing is always just trying to get ideas down versus creating beautiful sketch. The process, for me, is always like … 'okay, don't think about too much how it looks as long as you bring and get the ideas down to a paper and I'll push it forward.' If it's more of the personal process, and you're just doing it for yourself versus presenting it. I think that might have quite an impact on how successful it could be" (P2, Interview, 00:12:08).*

This feedback appeared to suggest that it is important for the user of the reductive technique to be informed that the reductive process is meant to be used for their personal idea exploration at the beginning of the process.

P3 suggested that the thinking approach of the user of the reductive technique should be disrupted when the designer's thinking lapses into the behaviour where their thinking is fixated within their familiar and comfortable subjects. P3 stressed that it is helpful to let the user be aware that there are alternative ways of approaching towards "reduction" in order to encourage him/her to get away from the comfortable thinking space:

> *"When you have gone through and run with lots of people and lots of groups, you could start to see patterns emerging. And then, it could be improved by introducing things that disrupt the patterns. So, at the certain points in the process where people start going to familiar ways of thinking, you introduce something that makes them aware of other ways of thinking about the same exploration and deconstruction. So, you allow people to go to their own comfortable approach to reducing and deconstructing before rebuilding. But, then you introduce alternatives by understanding, observing and generalising you can see where the gaps are and help people to see other ways of thinking. So, that would actually help people who don't normally think in certain patterns that would be where you make it more surprising because it's taking them outside of their normal thinking patterns" (P3, Interview, 00:24:34).*

P3 further suggested that this can be achieved by introducing typical examples of the ways of reducing/deconstructing to the user of the *Process Sheet* (P3, Interview, 00:25:58).

P4 stated that there is nothing to be improved within the proposed technique (P4, Interview, 00:23:15). The most critical element when the user engages with the reductive technique is their open-mindedness. P4 stressed the importance of getting rid of the elements that constraint the user's approach as less as possible in order to encourage their free approaches towards the technique. For example, P4 deemed the A3 size of the *Process Sheet* is too small so that the format of the sheet can be bigger for the better performance of the user.

#### 4.8.5.2.4 Deployment Within the Design Practice

The researcher also asked the professionals where and how the reductive technique could possibly be deployed within the actual industrial design process. P1 deemed that this technique potentially plays a role within the design pedagogical context:

> *"I think it can be applied more in education. I think in the education it would be a good exercise. Because it's an exercise. It's a method. So, it has the limitations of it. By the limitations, you learn things. (...) I think in education, in learning how to construct ideas, it can be helpful" (P1-F, Interview, 00:13:03).*

P2 considered that the reductive technique could potentially be deployed at the early stage of the design process where the ideas were explored without being critically judged

(P2, Interview, 00:09:01). P2 also described that this technique can also play a role at the later stage of the design process when the designers settle the concept:

> *"(…) maybe in the design development when you pin down a concept but you feel that you need to push further a little bit… just to look what you've been working on for very long time with fresh eyes. I suppose that sometimes you can't see what it is… you just have been concentrating on something for such a long time and you think it's right but actually it could have pushed it forward further than what you have. (…) And then I suppose it would work quite well because you would then really work with your product or whatever" (P2, Interview, 00:09:44).*

P3 described that the reductive process is valuable to be deployed within the design process since designers should essentially conceive new design concept and ideas through the reductive process: *"This sort of technique should be deployed in a design process. You should be deconstructing and reducing to understand and then rebuilding the new concepts and ideas. We should do that with structure and self-awareness of 'what,' 'why' and 'how'" (P3, Interview, 00:21:16).*

Although P4 stressed that the reductive process is useful as in enabling the designer to understand the essence of the prompt object (P4, Interview, 00:17:18), P4 did not particularly clarify where the proposed technique should exactly be introduced. P4, however, mentioned that the proposed technique is a good exercise as a visual brainstorming where allows the designer to have hypothetical thinking approaches (P4, Interview, 00:20:02).

#### 4.8.5.2.5 Effectiveness as a Group Session

The proposed reductive technique was individually challenged by the professionals except for the participant P1. The researcher asked them whether or not they consider that the technique can be useful for idea exploration when it is conducted with a group of designers. As a result, all the professional participants deemed that the proposed technique is useful for a group task. The reductive technique where demands the group of designers to reduce the original prompt to elements or distilled ideas can be generative (P4, Interview, 00:23:30) and it also allows the members to encounter unexpected discoveries through which the participants interpret the drawings differently (P2, Interview, 00:13:00). Further, the interactive conversations generated within the reductive process as a group task is critical for idea exploration (P1, Interview, 00:10:11) and, in such a situation, it is more efficient to be carried out with the team members who have worked together i.e. colleagues (P4, Interview, 00:22:23).

### 4.8.6 Summary of the Main Study 2

Although the approaches towards the development of thinking avenues were different, the professional participants conducted the reductive process through the high level of observation and interpretation of the prompt object and its attributes. The professionals elicited a wide range of information regarding the prompt object that are not only the physical aspects, e.g. form, structure, materiality and so on, but also conceptual factors based on the socio-cultural contexts.

The feedback from the professionals about this reductive technique appeared to be largely positive. This is partly because the reductive approach, in general, is familiar to professional designers as some of the participants mentioned (P1, Interview, 00:13:23; P3, Interview, 00:17:20). The professional designers, to some extent, unconsciously implement a reductive approach in the pursuit of understanding of things within their practices. However, they did consider how the researcher's proposed technique could be deployed in the context of industrial design process and how it could be adapted.

Through the dialogue with the professional practitioners the researcher believes that the reductive process encourages an in-depth interaction between the designer and the prompt object and it can also provide them with an opportunity to consider what the prompt object represents. Additionally, the abstract information derived from the reductive process allows the designer to interpret the subjects in a variety of ways. Also, the depicted elements on the *Process Sheet(s)* can visually reveal the process of their design reasoning as evidence. These visual elements possibly help the designer to overcome their fixated thoughts for generating ideas, allowing them to reflect their implicit behaviours at the preliminary phase of the design process.

On the other hand, the effectiveness of the reductive technique might have limitations when:

- The designer utilises the technique without a clear purpose.
- The designer is not continuously self-critical; or not being aware of what, why and how they are conducting their reductive approach.

As for the possibility for the deployment of the proposed technique, it potentially could be applied at the stage in which the designer explores diverse directions within the design process. Or, the technique can play a role in stimulating the designer's thoughts when they feel their ideation is fixated even at the later stage of the design process. Additionally, it potentially could be an effective training for idea generation if these techniques are deployed within the design pedagogical context.

## 4.9— CONCLUSION OF CHAPTER 4

As discussed, the entire process of the investigation has been incrementally developed by the preceding set of iterative studies. Insights derived from each of the studies acted as the key driver for the subsequent research activity. This section summarises what the researcher discovered from individual studies and how the findings formulated the entire structure of the research.

The first preliminary study illustrated that the student participants as design practitioners were capable of visualising objects from the different incomplete visual representation of an artefact. The critical information, i.e. materiality and composition of an object, played an important role as a clue for visualising an artefact within their reasoning. Further, these factors were highly supported by the participant's prior knowledge in a variety of ways. This insight was then used for designing the second preliminary study.

In the second preliminary study, the researcher investigated the impact of reducing the information of both "materiality" and "composition" of an artefact on the design practitioner's reasoning. The study was conducted using deconstructed and scaled-down components of the iconic Red and Blue chair designed by Rietveld. The researcher prepared three levels of colour-code of the same component sets that offered different degrees of material perception. The same task was conducted working with both design students and non-design students, comparing the differences of prior-knowledge of the participants. The result of the comparative study identified the characteristics of the design participants' route of inquiry, namely: reduced information prompted the design participants' diverse imagination in visualising the types of objects, the intended scale of the outcomes, materiality, and reference objects. Also, the reduced information encouraged the participants to take an open-ended thinking approach within their reasoning. This insight allowed the researcher to generate a hypothesis: "the process of reducing information by the designers themselves stimulates their design imagination."

The third preliminary study investigated the impact of reducing elements of an artefact (i.e. a wheelbarrow) by the design practitioners themselves on their creative reasoning, working with Swiss design master students. In it, the researcher developed a set of work sheets in which the design participants explored new design concepts within the act of reduction. This approach was called "autonomous reduction." The results showed that the aspects that the participants focused on varied, depending on the different levels of visual fidelity of the image prompt. The design master students, that were given a high-fidelity visual prompt, had a tendency to focus on the aspects of "functionality" and "form" of an artefact. In contrary, the groups that were provided with lower fidelity images tended to conceive "concept-driven" ideas, taking more abstract approaches in their reasoning. Although the researcher identified some characteristics of the design participants' behaviour while they engaged in the proposed reductive process, there were limitations in the approach. The researcher could not confirm whether or not the restrictive rules of the proposed technique effectively prompted the participants' creative reasoning. The researcher also could not fully understand how the participants carried out autonomous reduction due to the limited ways of collecting data. Accordingly, the researcher felt the need to critically review the technique of autonomous reduction.

The fourth preliminary study was a small evaluation of the proposed technique "autonomous reduction," working with an experienced industrial designer. The evaluation study was conducted using the same work sheets used in the previous study. This evaluation study gave the researcher the two critical insights that eventually played an important role in the further improvement of the technique: 1) the importance of the spatial freedom on the Process Sheet, and 2) the selection of the original prompt that includes rich attributes information. These insights were reflected upon the revised technique, autonomous reduction, which was used in the following two main studies.

The first main study was conducted with the advanced industrial design students and the processes were thoroughly observed based on the approach of think aloud/protocol analysis. This study was also conducted comparing two different visual fidelities of the same prompt (i.e. a French Rococo clock): a photographic image (Group A) and a dotted line drawing (Group B). The results illustrated that the participants of both groups created a high level of design concept as an outcome. Additionally, the types of outcomes produced during the task varied depending on the fidelity levels: Group A had a tendency to “redesign” a clock and Group B produced more radical and conceptual artefacts with broader interpretations of a concept of time.

The researcher also developed a mapping system that thoroughly visualised and time coded the processes of each participant. This mapping allowed the researcher to untangle the complexity of the participants’ behaviours during the reductive process and played a critical role in the analysis of the participants' reasoning. The analysis focused on the participants’ behaviours during the process, and the results of which showed that the reductive/deconstructive approach encouraged the design participants to have an in-depth dialogue with the visual prompts given. The participants of Group A carried out the reductive process, scrutinising the physical aspects of the prompt closely. The insights about the prompt derived from the scrutiny were then used as a key clue for the following ideation. On the other hand, Group B conducted the process by deducing conceptual aspect from the prompt and by generating critical questions. The participants of this group iteratively interpreted/re-interpreted the notions or questions generated and used the insights discovered as a key clue for generating ideas. The results of the study suggested that the proposed reductive/deconstructive technique allowed the design students to conceive a high level of and rapid concept ideation, navigating their focuses and considerations during the process. The researcher further considered how this reductive approach could play a role for experienced professional designers.

The second main study was conducted with professional industrial designers, visiting their companies. Although the same visual prompt and Process Sheet were used, different conditions were applied: time limitation, using only high-fidelity image and Process Sheet and giving an explanation about the project before the start of the study. The aim of the study was observing the impact of autonomous reduction on the professional designers’ reasoning and identifying the values/limitations of the reductive technique within the industrial design process from a professional point of view. The feedback from professionals about the technique was largely positive. The technique could provide a designer with an opportunity to consider and interpret what the artefact presented essentially represents. Also, the abstract concepts generated within the reductive process allow the designer to interpret the subjects in a variety of ways. However, the professionals also pointed out that the effectiveness of autonomous reduction could be limited when the designer uses the technique without having clear purposes and/or being critical of themselves.

Thus, the entire process of the research has been formulated iteratively and incrementally: each of the studies was developed based on the findings and insights discovered within previous investigations. Also, a creative technique autonomous reduction and its mapping system that played a critical role in the research were developed through the process. This explorative approach dictated the research design and formulated the direction of the research evolution focusing on the concept of “reduction.”

Chapter 5

# *c o n c l u s i o n a n d d i s c u s s i o n*

# 5.1 — INTRODUCTION

Understanding the complexity of the designer's reasoning when faced with reduced information is challenging. The way in which individual design practitioners develop their imaginative processes is neither explicit nor straightforward. Additionally, through the research it uncovered that each of the participants took an idiosyncratic approach that made any observation process highly complex. In the pursuit of revealing the designers' cognitive behaviour, conducting observational studies in a controlled, yet familiar environment allowed the efficient investigation into this complex subject. Controlled settings enabled the researcher to focus on the influences of reduced and incomplete information on the participants' reasoning, taking control over extraneous variables. The results of the investigation, including the preliminary and the main studies, illustrated the designers' capability of coping with, handling and utilising information incompleteness within their reasoning processes. Also, the feedback about the technique of *autonomous reduction* obtained from the professional design participants reinforced the possibility of deployment of the proposed technique within the context of the professional design practices. This research actively tried to closely represent a studio-based design activity. However, the researcher acknowledges the elements and external factors, such as client's needs and objectives, materiality, manufacturing and time constraints were excluded. However, as the professional industrial design participants could find values in the technique of *autonomous reduction*, the researcher believe that this approach can be a useful tool to stimulate and assist their reasoning within their design practices.

This research has also illustrated the characteristics of the effects of reduced and incomplete information on the designers reasoning, aiming at developing a reductionist technique that can potentially be beneficial and exploited within a real-world design situation. As the feedback from the professional designers about the developed technique was largely positive, the researcher believes that this *autonomous reduction* contributes a new understanding of how designers can utilise information incompleteness in their early ideation phase of the design process.

This chapter aims to answer the primary research question stated at the section 1.2:

> ***"How does reduced and incomplete information have a beneficial impact on the industrial designers' design imagination?"***

In answering this research question, it can be fulfilled by summarising the findings from all the studies. The summary of findings mainly argues the following two subjects:

1. *The relationship between incomplete information and the designer's reasoning.*
2. *The impact of autonomous reduction and the designer's idea exploration.*

Moreover, this chapter concludes the potential values and limitations of the technique of *autonomous reduction,* articulating the direction for the future studies as well as its contribution to new knowledge.

## 5.2 — ANSWERING THE RESEARCH QUESTION

Answering the primary research question is made up by identifying the discoveries underpinned by the evidence and results of each of the studies. The discoveries derived from the first and second preliminary studies articulate how information incompleteness provided as stimuli contributed to the design participants' reasoning and their creative outcomes. The discoveries derived from the third and fourth preliminary studies, and the focus of the main study also articulate how the technique of *autonomous reduction* that this research proposes impacts on the designers' creative reasoning is established. Moreover, it also illustrates key values and potential futures this technique contributes to design practice.

### 5.2.1 Relationship Between Incomplete Information and the Designer's Reasoning

The results illustrate that incompleteness of information given in the representation of an artefact, used as stimuli, generated within the designers an active, speculative, creative and reconstructive reasoning in the re-imagining of the original artefact.

The results of this study also showed that, when they were given reduced and incomplete information of an artefact, the designers tended to leave open-ended possibilities in which the object can be interpreted. In these situations, they cope with the uncertainty of information by developing personal strategic cognitive approaches.

The results of the first preliminary study showed that the design participants conceived ideas for artefacts by focusing on particular aspects (i.e. materiality and composition) of their conceived designs, when the state of information given is incomplete. In so doing, their long-term memory as prior knowledge played an important role as a back-up source for reason and personal reference.

The results of the second preliminary study showed several characteristics of the design participants' reasoning when given a deconstructed tangible prompt whose colour code was reduced or removed. The reductive prompt whose colour code is abstracted encouraged the design participants to take a bottom-up approach, in which ideas are explored and developed within the reconstruction process. In contrast, the richer information encouraged them to take a top-down approach in which the participants created an object, following on from the ideas they developed at the early stage of the exercise.

Additionally, the design participants' imagination was diversified by reduced information in a variety of ways:

- *The types of outcomes*
- *The intended scales of outcomes*
- *Reference objects associated within their reasoning (white colour only)*
- *Imagination of materiality of objects (white colour only)*

The findings of the first preliminary study suggest that the abstractness that resides in incomplete information activates the design participants' schematic knowledge about design. Following this, they identify uncertain elements of the incomplete information by inferring critical factors that consist of a three-dimensional artefact, e.g. its materiality and compositionality.

Moreover, the findings of the second preliminary study suggest that abstractness of information dictates the design participants' approach in reasoning. When they are given less information, they tend to take an undefined approach in their process of reasoning. It can be inferred that this tendency allows them to explore multiple meanings within the process of addressing uncertainty of information and, as a result the breadth of their imagination can be increased.

### 5.2.2 The Impact of Autonomous Reduction and the Designer's Idea Exploration

The results of the studies illustrated the design participants' capability of exploring and conceiving ideas of an artefact within the process of *autonomous reduction*. The act of *autonomous reduction* encouraged the design participants to have an in-depth dialogue with the artefact provided as a prompt. The process of *autonomous reduction* was carried out by exploring the elements that can be targeted for reduction through intensive reading of the multifaceted attributes and the meanings of the artefact. Additionally, the results showed that the aspects focused on by the participants and their reductive processes varied, depending on the fidelity levels of the image used that represent the same original artefact.

The results of the third preliminary study, conducted using an image of a wheelbarrow, showed that the design participants had a tendency to conceive function-oriented objects when given a high-fidelity visual prompt. However, as the level of abstraction of the prompt image increased, the types of the outcomes conceived by the participants became more conceptual.

Moreover, the result also showed that the participants took different approaches in their reductive processes, in accordance with the fidelity levels. The participants had a tendency to engage with the reductive process, by removing the physical components of the original prompt when given a high-fidelity visual prompt. On the other hand, when given a moderate or low fidelity prompt, the number of the participants who conducted the reductive process by abstracting the elements of the prompt object or changing the way in which they see the scale of the artefact increased.

These facts suggest that the decrease of the amount of information, given as a prompt, dictated the participants' ways of reading information into the artefact and this difference also affected the quality of the outcomes that the participants conceived.

The critical feedback gained from a professional design practitioner in the fourth preliminary study illustrated the limitation of the technique of *autonomous reduction* developed in the third study. The results revealed the following two key issues of the instruction of the technique:

1. *The Process Sheet ought to allow the spacious freedom where the user of the sheet can engage with the technique of autonomous reduction without any rigid rules as a restriction.*
2. *The original artefact provided as a prompt ought to include rich attributes.*

The rules applied in the third preliminary study required the participants to follow the sequential manner that was instructed on the *Process Sheet* potentially distracts or hinders the design participants' flow of reasoning and can result in forcing them to develop the process in an awkward manner. Additionally, multifaceted attributes of the artefact provided as a prompt can enhance the reasoning of the design participants during the process of *autonomous reduction*. The technique of *autonomous reduction* that was used within the main study was improved reflecting on these insights.

The results of the first main study, conducted with the mature industrial design students clearly showed the positive impact with these improvements of the technique on the participants' performance. A higher level of creativity was represented within the processes and the outcomes that the participants developed. Each of the participants developed their reductive processes, focusing on multiple aspects of the original artefact (Rococo clock) in a variety of ways and their reasoning processes became dynamic. For example, one focused on the aspect of physical attributes or another considered relevant behaviours that the original artefact potentially triggers. The objects designed by the participants were well conceived, and conveyed their design concepts explicitly.

The reductive approach that the participants developed was different depending on the level of visual fidelity of the prompt. The participants had a tendency to start the reductive process by scrutinising the attributes of the artefact when given a high-fidelity prompt (photographic image). The obtained information and insights, such as structure, functionality, design intention and so on, were then used as a clue for idea exploration during the process of reduction. As aforementioned in the section in 4.7.4.1.1, the following six behaviours were commonly observed within the process of idea exploration:

- *Discovery of key concept*
- *Dismissal/focus*
- *Interpretation/re-interpretation*
- *Thinking back and forth*
- *Elements synthesis*
- *Reflection*

The ideas were generated and fostered towards the final design proposals thorough these generative, selective, reflective and cyclical behaviours. A fundamental characteristic was that the participants start by scrutinising or close observation of the physical aspects of the clock used as a prompt, allowed them to re-design a timepiece, suggesting new interactions between the object and the user. Or, in one case a participant created a different category of object (a speaker unit), taking over the physical characteristic of the original clock.

On the other hand, the results of the low-fidelity group were different. The participants had a tendency to start the reductive process by seeking key concepts when given a low-fidelity prompt (dotted lines). The key concepts discovered played a role as a clue for further reduction or idea generation.

As with the results of the high-fidelity group, the following actions were identified during their reductive process:

- *Discovery of key concept*
- *Interpretation/reinterpretation*
- *Thinking back and forth*
- *Elements synthesis*
- *Reflection*
- *Recalling personal memory*
- *Material imagination*

Although some actions were commonly observed within the results of both groups, the low level of visual fidelity activated the participants' long-term memories and also encouraged to consider materiality of an object.

The characteristic of this approach was that the participants started the process by seeking key concepts, this encouraged the participants to conceive more conceptual or radical design concepts in their final design proposals. The low-fidelity prompt allowed them to consider more conceptual aspects of the original clock from multiple perspectives, and also to interpret these discovered concepts or questions in a variety of ways. This breadth of interpretations of concepts enabled the participants to take more radical approach in their reasoning.

The following second study was carried out using the same technique of *autonomous reduction*. However, different conditions were applied. It is worthwhile to mention the conditional differences from the ones applied in the first main study here:

- *The participants were required to complete the process within 30 minutes.*
- *The four design directors were selected as the professional participants.*
- *The only high-fidelity image was used as a prompt.*
- *The participants were invited to challenge the task only with the Process Sheet.*
- *The participants were informed regarding the context of this research before the commencement of the task.*

The aim of the second main study was observing how professional designers implement this reductive process and in gaining understanding into how they consider the developed technique of *autonomous reduction*. Thus, by necessity the study environment was significantly different to that of the design students and the professional designers.

The results of the second main study showed the experienced designers' high level of creative reasoning within the reductive processes. However, each of the professional participants took very different reductive approaches. The reductive process of the participant P1 was conducted mainly through the act of abstraction of the notion of time. The participant P2, on the other hand, conducted their reductive process by transforming the forms of the original clock. The reductive processes of P3 were by both exploring key concepts and meticulously observing the original clock from diverse angles. P4 developed the reductive process by concentrating on individual thinking avenues and the focus were flexibly switched one after another when they discovered different viewpoints. As a whole, the reductive process of the professional participants was intricate and varied. Therefore, it is difficult for the researcher to conclude with any generalised characteristics due to its complexity. However, two patterns of reasoning approach were identified through the analysis:

- *The first approach*
- *The entire process*

Two types emerged with the first approach within the reductive process amongst the professional participants. The first characteristic was that two participants (P1 and P3) started the process by setting out relevant keywords, such as "signalling time" or "intention" that directed the subsequent development of their reductive process. It appeared that the problem spaces articulated by these keywords allowed them to consistently develop their reductive processes. The second characteristic was that the other two participants (P2 and P4) started the process by focusing on the details of the original artefact. Then, they developed the reductive processes iteratively based on these details.

With regards to the entire process, all of the participants, except for P2, they developed their reductive processes without returning back to the original artefact. Most of them scarcely returned back to the original artefact but rather developed the process using the keywords or key aspects identified by themselves. Only participant P2, however, took a different approach focused primarily on the physical characteristics of the original artefact as a clue for reduction.

Another characteristic identified through the analysis was that some professional participants utilised the provided *Process Sheet* in unconventional ways. P1 prepared multiple *Process Sheet*s, each of these had a specific theme at the very beginning of the process. Or, P4 spontaneously developed an instant template for drawing, by ripping off a piece of paper. These spontaneous improvisations were unexpected and this suggested the flexibility of the experienced designers in engaging with *Process Sheet*.

Although the researcher has identified some interesting and unexpected patterns in the professional designers' design reasoning, it is difficult at this stage to draw any precise conclusion due to the small sample sizes. Instead, the researcher obtained their critical feedback that clearly suggests the potential values that lie within the technique of *autonomous reduction*. These will be concluded in the following section.

Thus, reduced and incomplete information provided as external stimuli for inspiration can dictate the design practitioners' reasoning in a variety of ways. Incompleteness of information can assist in diversifying the industrial designer's reasoning underpinned by their expertise. Moreover, the act of *autonomous reduction* can provide the industrial designer with an opportunity for discovering elements or insights with regard to the artefact selected as a prompt that is used as a clue for exploring ideas during the reductive process. In so doing, different levels of visual fidelity of the artefact appeared to affect the approach to the reductive process that the student participants took.

## 5.3 — VALUES AND LIMITATIONS

This section concludes the potential values and limitations, with regard to the developed technique of *autonomous reduction* reflecting on the results of the student participants and the critical feedback gained from the professional designers.

### 5.3.1 Potential Values

The potential values of the reductionist technique developed can be considered as demonstrating that *autonomous reduction* essentially provides the industrial designers with a dynamic flow of explorative thoughts consisted of a set of actions (Figure 227):

- *Critical scrutiny*
- *Extraction of insights*
- *Idea generation*

The act of *autonomous reduction* enables the designers to re-examine and better understand artefacts through critical scrutiny. Through this critical interrogation of existing artefacts, it allowed the participants to investigate them from multifaceted perspectives. The reductive process compels them to discover new aspects of the existing artefact provided as an external stimulus, as something they have never considered before, or to infer relevant notions about the prompt in a great variety of ways, such as *physical structure, materiality, functionality, technology, usage, rituals, production methods, aesthetic quality, product definition, socio-cultural values, historical background* and so on. Additionally, personal experiences, such as past memories and prior knowledge were also compelled during the reductive process.

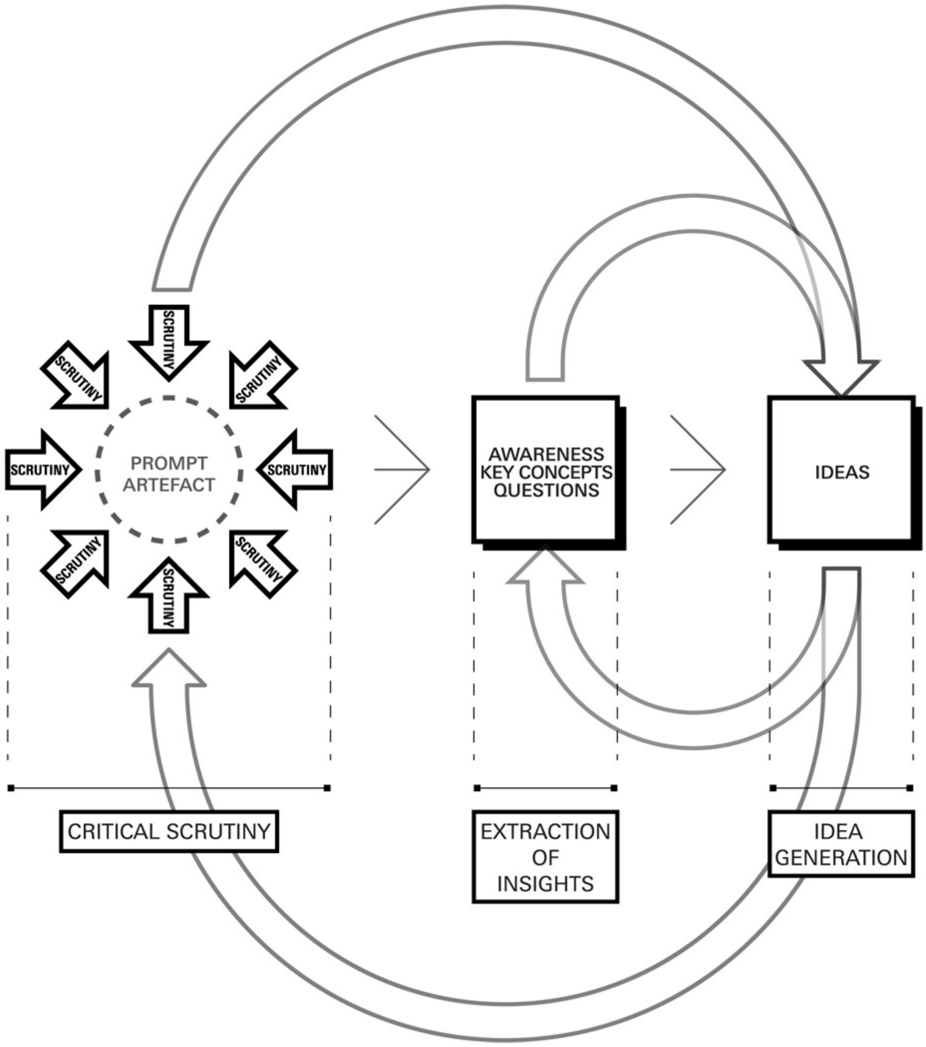



***Figure 226. Dynamic flow of reasoning process during autonomous reduction.***

As most of the participants (A1, A4, B1, B2, B3, B4, P1, P3 and P4) stated in the interview, the reductive process also demands the designers to consider the "essential element" of the artefact provided. This was often achieved through generating important questions such as *"What is its purpose? (B4, Interview, 00:26:37)," "What is this about? (P1-F, Interview, 00:11:00)"* or *"What the clock is doing beyond telling the time (P3, Interview, 00:00:10)."* This can play an important role as a key clue for reduction and consequently dictate the entire reductive process. These insights/awareness discovered as a key clue encourages the designers to systematically develop their design reasoning rather than randomly conceiving ideas.

Another value pertaining to this technique of *autonomous reduction* is that the use of a *Process Sheet* allows the designer to visually retain the processes that they already developed. The sequences of drawings or notes directed by arrows allow the designers to: *remember the context of the idea exploration process* (A1, Interview, 00:40:36), *comprehend the relevance or difference between the original artefact and the ideas developed* (A2, Interview, 00:15:10), or *acknowledge their preconceptions of the opportunity* (P3, Interview, 00:20:22). The elements depicted on *Process Sheet* as a visual record can support the designers to retrospectively reflect their reasoning processes. This reflection then assists them to further develop the thinking avenues or to conceive new ideas, integrating multiple directions of thought depicted on the *Process Sheet* as a track record. In fact, most of the participants could clearly describe how they developed their reductive processes in detail, pointing out their drawings on the *Process Sheet*, during the interview.

In conclusion, reducing attributes of the existing artefacts prompts an in-depth dialogue between the designer and the object. Within the dialogue, the designers iteratively explore the sources of inspiration for ideas, discovering insights and questions that they have never considered before about the prompt artefact. In other words, the *autonomous reduction* provides them with an opportunity to rethink the artefacts, transforming the *"familiar"* concepts to *"unfamiliar."* The researcher believes that this reductionist approach can be particularly helpful for overcoming thought fixation in which the designers unconsciously adhere to existing ideas or concepts during the idea exploration (Jansson and Smith, 1991). Or, the process of *autonomous reduction* can potentially be helpful for the designers to consciously and actively control their fixations, allowing them to delve deeply into particular aspects of the artefact presented. Either way, *autonomous reduction* can provide flexibility to the designers' reasoning when fixated and be a tool that allows them to explore and encounter unexpected and meaningful ideas for solutions.

### 5.3.2 Limitations

As the developed technique of *autonomous reduction* reported in this thesis is still a prototype. The following issues as potential limitations emerged within the analysis of the contents of the interviews:

- *The selection of the original artefact as a prompt*
- *Flexibility in approaching the technique*
- *Possibility of introduction of further structure and rules (emerging from discussion with participants).*

The first issue is the importance of the selection of the original artefact as a prompt. The process of reduction could be highly dictated by the attributes that the artefact selected as a prompt represents. The participants developed the reductive processes, focusing on the aspects of the original artefact in a variety of ways. This implies that the richness of information that the artefact includes inevitably provided the participants with an opportunity to read, understand and interpret it. The insights derived from this process encouraged them to develop further reductive processes. In other words, the artefacts that represent little attribute information cannot effectively compel the designers' reasoning within the reductive process. A3, for example, stressed that their reductive process could have been more challenging if the original artefact was much simpler than the Rococo clock used as a prompt:

> *"I think the image has to be carefully selected. There is a lot of stuff going on, detailing, material, the function of a clock, the figurine on the top. The image itself has to have a lot of stimuli. (...) It has to be something complicated rather than a simple shape like a football. If it is just a football there, I think the task could be more difficult" (A3, Interview, 00:25:57).*

Additionally, as P2 mentioned in the interview, the proximity between the type of a prompt artefact and the category of objects that the designer is trying to design can be critical. Although P2 concluded that the type of a prompt artefact should be distant from the category of objects the designer expects at the beginning of the process in order for unexpected results, further investigation is needed.

Thus, the original artefact as a prompt ought to include diverse attribute information, e.g. materiality, distinctive functionality, colours, intricate details, socio-cultural/historical values and so on, that can enhance the process of reduction. Also, the type of object may need to be carefully selected in accordance with the requirements of the design brief.

The second issue the researcher has learnt was that the users of *Process Sheet* should have clear instruction, so that they are allowed to engage with the process of *autonomous reduction* in a familiar fashion. The instruction indicated on the *Process Sheet* advises that the user of the sheet needs to develop the reductive process by drawing: "Reduce the elements of the original object gradually by drawing on the *Process Sheet*. Please speak aloud while you are drawing as much as you could." Although some of the participants spontaneously developed the process by writing down words or sentences as well as drawings, this instruction instructed the participants to follow a particular manner. This instruction has hindered some participants' development of the reductive process. For example, A1 stated that it was challenging to develop the process through drawing since they do not usually conceive ideas just through sketching

(A1, Interview, 00:45:01). Or, P1 usually carries out sketching activity at the later stage of the design process (P1, Interview, 00:11:55). For these designers who do not wholly rely on sketching activity within their early phase of the design practice, as they prefer to develop the process using words rather than drawings. P4 also stated that the two-dimensionality of the *Process Sheet* could be a limitation, as it does not particularly encourage the designer to use other physical media (P4, Interview, 00:15:05). Therefore, it could be more effective in stimulating the designers' reasoning if the instruction clearly states that the way to develop the process is not limited to sketching, but the use of other types of preferable means (e.g. words or tangible media) are also allowed.

The third issue was that the technique ought to have certain guidelines for the use of *Process Sheet* in order to effectively prompt the designer's reasoning. As discussed, the researcher acknowledges the importance of having more flexibility in the use of *Process Sheet*. However, the commentaries gained from the interview have also suggested that introducing guidelines that assist the designers to avoid confusions within the process could be helpful in order to maximise the impact of the reductive technique. Within the interview, some student participants (A2, B1, B2 and B4) stated that comprehending the complexity of many ideas and directions developed through the reductive process was challenging. Generally, the participants developed many thinking avenues within the process, and the subjects addressed were often abstract. This wide variety of directions of these abstract thoughts might lose some control in their thinking. A2, for example, described that they lost sight of what they were doing because they took a too "macro" approach within the process (A2, Interview, 00:16:40). B4 also explained that it was challenging to delve into a subject, staying in a single thinking avenue because they developed many directions of thought (B4, Interview, 00:29:12). These suggest that conceiving many ideas or developing thinking avenues divergently without directions can cause confusion within the process of reduction. In such a situation, B2 suggested that introducing a "parameter" that helps the designer to find relevance amongst multiple directions of thought could be useful:

> *"I think how much you could go so many different directions… at some point I got really confused. It was hard to find connections as I broke it down to so many different ways, different variations. My brain connects different things. (...) I think you need to have some sort of parameters" (B2, Interview, 00:24:10).*

Although none of the professional participants stated that they were confused during the process, the participants P1 and P3 also suggested that adapting a sort of guideline to the technique might be useful for the designers. As aforementioned in the section 4.8.5.2.3, P1 suggested that setting up the sub-categories for each *Process Sheet* at the initial stage of the process can be helpful in consistently developing thinking avenues (P1, Interview, 00:14:40). Or, P3 stressed that it is important to let the user be aware that there are alternative ways of approaching towards "reduction" in order to allow them to get away from their comfortable thinking space when necessary (P3, Interview, 00:24:34). These insights gained from the professional participants suggested that adopting a guideline in a suitable format to the technique of *autonomous reduction* could be beneficial for the designers in strategically reading particular facets of information within the original artefact provided as a stimulus.

Thus, several issues as limitations concerning the technique of *autonomous reduction* were identified within the studies. These suggested that the selection of the original artefact ought to be carefully made and the use of *Process Sheet* could be modified depending on the requirements of a design brief in order to maximise the performance of the designer's idea exploration. The limitations, however, also suggested the necessity of further investigations in order to better understand what types of selection criteria and what sorts of guidelines are suitable. These will be uncovered in further post-doctorate research.

## 5.4 — Contribution to New Knowledge

This doctoral study explores an area in which little design research has been done. This thesis investigated the impact of reduced and incomplete information upon the industrial designers' design reasoning, focusing primarily on the act of *autonomous reduction* of the elements of an artefact provided as an external stimulus. The research has uncovered aspects of the industrial design practitioner's behaviours when presented reduced and incomplete information and discovering insights when they explore ideas, autonomously reducing the attributes of an existing object. This section concludes these contributions to new knowledge.

**A new understanding of the industrial design practitioner's reasoning when faced reduced and incomplete information of an artefact.**

Previous design studies have identified the role and its significance of the information incompleteness typically occurred within the process of ideation, such as uncertainty, abstractness or ambiguity, for the designer's imagination. This research expanded the notion of the value of information incompleteness, observing the design practitioners' reasoning when reduced and incomplete information is presented in advance. This research uncovered that industrial design practitioner's reasoning is influenced when given reduced information of an artefact. In so doing, the information incompleteness derived from reduction compels their particular types of concern i.e. *"material"* and *"compositional"* aspect of the artefact. This means that these particular elements play an important role for the industrial design practitioners in recognising and envisaging an artefact. Also, these are highly supported by their schematic knowledge structure acquired through their design experiences or learning.

**A new understanding of the impact of information incompleteness derived from the reduction of an object's particular type of elements upon the industrial design practitioner's reasoning.**

This research also revealed that the incomplete state of information derived from the reduction of colour code and the deconstruction of its components, that an existing particular artefact represents, can impact on the industrial design practitioners' reasoning. The reduced colour code of the dismantled Red and Blue chair, provided as a prompt, diversified the type of outcomes in form and scale that they envisaged. Providing the them with sufficient information can activate their prior knowledge based on their design expertise and then encourage them to fixate this knowledge. This means that reduced information can allow the industrial design practitioners to take more open-ended approach in their reasoning within idea generation. This also encourages them to encounter unexpected design ideas.

**A new technique "autonomous reduction" for enhancing the industrial designer's creative reasoning in idea exploration.**

The previous design researches have argued how the incomplete information can stimulate the designers' imagination within their idea generation or, how it can be utilised as an impetus for prompting the interaction between an object and the user. This research further explored the potentials of incomplete information when manipulated by the industrial designer themselves for the sake of their own creative imagination. In the pursuit of understanding the benefit of *autonomous reduction*, the researcher developed a creative technique that aims at enhancing the industrial designer's design reasoning.

The study conducted with industrial design students using the technique revealed the dynamic flow of the process of design reasoning. The act of *autonomous reduction* encourages the designer to discover essential elements as an insight of the artefact presented as a prompt through critical scrutinising the object. These insights were then exploited as a driving force for generating design ideas. Additionally, the approach towards *autonomous reduction* can vary depending on the visual fidelity level of the prompt. The critical scrutiny of the artefact is carried out, focusing on the physical aspects of the artefact when provided a high-fidelity image (i.e. photographic image) of the object. This can result in redesigning an existing artefact with new perspectives. On the other hand, the process is carried out by discovering conceptual facets of the artefact beyond the physicality of the object when provided a low-fidelity image (i.e. dotted line drawing). This can result in conceiving more radical and conceptual design ideas.

The study conducted with professional industrial designers using the high-fidelity prompt revealed that the experienced designers take a flexible approach towards the concept of "reduction" along with a wider breadth of understandings or the scope of conceptual explorations through the high level of observation. In so doing, the information they read or the issues focused on within the reasoning can vary depending on the style of their professional practices.

**A new mapping methodology that thoroughly reflects and visualises design reasoning within the process of autonomous reduction.**

A mapping visualisation tool (Figure 227) that thoroughly describes and records how the individual user of the *Process Sheet* develops their reasoning during the reductive process along with the technique of *autonomous reduction*. The process of developing the visualised mapping allows the researcher to capture and review rich data based on the recorded materials. The data derived from protocol analysis is time coded and translated into the visual mapping system. This enables the analyser to understand the designer's behaviour within the reductive process and to identify patterns of the development of the user's design reasoning with practical evidence. This mapping methodology critically helps the researcher to untangle the complexity of the designer's reasoning process.

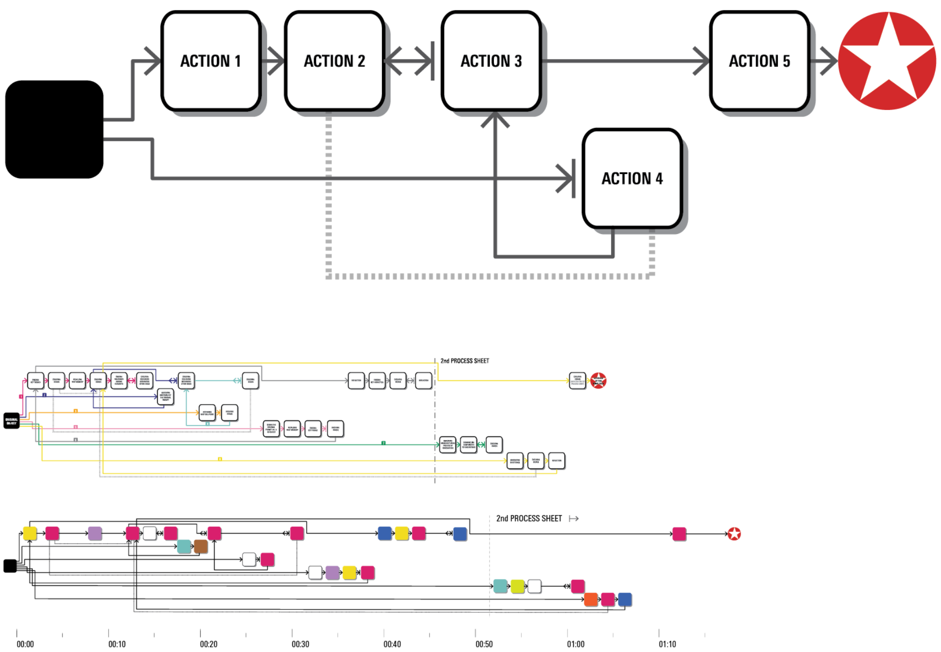



*Figure 227. Mapping system developed within the research.*

## 5.5 — Conclusion and Future Work

For designers, addressing reduced and incomplete information essentially prompts them to have an in-depth dialogue with existing artefacts and also provides them with an opportunity to reconsider or explore their cognitive frameworks for the ways to look at the objects. In other words, this opportunity encourages them to uncover and challenge the notions that they take for granted through reflective and critical consideration. The researcher believes that this critical consideration can contribute to the enhancement of an industrial designer's imagination when the technique of *autonomous reduction* is deployed during the idea generation phase within the early phase of the design process.

As discussed, the developed technique of *autonomous reduction* can be improved in many ways. The studies documented in this thesis primary concerned the impact of two-dimensional visual stimuli upon their design reasoning during the reductive process. However, the visual stimuli as an original prompt can also be a physical tangible object that affords the designers tactile sensation of the artefact. Thus, adapting multi-modalities of information potentially provides the designer with meaningful clues for their reductive process.

The researcher also acknowledges that a limitation of the study conducted within this research was that each of the observation studies was not lead by specific objectives or constraints that are usually imposed by specific design briefs. What was required during the studies, instead, was a more open-ended exploration of design ideas through the *autonomous reduction* using an artefact provided as a stimulus. As the professional participant P3 pointed out (P3, Interview, 00:13:11) during the interview, this conditional difference within the design situation made it harder for the participants to compare the design ideas developed in the studies and ones produced within real-world design practice. Or, as P4 argued, the designer's mind-set could also be influenced when more information is provided. Therefore, performances could potentially vary when deployed within actual design practice. Further research is needed to uncover the impact that *autonomous reduction* would have within the context of real-world design projects.

Lastly, this thesis mainly argues the potential of reduced and incomplete information, particularly for the industrial designer's imagination. The discovery of new knowledge derived from this research has also allowed the researcher to consider further foresight in the application of the technique of *autonomous reduction* beyond the field of industrial design. The researcher believes that the benefit of *autonomous reduction*, technique encourages the user to be aware of essential elements of existing artefacts and to explore new ideas, can potentially be widely applied in other design domains, such as graphic design, architecture design or service design. For example, the technique might be able to assist designers in challenging the complexity of the subject addressed, exploring critical and radical perspectives within "wicked problem" spaces if the technique was deployed in the service design sector. In such cases, it might be effective when the technique is used not only by designers, but also other stakeholders in order to elicit a wider range of working knowledge and ideas with regards to the issues to be addressed. Thus, the researcher believes that the technique of *autonomous reduction* has a lot of potential and exploiting the reductive methodology collectively could effectively contribute to enhancing creative imagination for the people that challenge complex and ever-changing social issues existing in the present day.

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