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Architectural cognition cards: a card-based method for introducing spatial cognition research and user-centred thinking into the design process

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ABSTRACT

In this article, we present the rationale, development and preliminary evaluation of a novel set of materials to encourage and improve the consideration of users and their needs during the process of architectural design. Our focus is specifically on two areas: user-centred design principles and spatial cognition research. To this end, we developed two decks of flash-cards, termed the Architectural Strategies Cards (72 cards) and the Spatial Cognition Cards (111 cards). We conducted preliminary evaluations of the cards in the design studio and in design thinking workshops with multidisciplinary groups of students and with architectural practitioners. Our results suggest that the cards improve designers' immersion into the perspective of building-users in a playful way and introduce scientific concepts effectively. In conclusion, we argue that serious-games and card-based methods should be part of the multiple approaches necessary to encourage and improve user-centred thinking, and integrate research findings into evidence-based design at large.

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Architectural design; urban design; user-centred design; spatial cognition; games; cards

Introduction

It can be argued that we demand so much more of architects and urban designers now compared to the past. The architectural design process is no longer just about designing something that looks good, fulfils a client's brief and is within budget. Today, an architect must also consider contemporary issues such as the health and psychological wellbeing of its inhabitants, designing for public, open spaces, integrating nature into designs, designing for ageing societies or diverse users and incorporating sustainable principles into the construction. Architects cannot be expected to have all of this additional knowledge at their fingertips and hence they increasingly require input from a range of disciplines such as cognitive science, environmental psychology, architectural and urban design and environmental engineering (e.g. Camargo, Artus, and Spiers 2018; Dalton and Hölscher 2016; Kuliga et al. 2014; Kuliga 2016; Krukar, Dalton, and Hölscher 2016; Mavros 2019). But how does an architect or urban designer even begin to find this 'outside domain' knowledge which often lies within knowledge silos in academia? The key question of this paper, therefore, is how can research, useful for design but originating outside the design world, be made accessible to designers?

This question is of particular interest to us because over the course of more than fifteen years, our team's interdisciplinary research work has centred on the overlap between architecture and cognitive science (Dalton, Kuliga, and Hölscher 2013; Hölscher, Brösamle, and Dalton 2010; Tenbrink et al. 2014) and particularly focussed on (i) spatial cognition or how people perceive, learn, remember and use spatial settings from rooms to cities and (ii) design cognition, or understanding the process of design, and specifically on how architects are able to put themselves into the 'shoes' of their building users, a concept known in psychology as perspective-taking (e.g. Gerace et al. 2013; Piaget 1967). Over this time we have worked on research problems and produced findings, around these two themes, that we have felt *would be* valuable to architects, *if only* we could make them accessible to them. We strongly felt that any approach to achieving this had to be 'design appropriate' meaning that it could be embedded in a typical design process: research should be taken to the designers rather than designers being forced to seek out research-findings in an unfamiliar milieu.

One potential solution to the problem of making academic research available to designers, which will be presented in this paper, was to develop a new resource, aimed at bridging research and design, aiding communication across disciplines and supporting architects in both spatial cognition and design cognition. Borrowing from the design thinking tradition (Norman 2013), we adopted a game-like approach. We created two decks of cards, the *Spatial Cognition Thinking* Cards and the *Architecture Design Strategies* Cards, designed to be used independently or together. The playful nature of using the cards is intended to make it easier to introduce research concepts into the design process.

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This paper is structured as follows. The first part provides the background to the general problem of integrating research into the design process and why it is so hard. The second part will discuss why perspective-taking is important for architects and why we are using this as one example of research which can be valuable for designers. The third part of the background to this paper will present a review of the pedagogy of games and cards. Moving onto the body of the paper, we will describe the rationale and process of creation of the two card decks. Finally, we report on our subsequent evaluation across multiple settings that revealed that this approach proved particularly successful for addressing perspective-taking.

Background and previous work

The importance of integrating research knowledge with design thinking

Design is often considered to be creative problem solving, and extensive studies show that designers and engineers combine their prior experience and knowledge (Rowe 1982; Schön 1983), with various ways of approaching a design problem, or *design heuristics* (Daly et al. 2012; Gray et al. 2016). Design heuristics support the creative process by providing information about the constraints of the problem at hand, or to explore potential solutions for responding to the project brief and its constraints (Rowe 1982; Daly et al. 2012). However, as architectural projects have become more complex, new challenges arise and, at the same time, more is expected of architecture in general (see the introduction). It is a well-documented fact that architectural practitioners simply do not have the time to keep up with scientific developments in all the fields that are relevant to complex architectural projects. As Fiona Samuel observes: 'the last place practitioners look for knowledge is academic refereed journals' (Samuel 2018, 83). Therefore, it is important to find new ways to bridge between disciplines, to encourage a dialogue between researchers and practitioners from different disciplinary backgrounds, and to make scientific knowledge (such as cognitive science concepts) more immediately accessible to designers. One way of doing this is to develop a shared vocabulary of terms and concepts, so that there is a common language between science and design. Given that designers do not always have the time to engage with advances in the scientific literature (Samuel 2018), or to conduct studies with users, the challenge is how to achieve a shared vocabulary across disciplinary boundaries – beyond the traditional approaches of textbooks and courses.

Here we are specifically concerned with *user-centred* or *human-centred design*, topics in which this issue is especially challenging, because of the current limitations on how architects acquire information about the users and their needs. As Hanington notes, 'at the beginning of a project, when the user group and its tasks are unknown to the design team, it is critical for members to immerse themselves in the user's world to develop a functional literacy of the material with which they will be working' (Hanington 2003). He argues that this early stage is exactly the point of a project where user-research is appropriate and necessary; yet other researchers have captured the difficulties of adequately integrating user-research into the design process. For instance, in their ethnographic research on how architects acquire knowledge about the end-users, Van der Linden, Dong, and Heylighen (2016), unearth a host of different issues: first, the traditional brief does not contain sufficient information about the end-use or end-users, knowledge acquired during the competition stage was not carried forward to the design development team, knowledge generated through the small-scale field study (interviews) stayed with the architect who conducted it. They argue that this issue is due to social and material limitations, a combination of lacking and organized knowledge sharing method, as well as 'a lack of adequate ways to represent this knowledge' (Van der Linden, Dong, and Heylighen 2016).

Other researchers have noted that designers often rely on subjective approaches, like their own intuition, to anticipate what users require from a design. In their discussion of introducing health and wellbeing considerations in the teaching of an architectural design studio, Oliveira et al. (2020) highlight that rather than scientific knowledge, students commonly use field visits and personal experience to enhance their understanding of what and how to design. As they write, 'examples of similar building uses featured in most reflections of "where one gets information"' (Oliveira et al. 2020). To remedy this issue, Grant and colleagues (2012) applied the scholar-in-residence approach, inviting a public health practitioner to join a design studio over an entire academic year Their approach was effective in broadening students' understanding of their role in the making of an inclusive environment, as well as providing input for improved designs (Grant et al. 2012). Other approaches may include involving end-users at various stages of the design process (Groat and Wang 2013).

These examples raise two questions. Given that human-centred design can be effective in healthcare settings, where clients and architects have a clear mandate, how can it be implemented in other, more generic, building typologies? Second, beyond the provision of mere guidelines, what other means could be used to educate and encourage design practitioners (architects, engineers and others) to more actively seek and adopt the perspective of the users? As Chrysikou stresses in her paper on this topic,

> we need to design for everybody without demarcation and for the people who design and build our environments to accept that "everybody", the users of their buildings, are not necessarily as physically or mentally able as them … We have a responsibility to teach them that "everybody is not necessarily like me". (Chrysikou 2018)

We examine this challenge in more detail in the next section.

The challenge of perspective-taking in the design process

Architecture, urban planning, and design are highly-complex decision-making processes, including multiple stakeholders, guidelines, requirements and design constraints. A key characteristic of complex buildings is their diverse range of occupants/users with different ages, abilities and needs. We argue that architects' ability to envision the use of the building, from the perspective of different user groups, is necessary to take into consideration the different users' needs.

The act of perspective-taking is essential to architectural design (Figure 1). An architect designs the building (design cognition) and a user interacts with it, the architect must additionally anticipate the users' interactions with the building, while making

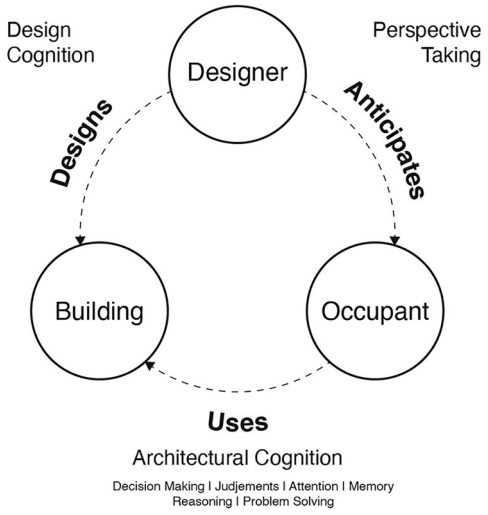

Figure 1. Diagram of the relationship between perspective-taking, design cognition and architectural cognition. Design practitioners design buildings (and other settings) while striving to anticipate and respond to the needs of end-users. The disciplines of architectural cognition, together with design cognition, can support this process by providing a knowledge-scaffold around the typical practice of perspective-taking. Diagram adapted from Conroy Dalton et al. (2013).

various assumptions regarding their needs and habits. During this design stage, the architect must also anticipate the architectural cognition (cf. Dalton and Hölscher 2016; Dalton, Krukar, and Hölscher 2018; Montello 2014) of the future building user. Thus, the architect must anticipate all of the decision-making, problem solving, spatial reasoning and judgements required by a building occupant to use a building: this is where the concept of perspective-taking comes in. Architects are trained to effortlessly switch perspectives from two-dimensional drawings and sketches to the corresponding, projected experience of being situated in the equivalent three-dimensional space – they are particularly adept at projecting themselves inside a floor plan. However, when doing so, there is evidence that this tends to be from their own perspective, relying largely on intuition and (self-) reflection to anticipate and incorporate users into their, as yet unrealized, conceptions of a building (Schön 1983, 1985, 1987; Yaneva 2009). As a consequence, architects and planners are ultimately limited by their own experience and knowledge in thinking about end-users (Van der Linden et al. 2019).

One aspect of buildings where this issue becomes often apparent is that of navigation; it is essential to the regular functioning of any building and urban environment (Iftikhar, Shah, and Luximon 2020), and a major component of *building usability* (Krukar and Dalton 2014). However, in controlled and in naturalistic studies it is observed that architects tend to underestimate the complexity of a floor plan compared to laypersons (e.g. Hölscher and Dalton 2008). As a result, there are numerous cases documenting that the architects of a building underestimated how end-users would eventually experience it, leading to issues with unintuitive circulation and other usability issues (e.g. Dalton and Hölscher 2016; Kuliga et al. 2019; Van der Linden, Dong, and Heylighen 2019; Chrysikou 2018). Taking into account spatial cognition is particularly pressing in the context of ageing societies across the world. Navigational ability declines naturally during the lifespan (i.e. in healthy aging; e.g. Coutrot et al. 2018), and more rapidly in the case of neurodegenerative disease such as dementia or Alzheimer's disease (Lithfous et al. 2013). In this context, we argue that equipping architects with a solid grasp of spatial cognition can enable architects to design places which are more intuitive for wayfinding and more sensitive to the needs of diverse user groups.

However, guidelines of design recommendations for inclusive or universal design, at present primarily aim is to provide basic principles for accessibility, and focus less on spatial reasoning or other higher-level user actions such as navigation. Furthermore, it is not sufficient to produce yet more guidelines for user-centred design as in many cases architects are not actually required to comply. As Chrysikou (2018) notes, in many architectural projects 'the need to implement a detailed guidance on neurodiversity might not reach the briefing process at all'. Unless the architects are working on healthcare projects, but instead work on the design of offices or airports, considering users with different abilities is often overlooked. And, unfortunately, this mindset is frequently passed on to architectural students (Chrysikou 2018). Therefore, it is important to establish methods to share scientific knowledge in a manner that shapes how designers think and approach projects.

In this context, our aims in the present work were, firstly, to develop another approach to support architects and designers to

> put themselves into the user's "shoes" (i.e. facilitating perspective-taking) within the typical design process, rather than a tangential activity or afterthought-checklist. Secondly, to enable and improve the sharing of "evidence" – theories, concepts, and empirical data – from spatial cognition research because of its relevance for designing "legible" environments. Since design is such an intuitive process, part of this must involve, at the most basic level, providing conceptual tools to make explicit one's own intuition, as well as facilitating discussions between different team members and stakeholders. Van der Linden, Dong, and Heylighen (2016) highlight that "informing architects about users" experiences includes more than just providing static information (e.g. through reports). It is also a dynamic process that involves design materials and interactive relationship.

One different way of achieving this might be through the medium of (serious) games.

The pedagogy of playful learning and (serious) games

Traditional pedagogy for architecture and architectural design has tended to focus on studio-based learning, in which learning is conducted through simulating the professional, real-world process of designing buildings (Schön 1983, 1985, 1987). In Schön's view, studio-based teaching is particularly effective because it reproduces the kinds of complex design problems typically encountered in the real world. The use of play and games (quasi role-playing) in architectural education has rarely been encountered in studio design, possibly because it might initially seem that nothing could be further from the rather serious aim of simulating real-world, professional architectural practice. In his book on the cultural role of games, Huizinga confirms that 'play is the direct opposite of seriousness' (Huizinga 1955). In Connolly et al.'s review of 129 educational games, when classified according to the subject discipline/curricular areas addressed by the various games, architecture and design do not feature even once (Connolly et al. 2012).

However, in the field of urban planning, simulation-type games are a frequently reported game genre (Connolly et al. 2012), mostly because of their suitability for participatory planning activities with expert and non-expert stakeholders. For instance, Mayer et al. (2004) describe how a planning game was used to support stakeholders envision design alternatives. They argue that collaborative play permitted alliances and cooperation to develop among the game players (Mayer et al. 2004). Indeed, as design teams are becoming ever more interdisciplinary, both in architecture and planning, the needs to communicate across professions and expertise are greater than they have ever been. Possibly one of the advantages of using a gaming approach in these professional settings is precisely about creating a safe space for communication.

Simulation-type games are more often digital simulations, for example, numerous researchers have explored the educational value of using the commercially available computer game *SimCity* (Electronic Arts / Maxis 1989), to create and run a successful city from scratch. This has been used to educate planning students (Gaber 2007; Minnery and Searle 2014). Terzano and Morckel (2017) observed 'that the game increased students' perceptions of the planning discipline as being fun and creative'. Aside from these examples above, few examples of using games to educate architects and designers can be identified (Roy and Warren 2019).

Playing games in higher education is not, however, as rare as in the specific domains of architectural education. Moseley and Whitton (2014) emphasize that games in higher education 'can provide a flexible option that has the ability to engage students, create active learning experiences, and enable students to experiment in safe playful environments'. They also provide a definition of what precisely constitutes a game, suggesting that it should contain the elements of rules, goals, progression and rewards, and note that this definition is intended to be a fairly flexible and inclusive model (Moseley and Whitton 2014). Furthermore, they suggest that -despite the growth of digital gaming in education-, more traditional games, such as board games and card games, are not only surprisingly robust (in the face of their digital counterparts), but are experiencing a resurgence in popularity. In the next section, we will specifically discuss how card games can be used in higher education settings.

Cards used in higher education settings

Traditional games in higher education settings are experiencing a resurgence in popularity, possibly because of their speed and ease of development (Moseley and Whitton 2014). Teachers and instructors are able to develop such games without the need for special skills, such as required to develop a computer game or mobile app. In this context, it could be argued that using cards in educational games is one of the most accessible forms of traditional games (others being board games, quizzes, and physical games). An emerging type of game are serious-games, which are typically used for educational purposes, or to encourage participatory situations and workshops. O'Neil, Wainess, and Baker (2005) have proposed a five-category taxonomy of serious games applications: *content understanding, problem solving, collaboration/teamwork, communication,* and *self-reflection*.

The most popular type of cards in higher education are the flashcards. Although not strictly a game, flash cards can also be used in a more or less gamified manner, and they have also been translated into digital, more game-like applications. Both in paper or computerized form, they have been found equally or more effective than traditional learning approaches, from foreign vocabulary training (Basoglu and Akdemir 2010), to paediatric knowledge for medical students (Sward et al. 2008). In psychology, and cognitive science, cards have been developed to translate insights from research theories about cognition, emotion, motivation, and behaviour into therapeutic tools (Rossa and Rossa 2018). An example more relevant for architecture is the SudoHopper3D card deck (McNeel Miami 2017), developed to teach Grasshopper, a visual programming language used for parametric design as part of the Rhinoceros CAD software.

Traditional card games have also been translated for learning; games based on Go Fish and Gin Rummy were used to teach gastrointestinal physiology (Gutierrez 2014; Odenweller, Hsu, and DiCarlo 1998). Cardiology and Pharmacology flash-cards, solitaire, and dominoes were used to teach organic synthesis problems (Barclay, Jeffres, and Bhakta 2011; Farmer and Schuman 2016; Knudtson 2015). Student feedback from those efforts suggests they are an effective non-lecture approach to teaching these topics, encourages student interaction and discussion, and makes students think about the topic in a new way (Barclay, Jeffres, and Bhakta 2011; Gutierrez 2014; Odenweller, Hsu, and DiCarlo 1998).

Cards used in design

Card-based design tools have already been introduced into the design process. In most cases they are used to stimulate creativity and out-of-the-box-thinking, and sometimes used to elicit input from stakeholders. Roy and Warren (2019) provide an extensive review of 155 card-based design tools, and classified thirty of those into different use-cases. These include: stimulating creative thinking, summarizing knowledge or methods, and providing concepts and checklists for specific design tasks. According to Roy and Warren (2019), most decks aim at facilitating creative problem-solving and domain-specific designing. Notably, there were only four card decks within the field of architecture/built environment and three for sustainable design. In this section, we review a small number of card decks, aimed at architects, designers, or other creative professions, that served as inspiration during the development phase of our card decks (described in the next section).

The *Oblique Strategies* (Eno and Schmidt 1975) served as key inspiration, because of its playful approach. Using questions, short design suggestions, and abstract ideas that aim at overcoming an artistic block, it prompts new angles to a design problem (e.g. 'cut a vital connection'). One important inspiration for us was the tactile and visually pleasing nature of the cards, with only essential, non-jargon information being displayed. This makes *Oblique Strategies* applicable for different contexts and bottom-up approaches, such as the ones we also aimed for (design and planning).

The *IDEO Method Cards* (IDEO 2003) are a deck of 51 cards aimed at design practice. They include an intriguing image on the front and short definitions of design methods on the flip side (e.g. 'Scale Modeling', 'how and when to use it'). More recently, the designer Ola Möller has developed 42 *Method Kits* (2012) intended as a concise way of introducing important concepts

for a different range of professions, including decks for architects. These cards support problem-structuring and discussing, such as understanding different perspectives, and structuring, mapping and discussing solutions.

In interaction design, a set of cards was designed to stimulate the generation of new metaphors for interaction, structure, and display – creating links between tangible real-world objects and digital actions – and generally to help reframe design problems. Two decks of cards were produced, the *Thing 1* and *Thing 2* decks: *Thing 1* cards consisted of photographic images of natural and artificial phenomena whereas *Thing 2* cards contained only text describing an abstract concept. Used in workshops, an image card and a text card were paired to form new and thought-provoking metaphors (Lockton et al. 2019).

In the context of architectural design, the *50 Urban Blocks* deck of cards (a + t research group 2017) contains urban block typologies. Each card consists of a plan and an axonometric drawing of different urban forms accompanied by urban performance metrics as well as a score of spatial density. This deck is not accompanied by any rules for playing. It illustrates different ways to, e.g. 'build the city', 'occupying and urban block' or 'reflecting how to organize land use… solids, voids and open spaces'. Ultimately, this particular deck serves as an inspiration –and reminder– for the designer, that there exist different approaches to accommodate the same building programme into the same plot.

In urban design and planning, card-like methods are often used in participatory planning and co-creation workshops, and often aim explicitly at supporting creative solutions and perspective-taking between different individuals and stakeholders (Tan 2020). For instance, the *OmaStadi Game* (Omastadi Platform 2018) card deck developed by the City of Helsinki and the UX design agency Hellon to encourage participation in civic decision making. The cards use archetypes of user groups (so-called personas) for perspective-taking, such as stay-at-home mothers, people with reduced mobility, or immigrants. Similar approaches exist for supporting discussions about critical topics in society, such as the *Drivers of Change* card-deck, which aims at evoking questions about climate change and other social, economic, or environmental topics (Ove Arup & Partners International Ltd. 2009).

Finally, a relevant example for our research is the research on identifying and applying design heuristics by Daly and colleagues. After systematically analysing the design heuristics used by mechanical engineering students and professionals (Daly et al. 2012), they turned them into a set of design heuristic cards and invited a new set of students and experienced teams of engineers to use them while solving an engineering problem (Yilmaz et al. 2014). Their findings show that the design heuristics materials were effective even with already experienced teams, by helping them become aware of design alternatives, organize the teams' internal exchange and discussion, and stimulate the overall discussion (Yilmaz et al. 2014).

The present work

To summarize, as building programmes become larger, more complex, and architects are asked to design for a diverse range of building end-users, typical design approaches do not sufficiently support user-centred thinking. While helpful guidelines often exist, understanding how a person will walk, perceive or remember how to navigate in a space are harder to grasp – or teach. Previous research has adopted various methods to encourage and enable user-centred thinking, from public participation to expert residencies, these approaches are particularly effortful and difficult to scale. In response, we have sought to develop a toolkit that complements existing approaches for supporting user-centred thinking and integrating scientific knowledge into design.

Our approach was to adopt card-based tools, harnessing their demonstrated capacity to facilitate discussions, provide structure, or widen the problem space, while at the same time providing a playful, flexible and pleasant experience for the card-users. Card-based serious games are typically designed to be engaging and summarize information without overloading the user/player, and have been used in higher education, to introduce and teach concepts to students. They have also been used in participatory planning processes, and in design to inspire and introduce new perspectives into the design process. The card decks reviewed above provided inspiration in terms of their design, content, and rules for playing in the development of our approach, as described in the next section. At the same time, the literature review has identified an important gap in the cards used in design. First, the reviewed card games focus only on a single topic, such as strategies, stages, or techniques. Second, using educational and serious games within architectural education might provide a playful method for promoting perspective-taking because they offer a self-discovery learning approach, rather than top-down teaching, and address the challenge of a lack of shared vocabulary between architecture and cognitive science.

In choosing to use cards in this study, we sought to answer the following research questions: (1) Can we develop a card-based game for integration of architectural cognition research in design? (2) *Do the cards improve user-centred thinking?* and (3) *Do the (resulting) cards facilitate communication between researchers and designers?* In the next section (a) we discuss briefly how the cards were developed and outline their structure, and (b) we present how the cards were tested and evaluated in different design settings.

Methodology

In this section, first, we briefly describe the rationale and structure of the two card-decks, and second, how we have employed them in different educational settings (design studio and workshop) in order to evaluate how they can be effectively used in different design contexts.

Description of the two card decks

We developed two complementary decks of cards (Figures 2 and 3), which can be used in tandem or independently, to invite designers and architects to think about the user and to establish a common vocabulary between architecture and spatial cognition. Why two decks? They do slightly different things: the *Architecture Design Strategies* Cards provoke perspective-taking and empathy; the *Spatial Cognition Thinking* Cards promote a shared

Figure 2. The two decks of cards: the Architecture Design Strategies Cards (left) aim to provoke perspective-taking and empathy, while the Spatial Cognition Thinking Cards (right) aim to promote a shared understanding of cognitive science concepts and evidence-based design, offering a shared vocabulary between researchers and designers.

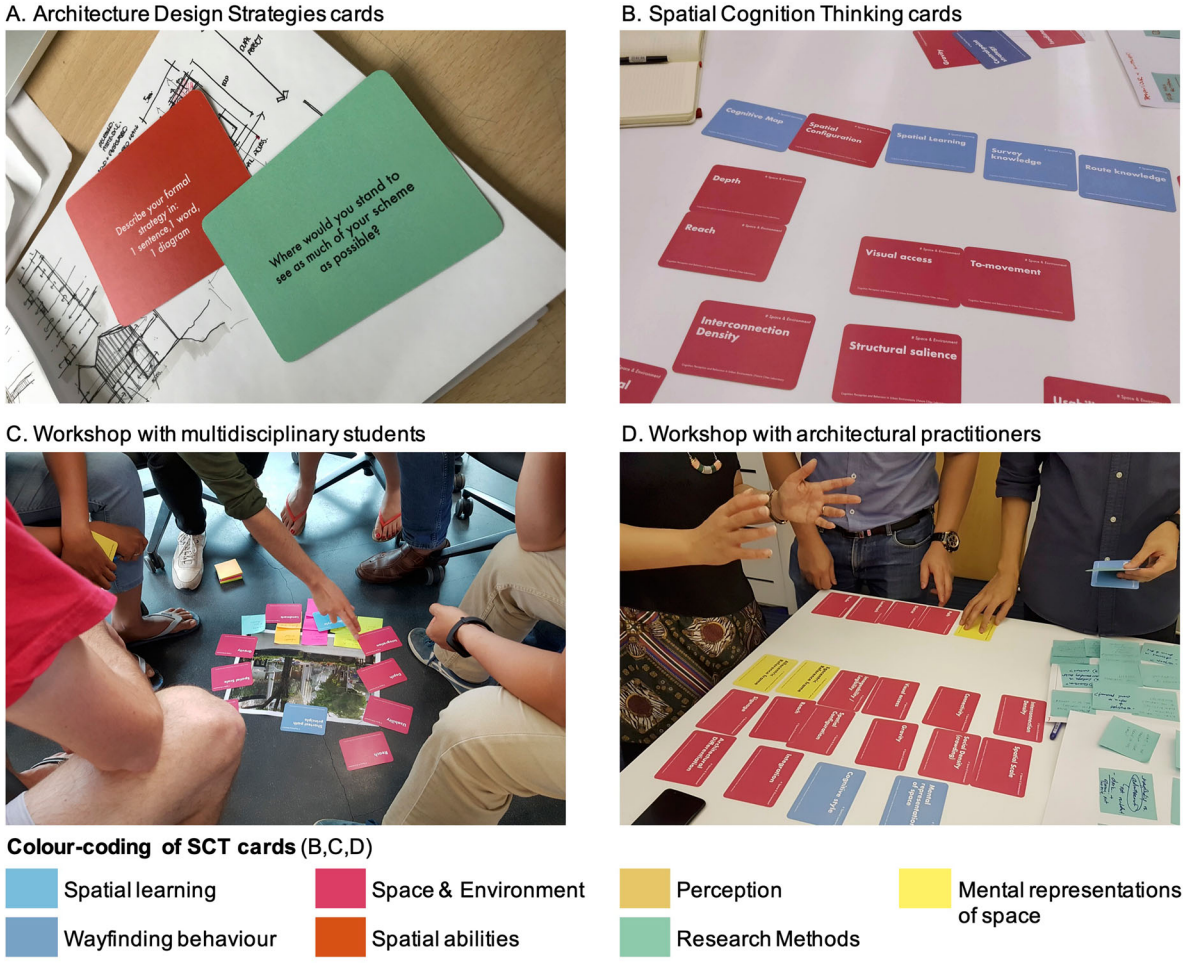

Figure 3. Images of using the two card decks in the design studio and in workshops. (A) the Architecture Design Strategies cards being used in the postgraduate architectural studio. (B) Spatial Cognition Thinking cards laid-out on the table at the end of the workshop with practitioners, organized in terms of (perceived) project relevance. (C) Group of multidisciplinary students, using the Spatial Cognition Thinking cards to discuss which aspects of spatial cognition can help understand people's behaviour in a major pedestrian street. (D) Spatial Cognition Thinking cards organized in column by practitioners and used to structure a discussion on user behaviour in complex buildings. Image credits: Dalton, Hölscher, and Montello 2019 (A); Saskia Kuliga 2019 (B,C,D).

understanding of cognitive science concepts and evidence-based design, offering a shared vocabulary between researchers and designers. Having these available as separate decks provides greater flexibility for the design team and allows them to choose the most appropriate emphasis according to their design activity.

Our cards fall into what Roy and Warren (2019) call a human-centred design card deck of their classification, i.e. to stimulate

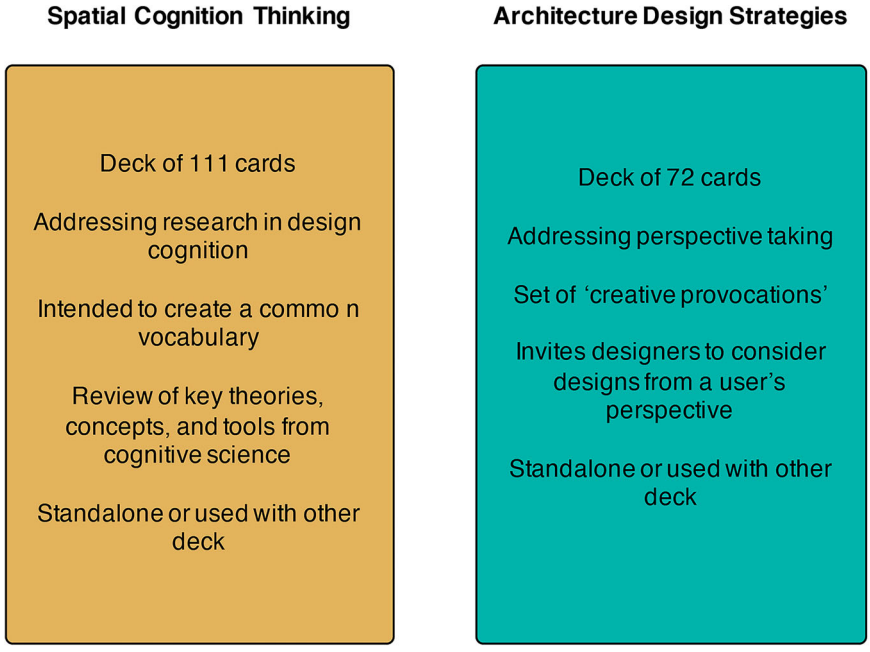

Figure 4. Distinguishing characteristics of the two card decks, including the number of cards per deck, objective, and mode of use.

thinking about others (here, the end users of a building or urban environment). The cards can be used within a team or individually in a manner not typically afforded via written media such as books/papers/design guides. Furthermore, the playful nature of a deck of cards seems particularly apposite to the creative spirit of the design studio. The cards are intended to be used in typical educational and design settings, such as the design studio or workshops. Figure 4 summarizes the key aspects of the two card decks, and Table 1 summarizes the overall structure of the cards in terms of topics and themes covered. Physically, both decks are designed as A6-size colour-coded playing cards (105 × 148 mm/4.13 × 5.83 in.).

Table 1. The structure of the two card-decks.

Architecture design strategies	Spatial cognition thinking
72 cards	111 cards
A set of prompts and creative 'provocations'	A review of key theories, concepts and methods from cognitive science
Aims:	Aims:
1. Prompting experience of being situated in envisioned space	1. Create a common vocabulary
2. User perspective-taking	2. Develop an initial understanding of key theories and concepts
3. Creative provocations	3. Dialogue between science and design
Organized into four groups:	Organized into seven groups:
1. Ideation	1. Wayfinding Behaviour
2. Analysis	2. Spatial Learning
3. Synthesis	3. Perception
4. Evaluation	4. Space & Environment
	5. Research Methods
	6. Spatial Abilities
	7. Mental Representations of Space
Average 18 cards per group	Average 16 cards per group
Coloured according to group	Coloured according to group
Key games:	Key games:
Pebble Throw	Prompt and Pick
Random Draw	Categorise
Additional games:	Additional games:
Prompt and Pick	Pebble Throw
Categorise	Random Draw

Architecture Design Strategies cards[1]

The *Architecture Design Strategies* card deck consists of 72 cards. Each card consists of either a question, a suggestion or an observation which invites designers to think about their project from a new and/or different perspective (cf. Eno and Schmidt 1975). The cards' content was developed based on the author's (RCD) previous research in spatial cognition, and informed by her experience teaching architectural studio. For example 'Seek inspiration from the space you are in now', 'What do you need more evidence for?', or 'Where would you place any signage?'. The objective of this card-deck is to prompt a shift in the designer's thinking in one of three different and distinct ways.

1. experiential-situating, to help the designer(s) situate themselves into, and imagine experiencing, the –as yet unrealized– three-dimensional building;
2. perspective-taking, to assist the architect(s) in 'stepping into the shoes' of a future building user;
3. creativity-provoking, to provide a general, creative impetus to overcome creative blocks or simply suggest new directions.

In order to further facilitate the utilization of the cards as a game and its appropriation to inform different design activities, the cards are organized into a thematic taxonomy. Building upon previous formulations of the architectural design as a cyclic process that comprises of four basic activities (Cross 2006; Goel and Pirolli 1992; Jones 1980; Kalay 2004; Lawson 2006; Rowe 1998), the cards were organized (and colour-coded accordingly) into four groups: *ideation, analysis, synthesis*, and *evaluation*. Notably the three initial aims of the card design, i.e. experiential-situating, perspective-taking, and creativity-provoking, cut across this taxonomy.

Spatial Cognition Thinking cards[2]

The *Spatial Cognition Thinking* card deck consists of 111 cards, concisely summarizing key terms, theories and concepts from the fields of spatial cognition, cognitive and behavioural science, and spatial analysis. The cards, similar to the flash card typology, consist of a keyword (scientific term or concept) on one side and a brief description as well as a few important references on the flip-side. Thus, the cards can both initiate the introduction into architecture-relevant topics from spatial cognition research, as well as be used with card-game mechanics (select/sort/prioritise) as part of a design thinking session.

The cards are organized in seven main groups of terms: *Wayfinding Behaviour, Spatial Learning, Perception, Space & Environment, Research Methods, Spatial Abilities, Mental Representations of Space*. Given that spatial cognition is a nexus of a wide-range of disciplines (cognitive psychology, behavioural geography, computer science), at present the deck covers a subset of topics which the authors considered relevant for design. These include, among others: how people perceive their environment (sensory information), how they remember spatial information (egocentric, allocentric and other types of mental representations of space), or how people quantify spaces and spatial networks for navigation. Two examples of cards are:

> (a) Central-point strategy (front side): During wayfinding in complex or multilevel environments, the central point strategy relies on visiting / passing through well-known (or salient) parts of the building, for example a major intersection, a lobby, an atrium. The architectural characterists of a space may encourage or impede whether it is in fact perceived by users as "central". (Hölscher et al. 2006) (flip side)

Or

> Structural salience (front side): A landmark, such as an object or building, which stands out from each surroundings because of its location. For example, a building at an intersection, or a statue in the middle of a square. (Roser et al. 2012) (flip-side)

Notably, in contrast to the *Architecture Design Strategies* cards, this deck does not attempt to situate the reader into a specific design-context. Instead, it provides a window into the terminology and theory behind spatial experience and behaviour. It enables the card-users (the 'players') to explore how a theoretic concept fits into a real-world context, for example asking 'what is structural salience of a landmark, and how it influences how people may perceive this neighbourhood?'

Testing the cards in multidisciplinary settings

In order to evaluate this approach for introducing user-centred research and thinking (perspective-taking) into the design process, we conducted several initial tests in educational and professional settings (Table 2), spanning two types of scenarios: the design studio, and a multidisciplinary design workshops. These two types of settings emulate how the cards could be used in practice as part of a long-term design process over several months, as part of a design charrette, or as part of interactions with different disciplines engaged in design (engineers, stakeholders, wider public). For clarity we note that the workshops did not include public participation from the wider community, i.e. laypersons or 'building end-users'.

Participants

Overall, we conducted four trials of the cards with a total of 70 participants that used and provided feedback on the cards as part of design studios or design-thinking workshops. Table 2 shows each user-testing engagement (i.e. card-deck trial), how the cards were introduced to the participants (facilitated/ non-facilitated), which deck of cards was used in each engagement, and how many participants were involved. Participants were informed in advance that the cards are prototypes, that they would be asked for their evaluation at the end of the workshop, and that their responses might be used in a future scientific publication (see Appendix 2). Institutional ethics approval was obtained from Northumbria University's Research Ethics Committee [RE-EE-15-160224-56cd926e809c4] in case personal data or personally identifiable data were recorded (e.g. the audio-recording of the focus group discussion).

Testing setup

Table 2 summarizes the preliminary tests of the cards discussed here can be distinguished into (i) design-studio or (ii) design-thinking workshop use, were we observed *how* they were being used and whether they were able to be *seamlessly integrated* into the design process.

An informal pilot was conducted as part of a science outreach workshop with sixteen design practitioners and cognitive scientists in January 2018, as part of 'The User in Mind Symposium' that was organized in Singapore (this event was not evaluated, thus not taken into account on Table 2). Following the initial observation that the two cards decks were well received and supported the exchange between the disciplines (i.e. designers and cognitive scientists) we used and evaluated the cards two types of settings.

First, we used the *Architecture Design Strategies (ADS)* Cards as educational material in Dalton's design studio at the MArch II (School of Architecture, Northumbria University) for two consecutive years (2017–2019). The students participating in the design studio worked for 2 semesters on a brief to develop a mixed-use site in Hartlepool (Durham, England). The students had to develop their own brief and building programme, and were encouraged to think about the building end-users in different ways along the way. The ADS cards were used by the studio leader (Dalton) in the course of weekly, individual tutorials with students. For example, while discussing with a student a card would be introduced to provoke a shift in thinking about the space, or to re-examine a design decision.

Second, we tested how the cards can be used in the fast-pace of design-workshops, and with diverse audiences (both architects and non-architects). To this end we employed the cards in several multidisciplinary design workshops that were organized with the primary objective to introduce spatial cognition research and human-centred thinking to students and practitioners (led by Mavros, Dalton, Kuliga, and/or Gath Morad during 2018–2019). Following an introductory talk on spatial cognition and behaviour, we provided participants with a 'nominal' design brief that could be explored in a short amount of time, such as to identify what issues a visitor of a building might face, and to brainstorm a few design strategies to address them. Visual materials, such floorplans and photographs were

Table 2. Testing of the Architecture Design Strategies (ADS) and Spatial Cognition Thinking (SCT) cards.

#	Event	Participants N (Female)	Card-deck ADS	Card-deck SCT	Evaluation method	Date
Facilitated						
1	2 years of postgraduate architectural design studio (1 semester × 2 years)	14 (2)	X		Observation & Focus Group Discussion	Spring Semester 2018 and 2019
2	Workshop with architectural practitioners	7 (2)		X	Observation & Questionnaire	Jun 2019
3	Workshop with multidisciplinary students	30 (12)		X	Observation & Questionnaire	Jun 2019
Non-facilitated						
4	Graduate summer-school with architectural design students	19 (13)	X	X	Observation & Questionnaire	Aug 2019
Total		70 (29)				

Figure 5. Example workshop materials for to use the two cards decks during user-centred perspective-taking exercises. Right: A picture from the Orchard MRT (metro) station in Singapore (Credit: Panagiotis Mavros 2019), was used for egocentric perspective-taking. Left: A plan-view of a major shopping mall in Singapore, used as an example of complex public building which should accommodate the needs of diverse user groups, serves as a prompt for allocentric perspective-taking (Credit: Panagiotis Mavros 2019).

provided. These were chosen deliberately to establish an allocentric (floorplans) or egocentric (eye-level photos) perspective of the spaces (Figure 5). In the facilitated workshops (workshops 2 and 3; Table 2), participants worked in small groups, each examining a real (and for some, familiar) building or location. First they were asked to identify 'what are the main challenges people face in those spaces', in terms of cognition, perception, experience and the building itself. Second, they were provided with the SCT card deck and were asked to browse through the cards, select those cards they found relevant for their case-study, and sort them from the most important to the least important. Finally, they were asked to pick one of the challenges they identified, come up with potential (design) solutions to address them and present them to the entire group. During the workshop, the facilitators engaged with the participants via active listening techniques, providing additional input or clarifying the meaning of card. These included summarizing participants' decisions and asking guiding questions, such as 'would you like to browse this deck of discarded cards again to see whether you are ok with your choices?'. This approach was found an effective discussion prompt both with undergraduate and postgraduate students from diverse disciplines (architecture, social science, and engineering) as well as with experienced practitioners' (average 11 years professional experience).

Evaluation and feedback

Different methods of eliciting feedback were used according to the audience and context. We discuss these in turn. In the case of the university design-studio, a focus group (for which institutional ethics approval was given) was conducted after the end of the semester during which the cards had been used. The focus group lasted 60 min and was attended by all (nine) students, who signed a consent form prior to participation. It was made clear that it would be recorded and they could withdraw at any time. Two members of staff (Dalton and Robson) acted as discussion facilitators. The focus group followed a semi-structured style (see Appendix 1) and spontaneous, follow-on questions were permitted. The discussion was recorded, transcribed and imported into *NVivo* (Alfasoft GmbH Germany, n.d.).

In the case of the design thinking workshops (i.e. workshops 2, 3, 4 – see Table 2), participants were asked to fill-in a questionnaire consisting of 22 Likert type questions (Appendix 2), developed based on the results of the focus group discussion. Questions included statements such as 'How informative did you find the content of the cards?', multiple choices 'How did you, as an individual, use the cards?' and open-ended questions such as 'Did the cards provoke any new thoughts / specific shifts in your thinking about the case-study?' (see Appendix for the full survey).

To assess the effects of facilitation and participant background, we applied inferential statistics on four of the survey questions, based on their relevance: 'Did you understand how they were meant to be used in a workshop / design studio?' (Q1), 'How informative did you find the content of the cards?' (Q2), 'The text was well- written / useful' (Q3) and 'Did the cards provide you with a better understanding of spatial cognition?' (Q4). The three workshops were categorized in two separate factors: *facilitation* (facilitated vs non-facilitated) and *group* (professionals vs students) which were entered as independent variables. To account for the ordinal nature of likert scales (Liddell and Kruschke 2018), responses were analysed using ordinal

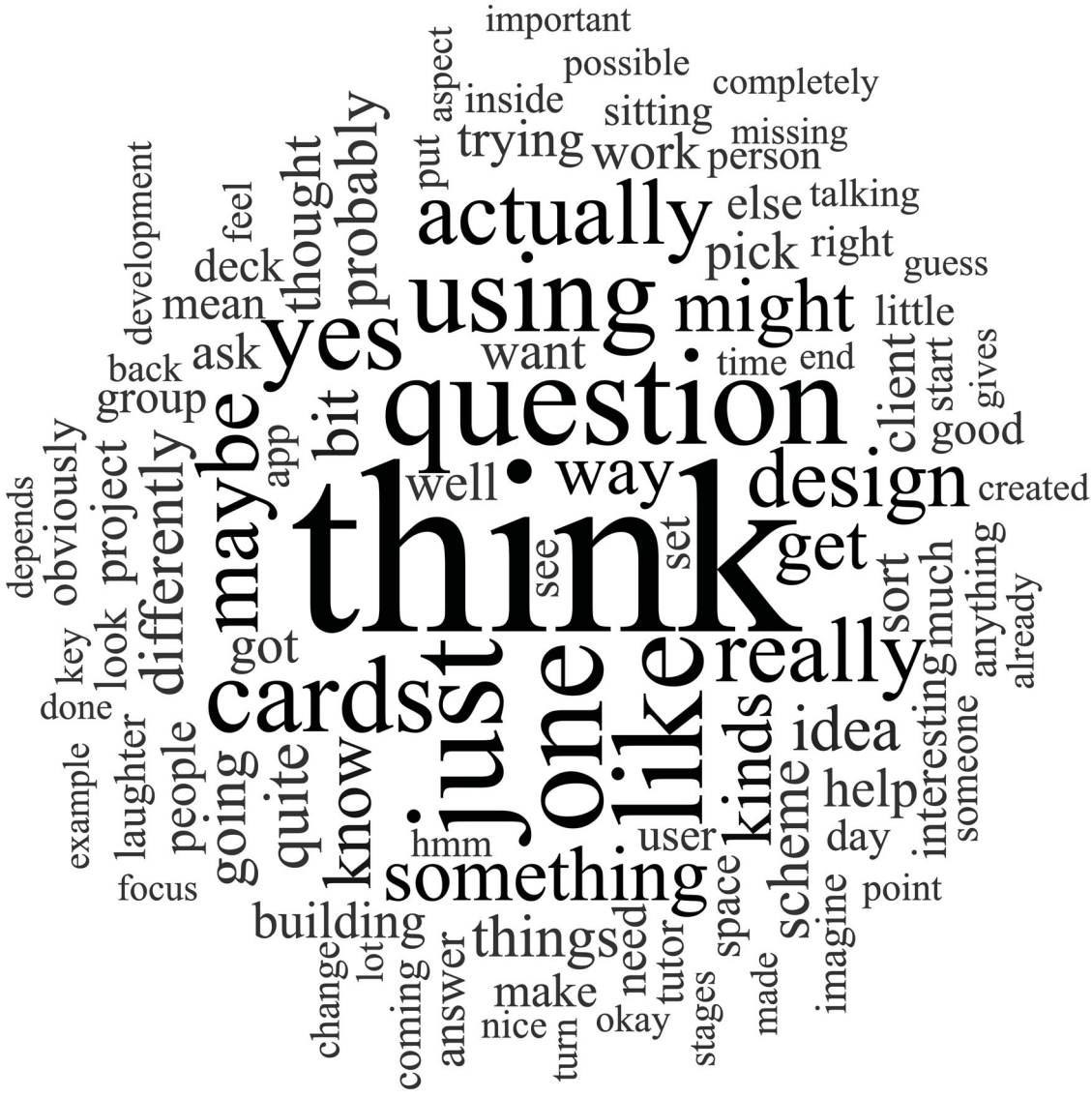

Figure 6. Word cloud visualising the word frequency analysis from the focus group discussions, where the Architecture Design Strategies Cards were used (n.b. common words omitted). The most frequent words, e.g. *think, question,* and *differently,* support our objective to encourage the critical reflexion (questioning and re-thinking) of the students' own designs.

regression, performed in R (R Core Team 2020) using the R-packages 'ordinal' (Christensen 2019), sjPlot (Lüdecke 2020) and 'likert' (Bryer and Speerschneider 2016).

Results

In this section we present the evaluation of the two card-decks by the participants in the different user-centred design activities, presenting first the qualitative analysis of the focus-group discussions that followed the semester-long design studio, second the results of the post-workshop survey completed after each design-thinking workshop, and finally we discuss informal observations made by the facilitators.

Design studio evaluation (focus group)

The focus-group transcripts were analysed by computing word frequencies (Figure 6). Word frequencies were then grouped and used to formulate the following eight (8) thematic codes (Table 3): *Inspiration* included any comments about gaining new insights or new ways of looking at things, because of or through using the cards. The focus here was on newness or novelty, and shifts in thinking or sudden insight. *Knowledge* was about knowledge or thinking that was either already available (i.e. knowing something) or was achieved (i.e. making you think), but with the exclusion of the sudden, designerly shifts/insights already covered above. The theme *Liking* encompassed any comments where a participant described liking particular cards or the whole deck/process of using them, etc. *Perspective-taking* included comments that described architectural perspective-taking, in particular about designers being able to imagine things from the perspective of the building user (especially via card-questions). *Spatial Quality* covered any comments to do with the qualities of space and how people might experience space (including emotions elicited from spatial experience). *Design Process* included anything about the act or process of designing not already covered in other themes. *Utility* consisted of anything about the

Table 3. Examples of comments assigned to different thematic codes.

Thematic code	References coded	Coverage	Example comments
Inspiration	10	3.31%	'It makes you think of something that you probably were not aware of thinking of on that moment'. '… that was one particular example, which changed the way I designed'.
Knowledge	17	4.35%	'You have to react and think, actually, "Have I even thought about that?"' 'So, I think that's probably what, if anything, will make you think more, because you just have to think on the spot'.
Liking	4	0.79%	'The one card I liked, I thought really helped my project was … ' 'I think I'd recommend it to a young, sort of, an architect student starting off … '
Perspective-taking	9	2.90%	'I think in the past, I feel I've designed the sorts of projects that is stuff that I like, and I've tried to create interesting spaces, but … this one, it was completely different … I just had to think about how they would use this space, where I wouldn't know how to … ' 'Essentially, I just created a false person and I called them 'Sam'. And I kind of used him to tell the story and the journey through my project'.
Spatial quality	5	0.59%	'I think [it] helped, sort of, create the key atmospheres that my building wanted to achieve'. '… what's it going to be like in the flesh … '
Design process	17	4.58%	'It made me improve what I'd already made, rather than just change everything'. 'That would really help resolve a couple of issues that I was having with the scheme at the time'.
Utility	19	5.21%	'The one card I liked, I thought really helped my project was … ' 'I think they're a really decent, good idea, especially, for undergraduates … '
Wayfinding and navigation	1	0.67%	'I saw one that made me think of one that I actually got when I picked one of them. So, it says, 'Where will people get lost?' And then that, kind of, makes me think of, 'Where would you place any signage?' Just because I remember some of our schemes are just really big or they're just that little bit too much'

cards being useful or helpful in any way. *Wayfinding and Navigation* included any comments about imagining moving through or around the scheme. There was only a small degree of overlap between the themes with, occasionally, a comment being coded for more than one theme (i.e. when it clearly did not sit in just one or another). Examples from each of these themes are shown in Table 3, together with raw counts and frequency of occurence.

The most frequent themes were about how using the cards had really challenged the students' thinking (Table 3). Students unanimously felt that using the cards had had a positive effect on the design process and on the design quality of their resultant building. The most interesting comments were about the effect of the cards on the student's perspective-taking, imagining putting themselves into the shoes of their users. Most of the students, in this focus group, reported that using the cards had made them think about their users in a different way, even prompting them to create a named persona to represent their user, as a result of a card they had selected. This aspect of increased perspective-taking is particularly interesting, as it is echoed in the results of the workshops as well.

Workshop evaluation (questionnaire)

Overall, 24 participants completed the questionnaire used to evaluate the use of cards in the design thinking workshops: 7 from the facilitated workshop with practitioners, 9 from the facilitated workshop with multidisciplinary students, and 8 from the non-facilitated workshop with architecture students (Figure 7). Table 4 shows how the SCT cards were rated across workshops. The ratings were analysing using ordinal regression to account for their ordinal nature (below we report the odds-ratio for a higher rating, model results presented in Supplementary materials). Mean ratings are reported below for easier comprehension, per group: students – facilitated (S/F), professionals – facilitated (P/F) and students – non-facilitated (S/NF).

The results show that the majority of participants in the facilitated workshops understood well how to use the cards while participants from the non-facilitated workshops had lower odds of reporting they understand how to use the cards ($Mean_{P/F} = 4.71$, $Mean_{S/F} = 4.89$, $Mean_{S/NF} = 3.12$; OR = 0.09, CI = 0.01–0.65, $p = .017$). Further, participants of the facilitated workshops found the text more informative than those of non-facilitated workshop ($Mean_{P/F} = 5.71$, $Mean_{S/F} = 5.56$, $Mean_{S/NF} = 3.62$; OR = 0.07, CI = 0.01–0.65, $p = .019$), and found the cards provided them with a better understanding of spatial cognition ($Mean_{P/F} = 5.29$, $Mean_{S/F} = 5.89$, $Mean_{S/NF} = 2.88$; OR = 0.00, CI = 0.00–0.11, $p = .001$). There was no effect of facilitation on assessing the text as well-written, but a significant effect of group, as students had lower odds of assessing the text as well-written ($Mean_{P/F} = 5.86$, $Mean_{S/F} = 4.56$, $Mean_{S/NF} = 3.88$; OR = 0.09, CI = 0.01–0.71, $p = .022$).

Across all workshops, participants adopted various strategies to use the cards: approximately half (45%) reported shuffling through the cards, and selecting concepts they found intriguing. Other strategies noted were: to randomly select one or sort them by category/colour and then select cards participants considered relevant. In terms of application, respondents considered the *Spatial Cognition Thinking* Cards deck to be most relevant for education, team-work, and self-study.

A small number of participants responded to the optional open-ended questions. Several cards were reported as the respondents' favourite one, for example the cards 'social density', 'shortest path', and 'satisficing'. The least favourite cards were described by participants as those with ambiguous definitions (on the flip side). To the question on usage, respondents mentioned they can be useful to identify topics relevant for the design process and try to understand. Example comments students wrote as optional free text included: 'It [the cards] gave us a systematic way of thinking about different potential issues about the site and which ones are most relevant' and 'We can use to explain more clearly as the card gives us a more structured terms in spatial cognition'.

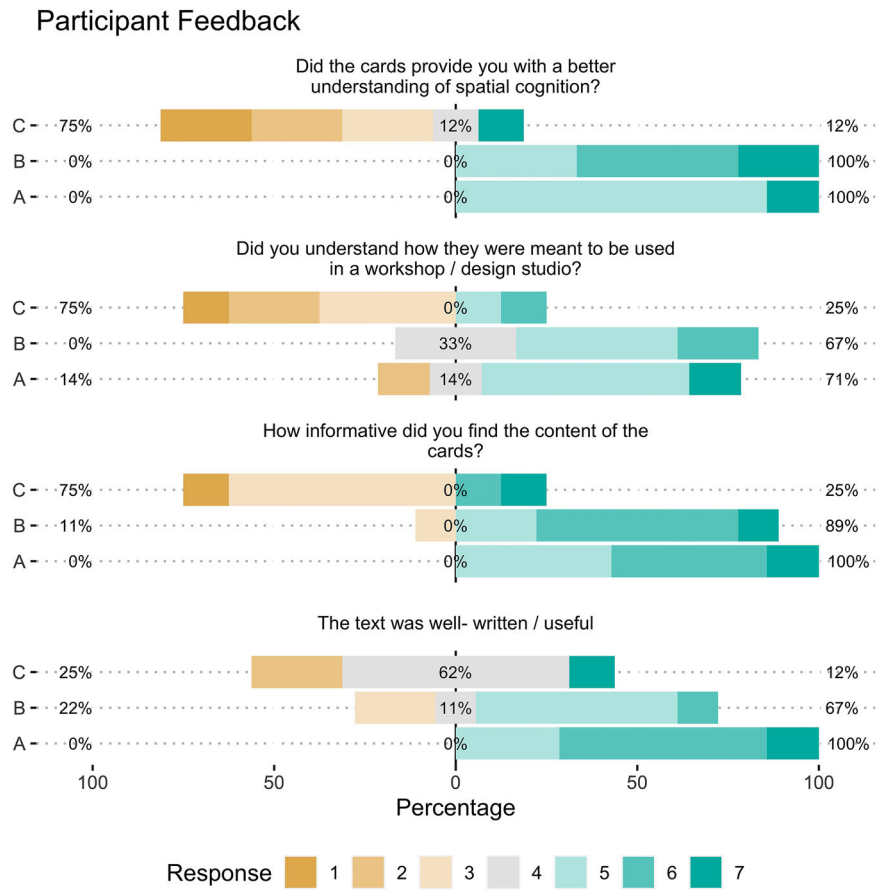

Figure 7. Likert-plot showing participant feedback to each workshop (note this does not include the design-studio). Reading from left to right, percentages show the percent of responses that were negative (i.e. aggregating responses 3 or lower), neutral (4), or positive (i.e. aggregating responses 5 and above). A difference in the responses can be observed for all questions between the two facilitated workshops (A, B) and the non-facilitated one (C).

Table 4. Descriptive statistics of responses to the workshop evaluations.

						Likert rating						
Question	Workshop	Mode	Group	Mean	SD	1	2	3	4	5	6	7
Did you understand how they were meant to be used in a workshop / design studio?	A	Facilitated	Practitioners	4.71	1.50		1 (14%)		1 (14%)	4 (57%)		1 (14%)
	B	Facilitated	Students	4.89	0.78				3 (33%)	4 (44%)	2 (22%)	
	C	Non-facil.	Students	3.12	1.64	1 (12%)	2 (25%)	3 (38%)		1 (12%)	1 (12%)	
How informative did you find the content of the cards?	A	Facilitated	Practitioners	5.71	0.76					3 (43%)	3 (43%)	1 (14%)
	B	Facilitated	Students	5.56	1.13			1 (11%)		2 (22%)	5 (56%)	1 (11%)
	C	Non-facil.	Students	3.62	1.92	1 (12%)		5 (62%)			1 (12%)	1 (12%)
The text was well- written / useful	A	Facilitated	Practitioners	5.86	0.69					2 (29%)	4 (57%)	1 (14%)
	B	Facilitated	Students	4.56	1.01			2 (22%)	1 (11%)	5 (56%)	1 (11%)	
	C	Non-facil.	Students	3.88	1.55		2 (25%)		5 (62%)			1 (12%)
Did the cards provide you with a better understanding of spatial cognition?	A	Facilitated	Practitioners	5.29	0.76					6 (86%)		1 (14%)
	B	Facilitated	Students	5.89	0.78					3 (33%)	4 (44%)	2 (22%)
	C	Non-facil.	Students	2.88	1.96	2 (25%)	2 (25%)	2 (25%)	1 (12%)			1 (12%)

Note: (A) facilitated workshop with practitioners, (B) facilitated workshop with multidisciplinary students, and (C) non-facilitated workshop with architecture students. Counts per rating level (1 = Not at all; 7 = Very much).

Finally, with regards to using the cards in the design process, respondents considered the cards to be useful: for participation (starting discussions with unfamiliar stakeholders); to kick-start the design process (brainstorming and inspiration); at the concept development stage; and as a checklist to keep important aspects of user-centred design in mind. As one respondent wrote, 'as a design engineer, we often do "human centred design thinking" without a firm understanding of how to bring in the user into the design process. These cards might be helpful there'. Respondents also highlighted challenges. There were possibly too many cards, and the need to include technical terms made some of them less accessible, highlighting the need to adopt different writing styles when reaching a wider audience.

In the non-facilitated workshop, students were working in teams of 2–3 students and were under time pressure to complete the tasks. As one respondent wrote: 'I didn't have much

time to use them. I only read them all [at] once'. This constraint coupled with a non-active facilitation style, led to varying levels of engagement, interests and satisfaction with the cards.

To summarize, overall the cards were perceived as useful and informative, and the majority of respondents could foresee using them with colleagues in a design studio or participatory process. However, participants of the non-facilitated workshop were less clear about how to use them and how to integrate them into the design process.

Additional informal observations

In addition to participants' own impressions of using the cards discussed above, it is useful to reflect how participants used the cards, based on the informal observations of the authors that facilitated these workshops. Specifically, we discuss three interrelated questions: (a) how did participants use the cards during the workshop, (b) whether they used any of the 'new' terminology during the workshops, and (c) whether the design solutions at the end of each workshop suggested a user-centred approach.

Use of cards during the design sessions

Firstly, in both students and practitioner groups (Figure 3), typically, individuals first picked-up a deck of cards, browsing through them in silence. Soon, both groups spread out the cards on the table so that all cards were visible. Student participants asked other group members to discuss/explain concepts, whereas practitioners directly asked the facilitators.

Independent of the workshop instructions, participants self-initiated recurring discussions. For instance, in the student group, these discussions revolved mainly around the *use* of several concepts for the application in their tasks. In the practitioner group, discussions remained more *theoretical*. They discussed which cards belonged to either psychology or architecture, which concepts could be quantified or not, and how cards on the table were theoretically interconnected (e.g. 'how are social density, connectivity, and cognitive style related?').

In the questionnaire, participants were asked to indicate which card they considered more important or useful. Participants of the student workshop chose: time–cost analysis, connectivity, dead ends, loops, cognition, signage, navigation 'A to B', axial lines, place, visual perception, memory, and accessibility. In contrast, participants in the practitioners' workshop referred to hierarchies/groupings of several cards, rather than a single one, perhaps reflecting that with increased experience they considered human behaviour more holistically. In the design studio, on the other hand, one student was fascinated by the card which asked 'what would your mother do?'. To him, this card was the most intuitive, a core way of rethinking his own design and methods. Other students argued that the cards could be used to better establish personas, that the open-ended style of the questions without providing answers is positively thought-provoking, and that a few concepts from the cards could be learnt daily to integrate the concepts more naturally into the design process.

Use of card terminology

At the end of the workshop, students were asked to present their proposed designs. Although they used terminology from the *Spatial Cognition Thinking* Cards, they did not always link the card concepts to their proposed outcomes. In contrast, experienced architects (practitioner workshop) tended to link card concepts to their own expertise, e.g. how planners typically evaluate spaces based on a floor-plan-perspective, considering the orientation of building, use-types, attraction factors, shop allocations, and different regions. In this context, they used the 'Visual Access' card to describe what users would see and where users would need information.

One interesting occurrence happened, in one of the workshops, when it became evident that the practitioners realized that they had discarded all the user-oriented tasks from the *Spatial Cognition Thinking* Cards in favour of having mostly architectural terminology on the table. They then started sorting the cards according to two perspectives (architects, users). Practitioners regarded it as a placeholder for a missing connection of predictive software for quantifying users, and stated the two piles represented 'what we know as architects' and 'what we don't know: the user side'. Notably, the *Spatial Cognition Thinking* cards served primarily to raise awareness around user-related issues, but did not yet lead into perspective-taking.

User-centred design solutions

Since these were preliminary trials of the two card decks without a control group who did not use the cards, we can only evaluate the design solutions from the workshops, and further research is needed (see Limitations and Future work below). Six out of seven student presentations about design solutions clearly included the perspective of users. For instance, the students noted that dead ends were confusing for people and that some areas should be more connected. The practitioners appeared to use the cards to establish a general glossary using research terms and concepts, and focused more on theoretical discussions.

In the workshop without an active facilitator, uptake of the cards varied depending on how developed was the design of each team when they started exploring the cards. In teams in which the conceptual design was still under development, the cards were used more frequently and acted as a source of inspiration; one participant wrote 'I liked the quote on the "Central Point Strategy" which was a concept we were using for our project'. In contrast, teams that were further in the development of their design concepts appeared to use the cards less or use it to seek confirmation and justification for their design choices: '[the cards] only reinforced our ideas and provided further evidence'.

Discussion and future work

The main question underlying this paper was *how* we could better integrate spatial cognition research into the (architectural) design process, with a specific focus on user-centred thinking and spatial cognition theory as knowledge domains that we wished to test. To adequately answer whether we could bring academic knowledge from spatial cognition research into the design process, we consider three important aspects: (a) how can such materials be used in different types of design education or science-design interactions, (b) whether they improved user-centred thinking and (c) whether they were able to facilitate

communication between researchers and designers. We discuss each of these sub-questions in turn:

First, we found several effective ways to not only use the cards but also structure the design thinking process around them. As with many games, it is important to give participants a clear context. This can be a task to review the cards and choose the three most important concepts, or to browse through the cards. The above rules are simple and easy to follow, even within the short time-frame of a workshop or a design review.

Second, we sought to investigate whether the cards improve user-centred thinking. In general, across the settings we evaluated the cards in, the cards supported familiarization with the terminology and concepts relevant for user-centred thinking. This is in line with earlier studies from other fields demonstrating the effectiveness of card-based educational materials to support knowledge acquisition from novel domains quickly and efficiently. However, in our context of user-centred design-thinking, we also noted that participants often created simplified user-journeys or 'personas', rather than engaging more deeply in perspective-taking and relating the cognitive aspects of spatial behaviour with the case-studies they were working on. This could be attributed to the short duration of the interaction with the materials in the workshops (1–2 h); in contrast, the year-long semester produced more profound shifts in students' design approach. Further work can explore whether longer or repeated interactions (e.g. multiple workshops) or self-study can improve the integration of user-centred perspectives and uptake of spatial cognition concepts into the design outcome.

Third, we asked whether these cards facilitate communication between researchers and designers. The results varied depending on facilitation mode. When the cards were introduced by an expert/scientist who facilitate the design studio (UK) or the workshops (Singapore), both the output and participants' feedback suggest that the cards provided a basic understanding of spatial cognition theory and methods for user-centred design evaluation. However, in the design workshop (Switzerland) where the cards were made available to participants without a facilitator to encourage their use, or explain concepts, uptake was reduced and remained more superficial, despite the fact that the workshop's objective was human-centred design. Further, we noticed that

experienced architecture professionals used the cards to discuss several layers at once (functional, aesthetic, etc.) and used their past projects as reference to enhance their understanding. Students, on the other hand, appeared to use the cards as helpful references perhaps because they were still in a formal learning process.

Taking together these observations, we believe that there is evidence that we were able to bring cognition research into the design process. However, we identified several potential improvements to this process. Compared to the facilitated workshops, without facilitation, participants used the materials less and appeared less satisfied with the process. Moreover, we noted that especially non-architecture students needed to be prompted more to think about the users and would otherwise focus too much on the specific case materials or their own ideas for design proposals. We conclude that facilitators can be beneficial to introduce the particular case-study materials, the different games/rules and steer the discussion. However, once this is clear, participants can use the cards independently, e.g. to think about how they can engage in evidence-based design.

There is a growing interest to not only understand 'how people perceive their surroundings', but also to use this knowledge to inform the architectural and urban design practice (Hollander, Ericson, and Wadley 2021). Publications that bring findings from environmental psychology and cognitive neuroscience to the challenges of design (e.g. Dalton, Hölscher, and Spiers 2015; Jeffery 2019) pave conceptual links between the disciplines. In this paper we focused on a complementary aspect of this equation, namely how to get this knowledge on the 'drawing board'. This effort requires that researchers can more effectively share their knowledge and findings, and also that architects can be supported to adopt the perspective of their users during the design process. In this sense, this research pertains to the more general problem of how to integrate any research (architectural and non-architectural) into the design process. In line with earlier and parallel efforts from other domains of design (Roy and Warren 2019; Moseley and Whitton 2014), our results suggest that the approach discussed here, flash-cards, holds important potential to encourage evidence-based design and communication between scientists and design practitioners. The educational potential of flash-cards has been demonstrated previously (e.g. Basoglu and Akdemir 2010) and here we have shown that it holds useful potential for the integration of spatial cognition research and user-centred thinking specifically in architectural education. Serious games, including card-based methods, are increasingly also used in professional contexts, to promote innovation and ideation (Yilmaz et al. 2014) or facilitate exchange and collaboration between diverse stakeholders (Tan 2020). We envision similar applications for the card-decks introduced here, such as using the cards in a meeting with other stakeholders, to understand the cognitive and other needs of the end-users of a design projects, to identify potential issues, or to build an argument towards a stakeholder.

Limitations and future work

The present work has a few limitations that should be noted here. First of all, the evaluation of the cards presented here relied on user feedback, thus measuring how the cards were perceived by participants of the design studio and workshops. Future work should also assess whether use of the cards leads to different design outcomes, and assess the quality of user-centred design that is generated through such an interface between architecture and cognitive science – i.e. is the evolved design more user-friendly, and responds to the user needs and abilities. A second limitation is that the content of the cards was developed based on the expert knowledge of the authors and our colleagues at the Chair of Cognitive Science (ETH Zürich) who contributed to their writing. As such, it is possible that more terms could be usefully added to the cards. We also observed that some concepts may be more complex or less intuitive to grasp; perhaps adjusting the materials and providing sustained interactions with experts could help address this. Third, our testing involved potential users of the cards, i.e. architects and engineers, rather than the end-users of the design. It will be helpful to further use and validate these card decks in different settings and with different users, including laypersons, in order to understand their

uptake and where improvements are needed. Further research is needed to understand the influence of team dynamics (e.g. hierarchy, group-thinking) on using these user-centred design cards, and how to facilitate workshops in different contexts. Last and perhaps more important, the cards were only used on a limited number of occasions in design studio teaching and brief workshops during two years. Thus we were not able to observe how these materials can be used, and influence designers thinking over a longer time-frame. There are various opportunities to combine these cards with other methods discussed in this paper, from software training to a dedicated architectural cognition curriculum, or even embedding an expert-in-residence at professional settings, and then examine how these approaches complement each other to assist in the production of user-centred design.

Conclusion

The core contribution of this work is the development and evaluation of two card-decks, the *Architecture Design Strategies* Cards and the *Spatial Cognition Thinking* Cards, as a novel approach to link and integrate knowledge from cognitive science, to support informed perspective taking, and to contribute to evidence-based design in architectural design pedagogy. Our objective was to better share research findings from spatial cognition research in the design process, to establish a way for multidisciplinary collaborations between architectural practitioners and cognitive scientists to take place, and overall to encourage and promote user-centred evidence-based design.

The approach presented here aspires to complement and be paired with existing methods to include users' needs in the design process, from guidelines to simulation software. The two card-decks were devised with the aim to address these aims in a playful and accessible manner, and to enter the creative part of the design process. The two card-decks were tested in a variety of settings: a design studio and multiple design thinking workshops. Evaluations of the materials suggest that they were perceived by participants as an easy way to learn and become acquainted with the terminology of architectural cognition, as well as a way to be inspired to integrate different perspectives (both designer and user) during the design process.

More generally, the adoption of the flash-card approach, which has been gaining prominence during the last years, appears a promising way to transmitting knowledge and concise yet playful manner, to share scientific research and findings and establish communication across different disciplines that can, or should, influence how the built environment is designed. This is essential to encourage adoption of new methods or knowledge in contexts of time-scarcity, e.g. design workshops, competition stage design work, and more. Finally, we encourage researchers in the psychology, cognitive and behavioural sciences to engage closely with sharing their findings with design practitioners, to support architects and designers to integrate insights from research findings into their design process, and to 'put themselves into the user's shoes'.

Notes

1. Developed by Dalton, partially inspired by Brian Eno and Peter Schmidt's *Oblique Strategies*.
2. Developed by a wide team of interdisciplinary researchers at the Chair of Cognitive Science, ETH Zürich.

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Appendix 1

Four different approaches – 'games' – are suggested to introduce the architectural cognition cards in different educational and professional settings.

Rules of the game(s)

In principle, both decks of cards can be used independently – without any specific rules for game-play. However, several techniques can facilitate their uptake and adoption as part of an educational game. For instance, in other design card approaches such as Möller's *MethodKit* (2012), players are encouraged to group cards, e.g. sort, prioritize, (mind-)map, cluster, timeline, selection grid, align (important/ unimportant) cards, in order to highlight their relevance to a specific context. For the two cards decks we proposed the following games for interacting with the cards:

1. **Prompt and Pick:** a prompt, such as a photograph or a drawing, is given to participants to illustrate a specific situation, anchor their perspective-taking, or elicit specific issues. Participants then choose cards with questions or topics of importance, optionally sort them, and assign the rest to a discard pile. Participants then discuss their choice. The discard pile can also be examined for blind-spots or less understood concepts.
2. **Categorise:** participants are provided with a predefined set of open-ended categories (e.g. building design, user-experience, etc.) and they are asked to distribute and rank the cards in each category, according to how they think the cards fit into the category.
3. **Pebble Throw:** similar to a pebble that is thrown into a lake leaving reverberating ripples, an educator or a team member can select and introduce a specific card into a discussion, workshop, design review. The aim is to challenge the direction of the discussion/design, to remind the group of an important aspect or simply to evoke a specific angle to approach a topic.
4. **Random Draw:** in many creative contexts, there are times when the creative flow can wane, then a card can be picked at random. We have found this an effective way to shift perspectives and introduce a different way of thinking about the problem-at-hand.

From the above list, the first two games tend to lend themselves to be more readily used with the *Spatial Cognition Thinking* cards whereas the last two games tend to be more suited to the Architecture Design Strategies cards. It should be stressed that this is not a clear divide and that either game can be used with either set of cards. We suggest that interesting interactions and outcomes can occur when there is a fluid mix between games and card decks.

Appendix 2

B1 questions used in focus group (students from the design studio)

1) Probe Questions:
   1 Do you feel familiar with the Design Strategy Cards Deck?
   2 Did you understand how they were meant to be used in studio?
2) Follow-Up Questions:
   3 What are your favourite and least favourite cards in the deck?
   4 Can you tell us a few words about how you used them in the studio for your design?
   5 Did the cards provoke any new thoughts / specific shifts in your thinking about your design?

6 If you had a deck of your own, can you image using them by yourself and in what situation?
7 In what situation do you think such a design aid might be helpful?
8 If these were available to own, would you like to have a set (would you buy a set if they were for sale)?

3) Exit Question:
(a) 9Is there anything else you'd like to say about the design strategy cards?

B2 questionnaires used in the workshops

1) Introductory text:This survey aims to provide feedback for the [workshop title] which was completed as part of [event] on [date(s)]. The responses are anonymous. We may use these responses for a forthcoming publication on new methods to embed Spatial Cognition into the design process.
2) Entry questions (Yes / No):
   1. Did you attend the < name / date > workshop on Architectural Cognition?
   2. Did you use the cognition cards in today's workshop?
   3. Do you feel familiar with the Cognition Cards?
3) Multiple Choice:
   4. Did you understand how they were meant to be used in a workshop / design studio? (1–7)
   5. How informative did you find the content of the cards? (1–7)
   6. Was the text well- written / useful? (1–7)
   7. How did you, as an individual, used the cards?
      1. I picked one randomly.
      2. I selected a category (colour) I was interested in
      3. I selected a title/concept I was interested in
      4. I shuffled through all of them
   8. Did the cards provide you with a better understanding of spatial cognition? (1– 7)
   9. Could you think in what context it would be useful to have these cards? (select as many as you want)
      1. Educational (as part of a formal course, etc)
      2. Self-study (on your own time)
      3. Professional
      4. Workshop with colleagues /team mates
      5. To explain my thinking to others
      6. To work together with a team
4) Open-Ended Questions:
   10. What are your most favourite and least favourite cards in the deck?
   11. Can you tell us a few words about how you used them in the workshop?
   12. Did the cards provoke any new thoughts / specific shifts in your thinking about the case-study?
   13. If you had a deck of your own, can you image using them by yourself and in what situation?
   14. In what situation do you think such a design aid might be helpful?
   15. Is there anything else you'd like to say about the Cognition cards?
5) Demographic Questions:
   16. What is your work expertise / role?
   17. How many years professional experience do you have?
   18. What is your field of study / degree?
   19. What is your level of study (BSc, MSc, etc)?
   20. What is your age?
   21. What is your gender?