The materiality of digital jewellery from a jeweller's perspective

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Abstract: Taking a research-through-design with craft sensibilities approach we present design propositions in the digital age that value the complexity and uniqueness of being human. We introduce exemplars of digital jewellery objects that offer alternative ways of connecting a person with personal anchor points, significant others and places. The pieces were inspired by the lives of three participants and the researcher who all frequently travel back to their native countries, but who live permanently in the UK and experience feelings of transition and what we describe as "being in-between". 'Microcosmos', 'Togetherness: Connected Brooches' and 'Topoi' expand our understanding of what digital jewellery can be by embodying interactions that highlight the sensorial and imaginative aspects of digital technology.

Building on our previous work on poetic qualities of interaction with digital jewellery we offer a reflective view on how digital jewellery can challenge our expectations of digital connectivity, sensor functionality and location awareness and we discuss the material qualities of the pieces by unfolding the narratives associated with their function and form.

Most digital devices come with a set of expectations such as: What does it do? How long is battery life? How cutting edge is the technology? By contrast, this research offers a focus on atypical personal interactions in order to address a different range of questions and potentially open up our expectations of the digital. By reflecting on our designs we continue the discussions on how jewellery practices and digital technologies can suggest more poetic interactions for people.

Keywords: digital jewellery, poetic interactions, sense of self,micro-transitions, craft,digital technology, contemporary jewellery

Method& Critique

Wearables and the Body: A need for a different approach

An increasing number of devices intimately linked to the body have become part of the consumer electronic landscape, bringing in new questions and challenges on what it means for people to be wearing digital devices. Many such devices are used to track body fitness, manage phone calls, messages or notifications from social-media. As objects worn on the human body, they are small in size and typically have limited functionality, with minimal interfaces, compact displays and lower computing power. These examples, otherwise named wearables or wearable technology (Ryan, 2014), are always connected to faster computing devices. They are often supported by an application that can be accessed via an Android or iOS phone, while the device works in the background. These devices, otherwise described as gadgets (Wallace, 2007), are typically aimed at early adopters in their twenties or thirties with an above-average income (O'Riordan, 2017). As a result, designing for such a group is largely driven by mainstream user-centred design (UCD) methods dominated by the commercial tech industry such as Apple, Google, Sony, Fitbit etc.

Wearables[1] are following the logic of what De Landa (2001) refers to as technological determinism, where technological innovation is looking for the next, expected level of evolution. This reflects a functionalist prejudice that technology is always in the present (Ryan, 2014). Activity monitors for fitness purposes can be "always on" to provide the wearers with detailed information on their everyday practices; count steps, measure heartbeat and record biosensory data in real time. Arguably, most of the existing examples of wearable technology rely on technological solutions that focus on functionality and efficiency.

The body and the data it represents has become central on issues of wellbeing and selfhood (Lupton, 2014). From an industrial perspective, combining as much data as possible is the key to take control over our minds and bodies (Sullivan, 2016). Hundreds of apps have been developed for achieving digitalised self-tracking and Wolf and Kellie (2007) list over 500 self-tracking tools including geolocation, health, fitness, weight, sleep, diet and mood or feeling tracking apps.

Several authors have called into question the aim of wearables to cure, correct and enhance the performance of the human body, arguing that wearables take a diagnostic approach such as sensing and displaying the wearers' emotions and assumes a view of the body as data (Ryan, 2014) as something that can be controlled (Höök, 2013). Longo (2003) asserted that within informational evolution "*the body becomes an object, losing its remaining personal characteristics*"(p.23). Morozov (2013) more broadly describes the field as *"madly devoted to articulating facts through numbers"*, which generate narratives or *"numeric imaginations"* that *"seek out qualitative and linear casual explanations that have little respect of the complexity of the actual human world"* (p. 260-261). This resembles Busch's (2015) critique of the narcissistic view of self-improvement through wearables and Hacking's (1982) critique of the fetishist collection of overt statistical data and *"the avalanche of printed numbers"* (p.28).

To move away from a *"corporate wellness"* and *"a circuit of self, device, work, gym, eat and sleep (repeat)"* (see more O'Riordan 2017 p.66) a deeper exploration on what it means for people to be wearing digital objects is critical and necessary.

In this paper, we explored the field of digital jewellery[2] from a jeweller's perspective and we present three examples of digital jewellery that suggest more poetic and experiential rich interactions with digital technology, acknowledging the complexity and uniqueness of being human.

Our position in conducting this research was to explore how contemporary jewellery practices and digital technology can be incorporated into forms of digital jewellery designed to support short-term micro-transitions[3]. In this exploration we were concerned with designing digital jewellery as objects that could potentially suggest highly personal and meaningful interactions for people.Our thinking drew on contemporary jewellery practices, as opposing to human-computer interaction or interaction design to bring the focus on sense of self, personal significance and the body.

1.We use the terms 'wearables' and 'wearable technology' interchangeably, following Ryan's (2014) definition of wearables in terms of display and functionality. Wearables are products worn by subjects whom intelligent systems sense and manipulate.

2. Digital jewellery refers to jewellery pieces with embedded electronic components (Kettley, 2008; Wallace, 2007). In the research digital jewellery is developed and researched not for its purpose as accessory, but in its capacity to represent highly personal emotional meanings and convey a range of concepts related to being human (Smith,1978), taking advantage of the increasing potentials of digital technologies in sensor functionality, connectivity and location awareness.

3 A micro level transition is concerned with experiences, negotiations and meanings in a personal setting (see more Holdsworth and Morgan, 2005). We use the term "short-term micro-transitions"to refer to the more everyday encounters that can cause nuanced unsettling to what one perceives, personally, to be a stable sense of life and of self.

Research Context and Motivation

The research is a part of the first author's doctoral research on digital jewellery and sense of self. Throughout the research, she has sought to make pieces of digital jewellery that could support sense of self during the transition of travelling between two places of home. She has drawn on her own lived experience primarily in this investigation As someone who was born in Greece, but who has lived and studied in a number of different countries she has become acutely aware of the shifts to her sense of self that occur during the journeying to and from Greece and the country where she happens to be living. There has been something significant and noticeable about the reflections that she has had during these journeys that highlighted this as period of time and particular context during which the shift between what her identity is in each country is more obvious to her and pronounced.

This doctoral research was framed to understand and investigate both if/how this context is experienced by others and if/where there are opportunities for digital jewellery to support fluctuations and changes to one's sense of self during such journeys. For this research, the first author worked closely with three female interaction design researchers born in different places in the world, but who currently lived and worked in the UK and periodically travelled back to their home of origin for short breaks. She selected these women; firstly, because they had the experience of living in two different places and travelling between them and secondly, to enable a particular level of discourse around the potentials of digital technology in the conceptions of new forms of digital jewellery.

Methodolodgy

Our Research through Design (RtD) approach is based on two key elements; craft practice and a dialogical engagement with people. These elements utilise practice in different contexts in order to understand possibilities of materials and the richness of a lived experience. More specifically, the research is characterised by activities of making (including participatory design practices), together with rigorous reflections with a view towards design outcomes. Through making, the first author gained a better understanding of the field of enquiry, which subsequently informed different parts of her study. This includes exploring materials, making methods for engagement and making digital jewellery.

In the research, the first author drew upon her personal biography and her own experiences to explore what it means and feels to be a person during a micro-transition and she brought insights from her explorations into the participatory engagements with others in order to construct a dialogue. Situating the research within the broader context of experience-centred design, she drew heavily on McCarthy and Wright's (2015) understanding of dialogue to guide her methodological decisions on the participatory part of the work. This aim to build a relationship with the participants that is rooted in trust, empathy and sensitivity to the context. Builting upon existing methods in design to understand lived experiences (such as probes and theatre methods), the first author opened up a creative space for participants to share aspects of a sense of self with the researcher (see more Koulidou, 2017a, 2017b). Such methods were used to develop mutual responsive relationships where both participants and the researcher can benefit from the participation. The participatory engagement lasted for a period of two years and participants were encouraged to contribute to the research in ways that they felt *right* to them. The work started with an initial meeting with each of the participants; an explorative workshop on an aircraft (that included all participants) and a number of one-to-one meetings. In those meetings, we shared opportunities for digital jewellery while reflecting on how such objects could support our transitional experiences.

Inspired by the lived experiences of the participants, her own experience of travelling and conversation with experts in aviation, the first author designed digital jewellery pieces that aim to support self through micro-transition, but this is not to over stress the point that these pieces are evaluated by others in their success or not to achieve this. The pieces acted instead as design propositions within a small group of experts (in the field of digital jewellery) to discuss the potential of digital objects in personal interactions with the aim to open alternative ways of looking at the potentials of digital technology within jewellery practice. Such a triangulation gave the first author a more detailed and balanced understanding of the data by responding to the objects. This approach reflects on the role of artefacts in exploring new design spaces. For example, Lim et al. (2008) offer an extensive discussion of prototypes in design, defining prototypes as *"filters that traverse a design space"* and as *"manifestations of design ideas that concretize and externalize conceptual ideas"*(p.7:3). Wensveen and Matthews (2014) used the term 'research archetypes' to refer to prototypes that *"are embodiments of research concepts or perspective that have broad application, but also that require specific examples to demonstrate their potential and justify that they constitute a contribution"*. (p.268).

Figure 1a(right top) Detail from the second layer of the microfilm when the light is illuminating inside the piece. **Figure 1b(right bottom)** Looking through the lens. Viewing the microfilm image inside the piece. Photos: Nantia Koulidou

Digital Jewellery: Narratives of Form and Function

This section presents three digital jewellery pieces that resulted from the research: **Topoi, Microcosmos** and **Togetherness: Anthos and Chronos Brooches.** Within each sub-section, we start with the description of the piece, followed by detail of what inspired each of them and the design development stages. We also included the first author's reflections-in-action during the making phases. We have chosen to describe this part of the work in the first person to echo the personal practice nature of the work.

Working with the digital

The making of the digital part of the prototypes were designed in close collaborarion with a creative technologist (third author). Throughout the making of the pieces, we used the Arduino platform for its accessibility and ease of use for artists and designers. This allowed me (first author) to directly manipulate and experience the prototypes.

Throughout the research, I was driving the creative decisions by responding to the third author's suggestions regarding hardware and their suitability. I was able to iteratively respond to changes creatively and develop an understanding of what I wanted to achieve. In that way, working with the digital became part of my own reflective material practices.

Figure 2. Topoi, 2017 by Nantia Koulidou. Milliput epoxy putty, coal, oxidised silver, magnifying lens 10x, found objects, electronics.

Dimentions:approx. 7cmx7cmx3cm
Photo: Nantia Koulidou

Topoi: a piece of digital jewellery

Description of the piece

Topoi is a hand-held piece of digital jewellery containing tiny microfilm images from two countries that are significant to the owner. The piece is composed of a digital and a non-digital element. The digital part resembles a rock formation that is made of modelling putty with embedded crushed coal and, oxidised silver. Within the piece are electronic components (which I will describe later) and layers of microfilm which are visible through a viewing window made from the edge of a found thimble (see Figure 1,2). The non-digital part of the piece is a magnifying lens mounted in a silver frame, with a handle made from a found teaspoon. This lens allows the owner to look into the rock shaped form

A light source is required from within the form in order to view the images when using the magnifying lens and this is activated in response to huma touch. When a person holds the digital piece, the surface of the piece, being made of silver, conducts electricity and turns on a small LED light. The electronic components are a capacity sensor, an LED light, a Teensy 3.2 board and a tiny battery (see Figure 3). The capacity sensor detects when the contact is made, and the LED light gradually responds to the human touch and pressure of the palm, slowly lighting up. When the contact is broken, the light goes out instantly, however, when a person holds the piece tightly for a while, the light reaches full intensity and stays illuminated for a brief period of time after contact has been broken. With external light alone, only the first layer of microfilm images is

Figure 3. Looking inside the piece. Form reworked to make the electronic fit inside the piece. Photo: Nantia Koulidou

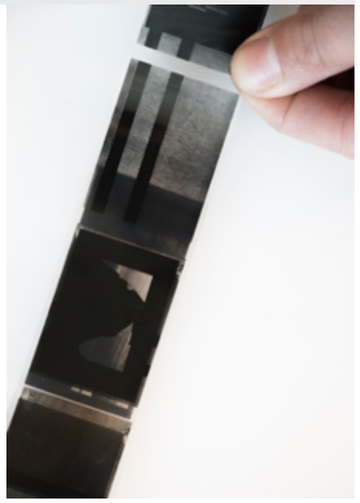


Figure 4. Exploring the materiality of microfilm. Blending 2 layers together.The microfilms are made from one of the participant's personal images Photo: Nantia Koulidou

visible, but by activating the internal LED light, the person can view the other images on layers, which appear and recede, by manipulating the magnifying lens. This gives the opportunity to peek briefly through the glass and interact with the images in short bursts, before the light fades gradually again.

Concept Inspiration

The concept arose from the design engagements with all three participants where discussions focused particularly on the value of meaningful connections from both countries and the dynamic notions of home. In particular, Topoi was inspired by one of the participant's (Laura) lived experience of traveling between two countries and her reflections on changes to sense of self during such periods. I was thinking about Laura when making this piece and that if she looked through the magnifying lens, she would be invited to blend the images, bringing to the fore certain aspects of home and senses of self in both countries. The piece also draws on inspiration from the context of miniatures. When something is represented in miniature it often creates a particular kind of intimate interaction that is private and uncommon in our everyday public life (Stewart, 1993). The miniature *"skews the time and space relations of the everyday lifeworld, and as an object consumed, the miniature finds its use value transformed into the infinite time of reverie."* (p. 65). Stewart suggests that viewing a miniature creates the space to allow one to spend time with oneself, which could be highly valued during micro-transitions.

Design Development

As is the case with all of the pieces that were made as part of this research Topoi was not made specifically for one of the participants and was in fact inspired by the creative conversations and design workshops with all of the participants. The form of Topoi draws inspiration from Laura's love for mountaineering however, and the images within the piece do connect with things that Laura shared about her life. The selection of the images reflects the significance of nature to her life in both the country where she was born and the one in which she lives now. The viewing hole of the piece incorporates the rim of a thimble and was inspired by a thimble that I found in a flea market that has a tiny little image inside to commemorate a royal wedding. A viewer is meant to hold the thimble up to the light in order to see the miniature image in the base of the thimble. The form of the independent silver magnifying glass echoes the shape of a mirror – my thinking was that this felt relevant as a mirror both reflects and reveals one's sense of self.

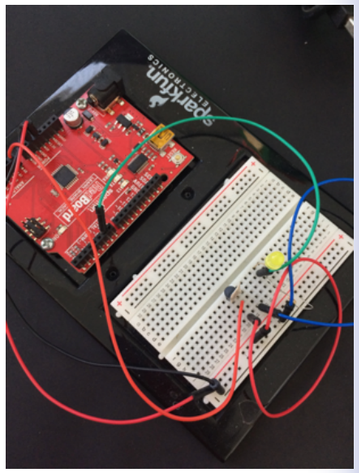
It felt that the mirror-like lens and the rock shaped piece provided a metaphorical space where one can be together with just yourself. The microfilm images that are enclosed within the piece were developed in collaboration with the Archives and Collections Department at the Woodhorn museum.

From a craft perspective, it was interesting for me to explore the materiality of the film and its interactive qualities and how these attributes could inform my practice. In an overexposed photo, for example, the images were turned into black silhouettes, which was a good asset for masking or simplifying details of personal information, such as specific features of a person in an image, and instead creating a stylised image that would still be recognisable to specific viewers, but more abstract and representative of a human (rather than a specific person) to other viewers. I also discovered that the positive and negative images on microfilm could be viewed as layers of the same image (see Figure 4), allowing someone to blend certain parts of the pictures wih another image.

Figure 4 shows the development of the working prototype. For the first prototype, I integrated a temperature sensor (TMP36) with the SparkFun RedBoard (see Figure 5a). I was thinking that the LED light could respond to the temperature of the hand, however, the cumulative effect of the ambient temperature and the variations in temperature of my hand but made it difficult to return consistent results. The third author advised me to look at the Teensy 3.2 board (see Figure 5b). This board supports a hardware-based capacitive touch sensing circuitry on specific pins, which offers much faster measurements with better stability over temperature variation. To run the code on the Arduino board, I downloaded the Teensyduino software as an add-on for the Arduino Software and I used the touchRead(pin) command to read the capacitance on the pins. In terms of the interaction, I paid close attention to the length of the fade and the dim of the LED light after the piece having been touched. This was done through trial and error, were the third author wrote the code in a manner that allowed me to test and iterate these changes.

Alongside the interaction, I was experimenting with the form of the piece. Figure 6 shows my initial ideas to use found limpets as the viewing window. For clarity, limpets are sea shells that live by attaching themselves to rock surfaces. My thinking was that limpets was a nice metaphor as they make an indentation in the rock (called a home scar) on which they live and although they move around to feed they always return to the same indentation. In metaphorical terms, the owner returns to the same place to look for comfort and connect with home. However, opening a hole on the shell was challenging as the shell was brittle. Instead, I decided to use one of the found thimbles as a reference where the idea of the piece come from.

Concurrently, I was working with air-drying clay and later on with the milliput epoxy resin putty (black colour) to find the rock-like form of the piece. I made a number of prototypes for form-finding and when I had the final electronic components I made the final form. I left extra space inside the piece for the electronic components, but I did not consider the extra space for the JST connectors which is required to attach the battery to the board. Figure 3 (p.7) shows the final form of the piece with the enclosed the electronics and layers of film.



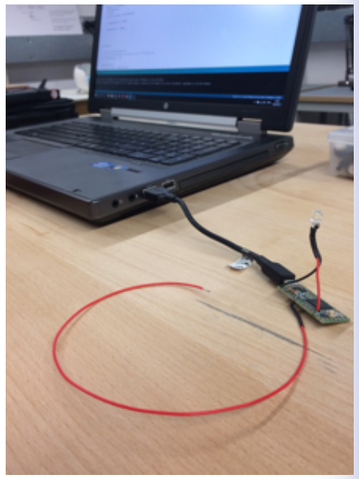


Figure 5a (top). Working on the prototype. From left to right a) Sparkfun RedBoard, temperature sensor (TMP36), LED **Figure 5b(bottom)** Teesy 3.2 Board, LED. Photos:Nantia Koulidou

Figure 6. First explorations the form of the piece Topoi. Working with milliput epoxy resin putty and exploring the viewing window for the microfilms. Photo:Nantia Koulidou

Figure 7a (top left). Microcosmos, 2017 by [surname]. Silver,magnifying lens 60x, found objects, electronics. Dimensions: 5cmx5cmx3cm **Figure 7b (right).** Looking through the glass Photos: Nantia Koulidou

Microcosmos: A piece of Digital Jewellery for the Airplane

Description of the piece: Microcosmos is a hand-held piece of digital jewellery containing a 16mm microfiche image that can only be accessed during an airplane flight. The image depicts an image of a potent text that is significant to the person. The piece is made of found objects, silver and velvet fabric (see Figure 7a,b). Enclosed within the found tin are the magnifying lens, the tiny image and the electronics (Arduino nano 3.0 board, BMP180 Barometric Pressure Sensor, an LED light, push button and a lithium battery). The handle, made from a found spoon, acts as a slider allowing the person to move the lens up and down, while the velvet fabric covers the opening of the slider to ensure smooth motion and minimum light inside the piece. Below the slider there is a push button; once the button is being pressed down the electronics start measuring the air pressure in the environment. The viewer, made from the edge of a found thimble, allows the person to view the film that is located at the bottom of the piece, when light comes through.

As the plane reaches its maximum altitude (approx. 30.000 feet), an LED light inside the piece gradually illuminates allowing the individual to manually focus on the text by moving the slider. After the take-off, the cabin pressure gradually drops until it stabilises again as the plane climbs to the cruising altitude. The light then stays on until the sensor detects a significant increase on air pressure, which indicates that the plane begins to descend (dropping its altitude for landing). Consequently, the light starts fading out, allowing one to view the image one more time for this journey.

Concept Inspiration: The pieces arose from discussions with the participants on the value of having a personal time to be with oneself during the flight and to feel comfortable with the change. Diane and Jude shared their reflections that their feelings of transition are very internal to them and being on the plane makes it even more implicit. The women prefer not to share or show how they feel to others and to enable this they create a personal bubble on their seats by wearing their headphones, reading books or wearing sunglasses. They value the time they have to relax between the practicalities of travelling with check-in and passport controls or migration control on their destination.

From the moment of being on a plane we give up many of our conventional freedoms, we are in a condensed space among strangers for a period of time and that makes us feel often uncomfortable. An insight from my engagements with the participants and reflections on my own lived experience revealed the significance of a plane as a space where people can reflect on feelings of transition and recover their sense of self. The piece allows one to spend time with oneself and connect with what is personally important, which is potentially of high value during the flight journey. The piece responds to the changes in the environment giving the opportunity

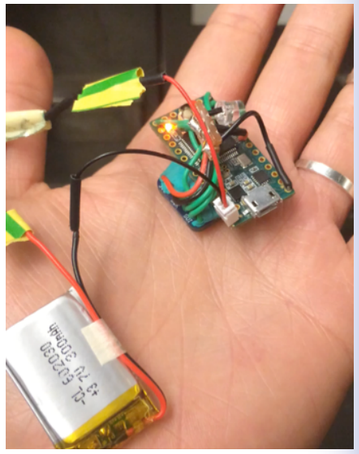
for someone to look inside the piece and explore personal feelings of transitions and meaningful connections. This can be supported by one of the participant's reflections that microfilms allow a slow and very careful interaction with personal images that gave her the time to reflect on the meaning of each image.

Microcosmos is inspired by the Greek words mikròs kósmos, which mean 'small world'. In literal terms, a microcosm is a world in miniature and metaphorically, the word can be used to describe a small group of significant others. The text depicted on the microfilm (inside the piece) was a text my mum sent to me through piloting ideas with her. The text accompanied a photo that pictured a number of photographs from my childhood that my mother sorted out and had put in a specific order. It is a narrative that linked the old photos with my life and some of the emotional challenges I was facing during the research. Whenever I read the text, I think of my mother telling me that everything is going to be alright. The image was inked into film using microfilm technologies.

Design Development: For Microcosmos I used a found tin. Its form resembles a film canister (with a lid) widely used in the 1980s for safe, archival storage of 16mm and 35mm film. In my design, the piece holds a microfilm image. The vintage tin was a container that represented something from another decade, which fits well with its use to hold microfilm images. The velvet fabric seals the light thanks to the fabric's light-absorbing qualities, while the handle made of the edge of a found teaspoon invites a person to hold the piece from this and to explore the interaction. Similar with the piece Topoi, the viewing space is made from the edge of a found Stanhope thimble.

For the interaction I needed to understand how the pressurisation in the cabin works in order to set the parameters for the barometric sensor. In order to more fully understand the dynamics of cabin pressure I interviewed a pilot in the cockpit of the plane during a flight to Greece. During the take-off the cabin is pre-pressurised at a rate of 100feet/minute (30m below the sea level) to avoid discomfort for passengers and crews. During take-off the cabin is pressurised gradually during the climb phase until the plane reaches its cruising altitude. At typical cruising altitudes in the range 11 000–12 200 m (36 000–40 000 feet), the air pressure in the cabin is equivalent to the outside air pressure at 1800–2400 m (6000–8000 feet) above sea level which is approx. 1.6-2.4 atm (interview notes). The piece responds to this threshold and the LED illuminates.

For the first prototype, we connected the sensor with the Teensy 3.2 board , a BMP280 Barometric Pressure Sensor and an LED light (Figure 15).The third author wrote the code for this prototype and I made adjustments in later stages of the process. To see if the prototype was working, we tested it in an elevator, by changing the pressure threshold to be equivalent for 40metres (Figure 16). After a few trials and errors, the light was fading in above a certain height and fading out respectively. For the first prototype I had a number of challenges to make the circuit work consistently on a battery power source (instead of my laptop). We ended up making a new prototype using different electronic componets (Teensy board and BMP280 sensor). The battery, the LED light and the push button were the same ones we used for the first prototype. This prototype was taken and tested during two flights when I visited home for Christimas in 2017.



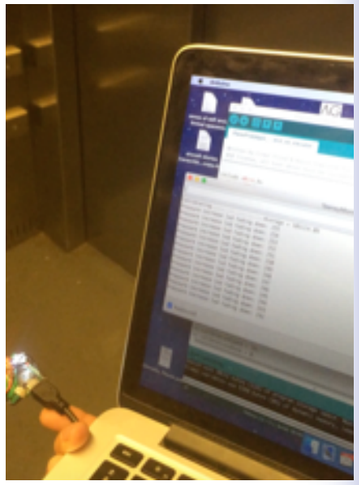


Figure 8a(top). Building the digital part.
Figure 8b(bottom) Testing the prototype on an elevator
Photos: Nantia Koulidou

"I took the piece with me on my next trip to Greece and on the return journey to the UK. On the outbound trip, I left the piece on the seat table and was positively surprised that the piece illuminated 20min after the take-off and switched off approximately 10min after the pilot's announcement that we were ready for landing. The lights faded out more slowly this time and the slowness of the interaction gave me time to accept that this connection would soon be over.I loved the fact that I knew the piece would work for a certain period of time. I was not sure of the exact time, but this lack of precision made the interaction more exciting and my anticipation was heightened". First author's reflections.

Figure 9 (above) Chronos brooches 2017 by [surname], a found twig, coloured resin and stainless-steel pin. Dimentions 2cmx2cmx2cm
Photos: Nantia Koulidou

Figure 10. Cross sections of layers of coloured resin. Developing the Chronos Brooches.
Photos: Nantia Koulidou

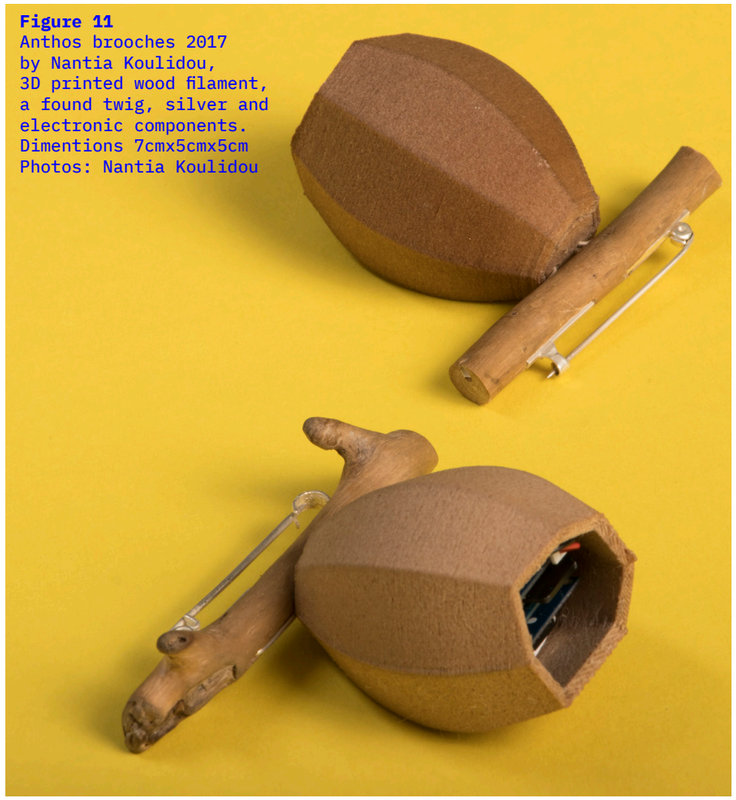


Figure 11
Anthos brooches 2017
by Nantia Koulidou,
3D printed wood filament,
a found twig, silver and
electronic components.
Dimentions 7cmx5cmx5cm
Photos: Nantia Koulidou

Togetherness: Anthos and Chronos Brooches

Description of the piece: Togetherness is suite of four brooches. The first elements are a pair of digital brooches 'Anthos', meant for two wearers - each living in a different country (see Figure 11). They are made from 3D printed wood filament, a found twig, silver and electronic components. The second element of the suite is a further pair of non-digital brooches 'Chronos' made (as we will describe further) as a result of the data collected from how the first pair of 'Anthos' brooches are worn. They are composed of a twig, layers of coloured resin and stainless steel (see Figure 9).

Two people each wear one of the Anthos brooches over a period of time and as they do so the electronic components within each brooch (Tinyduino boards - a real time clock, processor with battery support, a USB shield, a protoboard, an SD card and a 140mAh lithium polymer battery) capture time and date data comprising how long and when the brooches are worn. Each Anthos brooch is constructed such that once the silver brooch pin is fastened (i.e. when someone pins it onto their clothing) the electronic circuit is closed, and the data is recorded and stored. As such the brooch pin itself acts as the on/off switch in the electronic circuit.

After the two people have worn the Anthos brooches for a period of time (designated by them) the SD cards are removed and the stored data is used to inform the composition of the new Chronos brooches. Chronos were made by using another portion of the twig used in the Anthos pieces and dipping this into pots of coloured resin in response to and guided by the data of how long the Anthos brooches were

worn. Once the twig has been dipped into multiple layers of different colours of resin the piece is cut open to reveal a cross section of coloured rings (see Figure 10) and the forms are made into the new Chronos brooches through the simple addition of a stainless-steel pin.

Concept Inspiration: The pieces arose from the design engagements with two of the participants and my own lived experience. Discussions focused particularly on attempts to find ways to connect with loved ones over distance in subtle and indirect ways and the significance of these connections during a journey back home itself. From talking with the participants and from reflecting on my own experiences I understood that "each journey has its own story" based on the complexities of life and events in people's lives. I reasoned that there were opportunities to capture the experience and feeling of a specific journey and that this could be valuable.

Design Development: The Anthos and Chronos brooches are made from the same tree twig (see Figure 12). The 3d printed part of each Anthos piece resembles a flower bud, which has references to time and growth. They are made of a wood filament, which was chosen as a compliment to the twig and a visual contrast to the electronic components that are hosted within each pod. The side of the bud that faces down (when the piece is worn) is open, leaving the electronic components visible (see Figure 11). This decision was taken for two reasons: a) to acknowledge that the electronic components are part of piece and b) to unplug and recharge the battery. It is uncommon for jewellery that houses electronic components to expose or reveal them. I wanted to do this in order to propose a form where the aesthetics of the

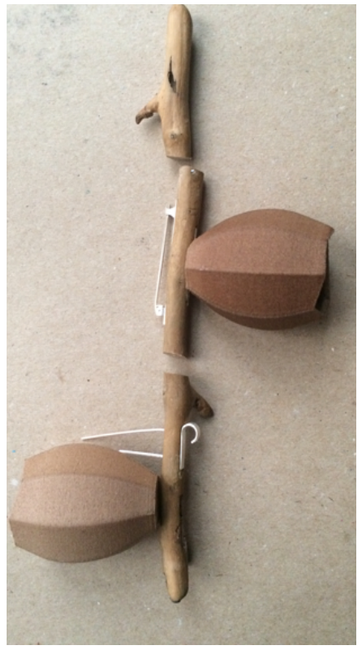


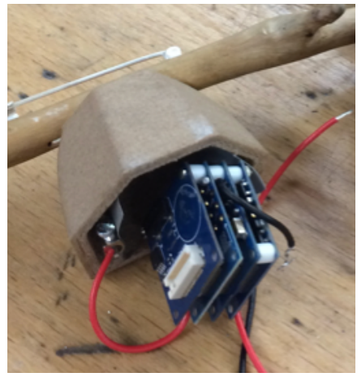
Figure 12. Making the Anthos Brooches using the same twig. Thinking on how to connect the silver pins with the electronics. Photo: Nantia Koulidou

Figure 13. Explorations of forms for the Anthos Brooches. 3d printed wood filament. Photo: Nantia Koulidou

electronics were championed and visually part of the piece. Although they are not overt and you have to look up inside the wooden printed buds to see them they are evident and are also somewhat vulnerable in the piece, as they are not encased. My rationale was that a wearer would be fully aware of the electronic components in handling and wearing the piece and that this would heighten the awareness that the jewellery was capturing data of wear and that there was a preciousness to this, echoed in the vulnerability of the components.

For the Anthos Brooches, we used the Tinyduino boards (a real time clock, processor with battery support, a USB shield, a protoboard, an SD card and a 140mAh lithium polymer battery). The third author helped me with the code in first place, but in later stages of the prototyping, I was able to add lines of code when necessary. For all prototypes, I used the Serial Monitor (a function in the Arduino Software). The Serial Monitor was really important as a beginner in understanding what was taking place and having a more direct understanding of what was happening. For example, Figure 14 shows that when I connected the two wires (to close the electronic curcuit), a message "Brooch is attached" appeared on the Serial Monitor alongside the date and time when the connection was made . This helped me to test the prototype in a quick-and-dirty way.

My first experiment with the 3d printed wood filament was during a workshop at Fab Lab Berlin in 2015. I was intrigued by the result of the 3d printing as the layers of material were subtle. The piece had the smell of wood and a very smooth texture to it. When I started experimenting with the same material myself, I found out how the printed object varies in colour and texture, depending on the temperature and the speed of the printing. Sections could appear scorched and darker if the filament was heated too much or printed too slowly. These gentle variations in colour inspired the aesthetics of the Anthos brooches. I wanted each Anthos brooch to be unique, but at the same time to be visually part of the same whole. The final forms are similar, but not the same; they have subtle variations in colour (see Figure 13).
The size of the electronic components informed the size of the 3d printed form. Small variations in size where necessary to find out the best fit of the components. Before I move on dipping the third piece of the tree twig (used on the Anthos Brooches) I experimented with other forms and fillers to find out a system that I could use later on in the process of the Chronos brooches.



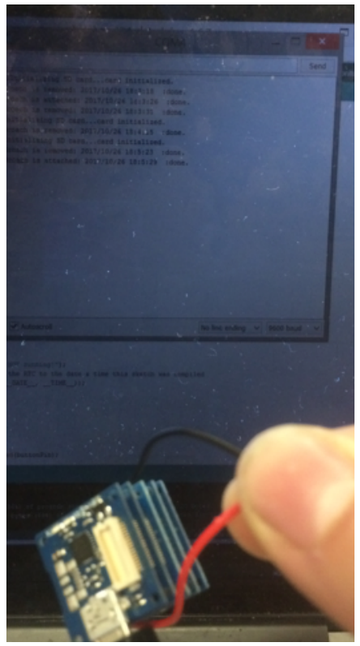


Figure 14(top, right). Building the Anthos Brooches prototype. TinyDuino boards mounted together from the top: A battery-backed real-time clock (RTC), a Proto Board TinyShield, a USB TinyShield with a TinyShield microSD, a Processor with lithium battery support. Testing the prototype using the Serial Monitor on the Arduino software. Photo: Nantia Koulidou

Digital jewellery Challenges Exisiting Conceptions of Digital Connectivity

In the previous section we described the narratives of the form and function of three pieces of digital jewellery **Topoi, Togetherness: Anthos and Chronos Brooches and Microcosmos.** Building on our previous work on poetic qualities of interaction with digital jewellery (Koulidou, 2018, Oliver and Wallace 2009, Wallace, 2007), in this section we offer a reflective view how the digital jewellery we present in this paper challenges our expectations of digital connectivity,

Topoi introduces an interaction with layers of microfilm images from places that are significant to the individual from both countries that one can view only in short bursts. The digital in the piece enables a personal space where one can enter, when one decides. The personal data is hidden in the piece and nowhere else, offering a controlled space where one can explore aspects of herself or himself in private. Only you have access to the piece. We can think of personal space as a way of allowing people into it as a form of permission that is granted by the wearer. In Topoi, it is not just about permission, the digital jewellery itself might only function when connected with a wearer. Thus, we can consider the wearer to be a type of key that allows access to the piece. Topoi is activated when one decides, offering a controlled space where one can explore aspects of herself or himself in private. The gesture of holding the piece tightly is a prerequisite for the interaction. The body in this instance becomes an active part of the piece; its power source in metaphorical terms, suggesting a sensorial interaction. The personal data is hidden in the piece and nowhere else that one can view only in short bursts. This time-specific interaction brings the attention to the person and the connection between the piece, the body and its meaning for the wearer.

Togetherness suggests an indirect and non-intrusive way of connecting two significant others, where the digital enabled the

creation of a new piece that signified a trace of a relationship. In this instance, the digital brooches become the medium to create new forms of jewellery through meaningful encounters. Two people might choose to wear the brooches in each other's birthday day and not the rest of the year - and they know that the third piece is made as the memento of that day. Thus, people can be actively part of the creation of the piece in a very playful way. The Anthos brooches allow us to think more critically about current examples of wearable technology that is continuously measuring and monitoring activities. When the pieces are activated, they capture time and duration being worn on the body much like other wearables that track a user's activity. However, they differ from existing wearable technology as the pieces are not connected to an additional app, nor they are connected with each other explicitly. There is no explicit coordination that is actually telling the wearers of that implicit "togetherness" and the physicality of the third piece would not exist without the co-created experience. The Anthos brooches through an ambiguous connection suggest an indirect form of communication between two people. The wearers do not get any feedback if the other person is wearing the piece, leaving room for each other's imagination. The Chronos brooches are unique and tethered to a specific period of time when the Anthos brooches were worn simultaneously. The data gathered over time are interpreted by a maker in a very open and imaginative way, allowing room for further interpretations.

Microcosmos introduces a similar interaction with the piece Topoi, however, the digital in this piece enables a personal space where one can enter, when the environmental conditions are right. The owner has no control over the interaction which introduces a very different dynamic to other digital objects we encounter. The owner knows that the personal data hidden in the piece are there and nowhere else. This very controlled interaction has elements of ambiguity, as the conditions are not always the same in each flight and the owner does not know the exact time of the activation. The environment of the plane can be considered as a form of control for digital jewellery. The specificity of the interaction adds value to the interaction and the space where it happens. Knowing that the piece will function at some point in each flight even for a short period of time, invites someone to await for the interaction. This creates anticipation, which can be seen as an attribute of digital jewellery. Microcosmos functions only during a flight, offering a site-specific and time-limited interaction. From my (first author) reflections on the interaction with the piece during two flights, I found the personal space to connect with the data inside the piece in an intimate way. Looking through the lens brought my body closer to the content of the piece in a physical way, introducing a sensorial interaction. I enjoyed the fact that I knew the piece would work for a certain period of time. I was not sure of the exact time, but this lack of precision made the interaction more exciting and my anticipation was heightened.

The Value of Digital Jewellery as Single Function Digital Objects

Digital jewellery often functions for a limited period of time (Topoi), in a specific place (Microcosmos), or under certain conditions (Microcosmos, Togetherness). For example, a capacity sensor is enclosed within Topoi and data from the sensor becomes the input for the illumination of a LED light. Similarly, Microcosmos responds to data retrieved from a barometric sensor. In Togetherness, each Anthos brooch acts as a simple switch mechanism that allows each brooch to store the time and date when the piece is worn. However, what is important is that these functions can potentially trigger personal interactions for the wearer in an often subtle way.
One could argue that the digital functionality of the pieces presented in the paper is very limited in comparison to the vast amount of functions usually found in mass-produced wearables. We suggest that if makers understand digital technology as being another material for design with its qualities and limitations (such as those limitations associated with wood or silver) then they should have the freedom to choose the digital functionality they find relevant to their concept. The more makers understand the potential of the digital through making, the more they learn how to manipulate it (the digital) through experience. More complex manipulations of data and interactions may be integrated within practice over time, but this is not to fixate that this an ultimate goal of making digital jewellery. The digital jewellery pieces presented in this paper offer simple interactions if we look at the technology alone, however this does not mean that the interaction with the piece cannot be highly significant for a person.

We highlight that digital jewellery are often single function digital objects; they are crafted, tailored and personal. Wallace et al. (2018) articulates that there is personal value in the bespoke and one-off digital design artefacts. Concentrating on a single function allows makers to sidestep the noise that comes with functional complexity and directly address how these pieces could be meaningful on a personal level (ibid.). In designing digital jewellery makers can design digital artefacts that are

single function objects and *"much more than its parts"* (p.423), allowing the maker to think of their poetic potential within people's lives in enchanting ways. The digital jewellery pieces we presented can be seen as counterpoint to existing examples of wearable technology with *"the increasing level of interaction complexity"* (ibid, p.423). In its conception, digital jewellery seeks to discover significance beyond the functional. In this conceptual space, Wallace et al. (2018) argues for the role and value of craft as a methodology in designing digital objects that are bespoke and tailored.

Manipulations and Representations of Digital Data from a Craft Perspective

The consequences of computer-aided (CAD/CAM) and digital fabrication processes (3D printing, laser-cutting) enabled new opportunities for designing jewellery outside the field contemporary jewellery. Companies (see for example Makkoo, Nervous.com) offer a wearer the possibility to design their piece of jewellery and personalise it based on their input. The notion of democratising access in the design process in one of the main advantages of this technological phenomenon (Bernabei, 2014), however, taking a more critical view, the wearer's involvement is limited to pre-defined parameters. The code has limitations and I wonder how democratic is this approach? On the contrary, The Anthos brooches invite people to create a new piece in an unpredictable way. Two wearers can actively wear the pieces and tether their experiences to the things that are meaningful to them. People can be actively part of the creation of a new piece in a very playful way. This experience reminds me of Ted Noten's participatory project *Chew your Own Brooch* (1998) that gave the participants the creative influence on the end product alongside the anxiety of being an artist for a few minutes. Each participant chews a piece of gum (which he or she then forms into a shape) and sends it back to a jeweller. Each piece was then casted into silver or gold and sent back to the participants. Even though a jeweller is involved in the making of the final brooch in the *Chew your Own Brooch* piece, he/she does not have an active role in this process. Togetherness gives the opportunity for both wearers and makers to be creative in their own right and influence the final Chronos brooches. There is a great of potential for makers to use digital data created by people during meaningful encounters as a material within their practice and to think of creative ways that data (data of use or biometric data) can be interpreted and shared in ways where people can add their own meaning.

This is not a new form of interaction. People used to codify messages in jewellery for many years. In Georgian times (early nineteenth century), for example, gemstones were used to encode messages. The first letter of the gemstone and the different colours of the gems could be decoded by the wearer (Luthi, 1998). Similarly, Chronos brooches represent an encoded message that only two wearers can best interpret. This message is just about them and the time they were connecting with each other through the Anthos brooches. The piece, therefore, offers an interpretation of encoding meaning in jewellery in a contemporary way.

Interaction with wearables are often fast paced and people expect to read data retrieved from a wearable device in seconds or create a piece with digital fabrication methods because it is easier. I could have taken the data from the Anthos brooches and printed a 3D form instead of making a piece from resin. My reasoning was that I wanted to represent time in a physical and slow way and thus, symbolise connectivity between the wearers. Time is embedded within the Chronos brooches. It takes time to make each layer of Chronos. One has to wait long enough for one layer of resin to set in order to create another layer. The thicker the ring, the longer the setting time and the longer the time the Anthos brooches were being worn by two people. This process includes an open interpretation of data. The fact that the interaction with the Anthos brooches is time-limited and also ambiguous suggests that digital jewellery interactions could also consider moving away from well-defined measurements (such as heart rate and step counting) and move towards more subjective visualisations of data which can be interpreted from a craft perspective and not from a pre-defined algorithm. We see a great potential within craft practice to design pieces that are made because of two other pieces being worn.

Conclusion

The relationship between jewellery practices and wearables research is often debated and, at times, polemic. One component of this relationship that has not yet been widely investigated is the role of digital jewellery as an emerging field within contemporary jewellery practice. The field of digital jewellery is misunderstood and often it is neglected by the contemporary art jewellery world due to its close proximity to wearable technology and the commercial application of technology. There is still an important contribution to be made in further exploring the role of digital jewellery in contemporary jewellery practice. Although digital jewellery differs from existing examples of wearable

technology, this thesis is not intended to be reactionary. We should be concerned when people talk about wearable technology and digital jewellery as if the terms are interchangeable. However, just as we worry about a focus on technological evolution, so too should we be concerned with research that looks for alternative uses of digital technology. We believe that digital jewellery (within the field of wearable technology) is undervalued. Arguing for a fundamental reconfiguration of our understanding of digital jewellery, this research suggests that there exists a rich conceptual space for jewellers when they start thinking about "the digital" as a material that can be adopted for use within their practice. Our argument, however, is not an attack on wearable devices or other technological developments. We do not dismiss the many advantages of current digital technology such as smart phones or healthcare devices – it is simply that there are different concerns of this phenomenon, and that as makers/designers/jewellers we should look more closely at our own interpretations of materials such as the digital.

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