Studies in Material Thinking
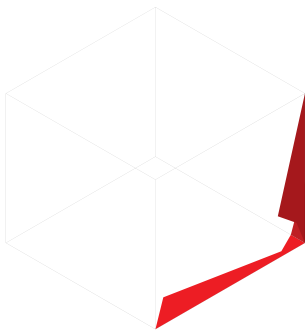
PAPER 03

Understanding and Designing with (and for) Material Traces

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ABSTRACT

This paper offers a product design perspective to emerging material-oriented design methods in human computer interaction (HCI). It outlines a research process for facil-itating the de- sign of connected objects that deliberately use material traces as texture for communication and interaction. In doing so, it reports on initial findings on how materials are perceived to 'mature' with use, and discusses a design concept related to such findings.

Understanding and Designing with (and for) Material Traces

Introduction

Whether deliberate or unintentional, every crack and scratch that materials manifest as we interact with objects inscribes a story. Interactions with materials result in alterations, imperfections and ultimately unique objects, which carry traces of time and life (Rognoli & Karana, 2014). Understanding and interpreting material traces will be of growing importance in design practice. Traces make a product unique, impact how objects are perceived and valued over time, and may provide an additional texture for interacting with the shadow of data that ordinary objects are beginning to grow as they become connected to digital networks (Giaccardi, 2014).

This work is guided by the research question: how can traces be used to design connected objects that grow, mature, and evolve with their users? Connected objects, which are one part computational the other part physical, are an intriguing ground to examine how the physical and the digital should co-exist with one another. Specifically, how should this physical manifestation of non-physical content age and wear?

To begin to unpack this overarching question, this paper starts with an investigation of the qualities of material traces that can be found acceptable. These findings are then applied in a product design perspective to consider how traces can be utilized to add a layer of communication to connected objects. In this paper, a product design perspective serves the purpose of concretizing the more abstract and conceptual aim of our research question in a material form, which is very relevant to the discipline of human computer interaction (HCI). With this approach, the question at hand can actually be engaged with in physical objects, thus providing opportunities for a deeper layer of interpretation with a materials experience approach (Giaccardi & Karana, 2015). A materials experience approach looks at how materials shapes, and are shaped by ways of doing and practices, and how this situated experience is supported with design. Taken together, these approaches provide the foundation from which to probe our research question.

This paper empirically and practically examines how to design for material traces that people may perceive as 'acceptable'. 'Acceptability' of a material trace was measured

by whether the study participant was willing to keep the object, with the trace upon it, as a possession. The objects used in the study were not already possessions of the participants; therefore there was no preexisting attachment, and thus our question more directly refers to the trace itself. To be clear, this study is not pursuing an understanding of the material qualities of attachment to cherished personal possessions and heirlooms. Rather, we are after the engagement people may have with objects of everyday use, which might not be necessarily special to them.

As part of our process, we conducted a preliminary study (Study 1) to understand how materials and traces coalesce in objects of everyday use (Muntslag, 2014). We then conducted a study (Study 2) considering the acceptability of these traces on objects. This led us (Study 3) to apply these findings to a series of design explorations of material traces experimenting with aesthetic qualities. Finally, we applied these foundational discoveries to produce (Study 4) an initial conceptual design of a product that enables traces on ordinary objects to inscribe digital content onto the object and develop over time on its surface, and thus be used for generating meaning to their owners (Mousavi, 2014).

Each of these studies built upon the previous one's findings to help us develop a comprehensive analysis of material traces and how they can be utilized as a tool for design. We uphold that traces have the potential not just to degrade objects, but that they can also make an object more acceptable in the eyes of people who encounter them (van Hinte, 1997). Further, the traces that participants found to be acceptable had some consistent characteristics and qualities, which indicates that traces suggesting repetitious use and imperfect surfaces hold the most promise for our design goal. Accordingly, we argue that objects carrying traces that are perceived as an intrinsic element of the material itself are potentially kept longer, and are more likely to become meaningful over time. The four studies culminated in the design of a conceptual product, the Chiocciola (see Study 4), which implements the findings from all of the previous studies to demonstrate that there are fruitful directions in which interaction designers can utilize material traces in their work. We do not consider the Chiocciola to be the ultimate conclusion of our studies. Instead, we see the conceptual product design as part of a longer process investigating traces on connected objects and the potential that they hold for connected objects to grow, mature, and evolve with their users.

Related work

In HCI the category of material traces is introduced to consider the impact that traces have on an object, and how this affects the relationship that humans can have with that object (Rosner, Ikemiya, Kim & Koch, 2013). Based on science and technology studies (STS) and fieldwork in creative processes of making, Daniela Rosner and colleagues (see above reference) contribute a comprehensive set of lenses to examine and craft material traces in terms of particularities of form, contingencies and temporal patterns. Their work introduces the concept of material traces into the HCI context and explores how traces can communicate through different materials and means—especially at the intersection of design and technology. They offer a perspective on what constitutes a trace and how it communicates time, the ways of the hand, endurance, and provenance, and open up new spaces for inquiry regarding how traces upon products are perceived and how these can be applied to design.

In product design studies, considerations of material traces have a long tradition and usually concern issues of ageing (Rognoli & Karana, 2014), patina (Saito, 2007) and maturation of materials (Candy, Sommerville, Kalviainen & Oksanen, 2008). These studies highlight the need for ensuring that the way in which materials manifest traces is aesthetically 'acceptable' (Fischer, 2007). They suggest that such aesthetic quality of material traces acquires a yet unexplored dimension with respect to their ability to support (or not) meaningful experiences (Manzini, 1990; van Hinte, 1997). Another existing practice that utilizes material traces throughout the process of the use of an object is the Japanese wabi sabi tradition of repair. This practice accepts and embraces the imperfection of the 'wear and tear' of use and breakage. In the context of ceramics for example, cracks and chips are mended with some kind of adhesion filler and are put to use again (Rognoli & Karana, 2014).
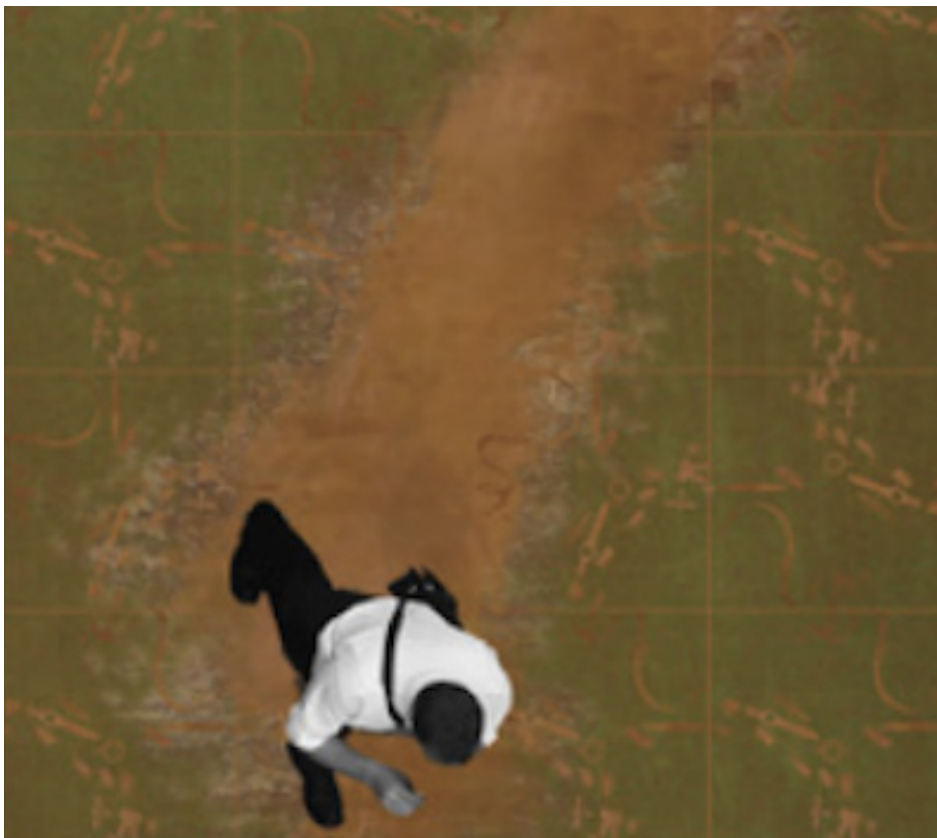

Figure 1 >
Copper tiles 'maturing' with use. Verderame, design by Odo Fioravanti for The Italian Copper Institute, 2009.

Study 1

Exploring existing material traces

Purpose

In the first stage of our research process we surveyed existing material traces on everyday objects to explore their diverse manifestations. This yielded such rich results that we created a taxonomy to process the data. This study gave us a foundational vocabulary concerning what constitutes material traces and what physical qualities define it.

Rationale

As we interact with objects, material surfaces inevitably 'lose' their initial qualities and manifest 'traces' in the form of scratches, discolorations and other alterations. Chemical-physical properties — as well as environmental stress and use — lead the surface of a material to an inexorable decline. Some materials 'degrade' whilst others 'mature' by maintaining or improving certain qualities over time. This more favorable framing of 'maturity' tends to be used in reference to natural materials such as stone, paper, wood and leather (Manzini, 1990). These materials acquire scents, colors and texture—distinct characteristics that don't diminish their qualities, but rather add a sense of provenance and experience (Rognoli & Karana, 2014).

This observation that some objects carry material traces that can become valuable led us to investigate what are the qualities of the material traces on everyday objects that are acceptable to people. Objects that are encountered on an everyday basis become especially prone to wear and tear, markings, and breakage.

Methods

In this preliminary study we used a materials experience approach (Giaccardi & Karana, 2015) to understand how traces manifest on everyday objects and materials. To this end, we surveyed objects with traces. We asked 12 study participants to send us images of objects of daily use from their lives exhibiting prominent material traces. In total, we received 133 images of objects. Some of these objects are pictured on the previous page (figure 2).

Pictogram taxonomy

After categorizing the submitted objects by their material family (metal, wood, plastics, ceramics and textiles), we identified the topographic features of the trace manifested upon each object. The traces were then rendered in a pictogram to provide researchers with a visual representation and catalogue of patterns that emerge across and within material families. These aided researchers in developing the taxonomy of traces as well as identifying which traces were specific to families versus those that were common to all material families. The pictograms (figure 4) provide detailed information about the object regarding the material family, and the types of traces that can be found on it. The color of each pictogram square represents a different material family: gray for metal (M), red for plastics (P), brown for wood (W), beige for ceramics (C), and purple for textiles (T). The different markings within the pictogram represent different types of traces on the materials (figure 3). For example, a bend on the material surface is represented with a pattern that can be seen in pictogram M8. If a part of the material is lost (e.g. broken, torn, etc.), it is represented as in pictogram P7. When a material obtains a trace via an additional material (e.g. paint), it is represented with black annotations, such as in pictogram W21. Scratches on the material surface can be noted with lighter hues of the material family color, such as with pictogram M23.
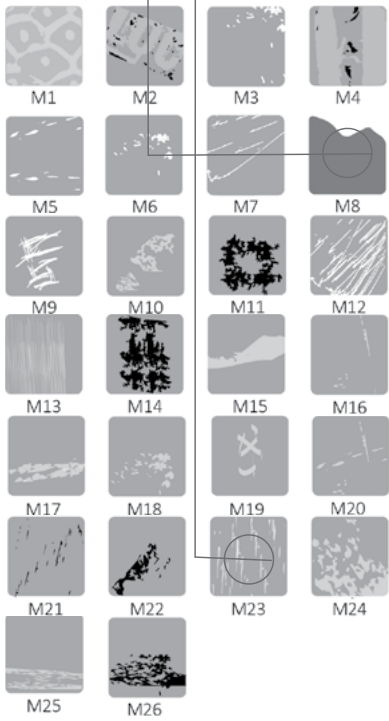
Findings

After collecting 133 objects, 103 of which met the criteria of our study, trace types were annotated by pictogram. These pictograms illuminated the existing categories of trace types from which a foundational taxonomy of material traces could be derived.

Figure 3 v
Examples of how trace types are annotated in pictograms.

M8 - Bend on material surface (metal only)

P7 - White annotation: part of material lost (e.g. broken, torn, etc)

W21 - Black annotation: contains trace via another material

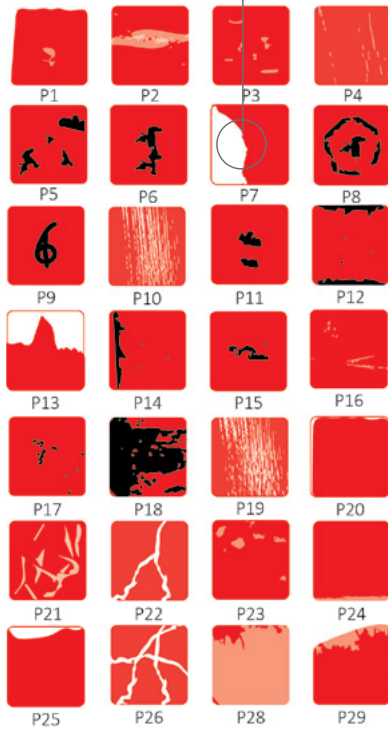**M23 - Lighter hues of material family color: scratches**

Figure 4 >
Pictograms depicting material traces from the objects collected. Pictograms are colored by the object's material family: gray for metal (M), red for plastics (P), brown for wood (W), beige for ceramics (C), and purple for textiles (T). Each type of trace has a different annotation. See **figure 3** for annotation description.

M8 — Bend on material surface (metal only)

M23 — Lighter hues of material family color / scratches

W21 — Black annotation / contains a trace via another material

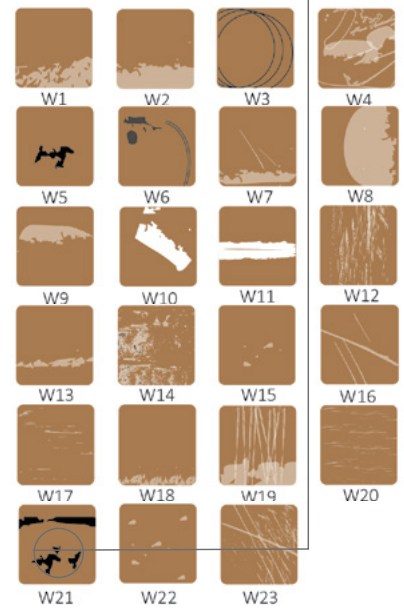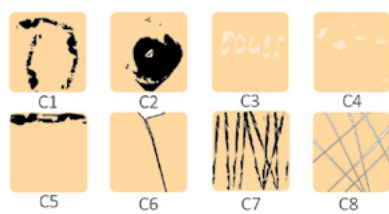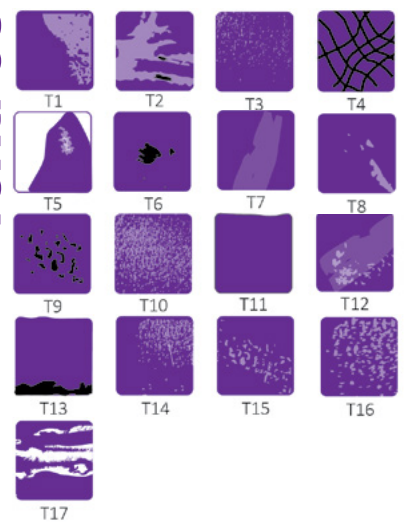**P7** — White annotation / part of the material is lost (e.g. broken, torn, etc.)

Metals

M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12, M13, M14, M15, M16, M17, M18, M19, M20, M21, M22, M23, M24, M25, M26

Plastics

P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12, P13, P14, P15, P16, P17, P18, P19, P20, P21, P22, P23, P24, P25, P26, P28, P29

Woods

W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W18, W19, W20, W21, W22, W23

Ceramics

C1, C2, C3, C4, C5, C6, C7, C8

Textiles

T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14, T15, T16, T17

Study 2

Perception of acceptability of material traces on products

Purpose

For our follow-up study we explored what material traces, within our taxonomy, were deemed 'acceptable' by participants. Or, which objects, with material traces upon them, would participants keep? This study is directed towards extrapolating which specific forms of material traces would be the most promising design directions for designers.

Rationale

With an understanding of what types of material traces exist on everyday products, we then directed our inquiry towards understanding how those characteristics impact how the objects are perceived. What role does the aesthetic quality of material traces play in supporting (or not) the engagement people may have with ordinary objects, which might not be necessarily special to them? What role does the material of the object itself play — are there traces that are 'material specific'? Likewise, are there traces common to all materials? Being able to identify and understand these characteristics will provide designers with a language to implement with their work.

Methods

In this study examining acceptability of traces, we selected a sample of trace types (from the library collected in the first study, figure 4) to be considered by another group of participants. Based on the taxonomy developed via the pictogram system, a sample consisting of 15 trace types was selected. The sample included one material-specific trace for each material family, and two common material traces to all material families. Fifteen corresponding objects for each trace type were then selected from our original set (figure 5). We asked 22 participants to evaluate the objects with these trace types and explore their aesthetic qualities and perceived acceptability. For each object, individual participants were asked probing questions to understand what type of traces were perceived as aesthetically acceptable, and why. Participants were asked questions such as: would you buy this object in a second hand store? Would you use it if a family member or a friend bequeathed it to you? Assuming the object is yours, would you replace it with a new one? Would you throw it away? For each of these questions the impact of material traces was evaluated.

Figure 5 >
(On the following page) A sample of 15 trace types from the original set of objects, and their corresponding pictograms, were collected for participants to evaluate. These trace types were categorized into three groups of 5 samples: two groups of trace types common among all materials, and one group of material-specific traces. At the bottom of the page, a close up of sample W23, the wooden cutting board.

Common among all materials | Shallow nicking

M24 **P23** **W1** **C4** **T15**

Common among all materials | Deep linear scratching

M23 **P19** **W23** **C8** **T14**

Material-specific traces

M8 **P26** **W14** **C6** **T2**

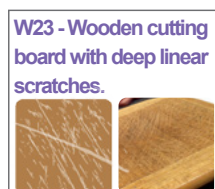**Findings: from imperfection to maturity**

According to our results, the most acceptable traces were on the mortar and pestle (M24), the leather wallet (T15), and the wooden cutting board (W23) (figure 6). Clear patterns of use and additional imperfections were reported as appreciated aesthetic qualities in the aging and maturing of these objects. But, this appreciation often extended beyond the aesthetic qualities themselves, and also encompassed what the material trace communicated about use. As one participant explained:

> I think that the persons that the traces belong to have their [own] specific reasons for keeping them, that is, why [they keep the objects] will always be very subjective. I have stuff that looks really bad but I still love to use it because it feels comfortable. It goes beyond aesthetics only. (Muntslag, 2014, p. 40)

This layer of communication of use extended further. Those material traces that demonstrated how the object has been used in a repetitive manner were valorized even more. This was especially true of those that had surfaces that were inherently imperfect, such as with the wooden cutting board. Thus additional scratches, wears and tears were perceived as embedded naturally in the materials.

From these results, we now understand which types of material traces on everyday objects are found to be acceptable. Similarly, the consistency among these indicates that the most communicative and acceptable material traces are those that clearly communicate use, especially repetitive, and that are on imperfect surfaces. In other words, rather than degrading, these types of traces contributed to objects being perceived as maintaining and developing certain qualities over time. This gave us clear directions for which we could begin to experiment with our designs.

Figure 6 ∨
Participants identified the following samples to have the most acceptable traces.

M24 - Mortar and pestle with shallow nicking

T15 - Leather wallet with shallow nicking

W23 - Wooden cutting board with deep linear scratches.

Study 3

Design Explorations

Purpose

In this phase, we embarked on a series of design explorations to explore the particular materials and trace types, which we had been directed towards by the other studies, as being the most suitable for material traces. These explorations would serve as the bridge between our taxonomy of traces and the eventual design of the connected object.

Rationale

With the knowledge from the previous study that the most 'acceptable' traces were those of patterns suggesting force and repetition, and were on imperfect surfaces (of 'natural' materials in particular), we moved to the next phase: design explorations. The focus of these design explorations was to create a deliberate and permanent trace on materials that are natural with irregular surfaces and achieve a similar effect of maturity. Specifically, the investigation was on how to mimic the form of a clear pattern, similar to the customary ways in which the material wears and tears through use. In this study, we wanted to develop an aesthetic language incorporating our previous research on the 'acceptability' of traces, which can inform designers of future prototypes.

Methods

The design exploration was limited to three material families with natural and irregular surfaces: wood, metal, and textiles. The previous study gave an overview of what kind of material-specific traces are likely to be found in daily life, e.g., corrosion on metal, color fades on textiles, and burn on wood; which this design exploration would consider further. For the metal family, copper was selected and the focus was on creating traces, via corrosion, was accelerated with nitric acid or sulfur. Nitric acid is volatile and leaves a familiar green residue on the copper surface. When sulfur is applied, the copper surface gets darker. In both cases, varnish was used to mask the copper surface with the desired patterns. For the textile material family, traces were made with bleach — either applied with a brush directly on the textile or masking the textile with tape and spraying the bleach directly onto the surface. Wood was manipulated by masking and burning the surface, or by carving different types of holes and indentations. These design explorations are pictured in figures 7 & 8.

Figure 7 >
On the following page, some samples from our design exploration. The columns from left to right: samples of copper with nitric acid; textiles with bleach; and lastly wood with burning.
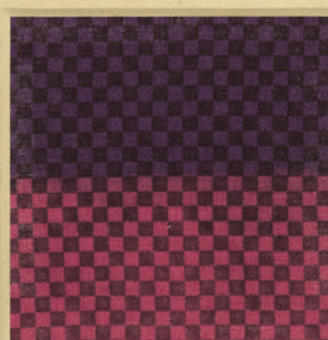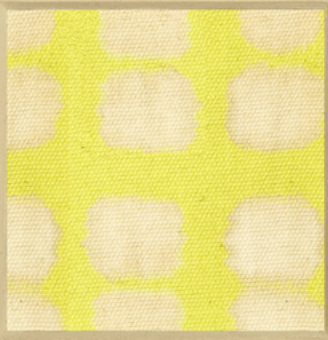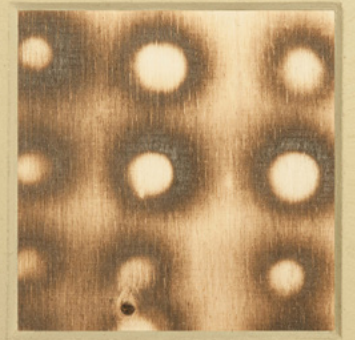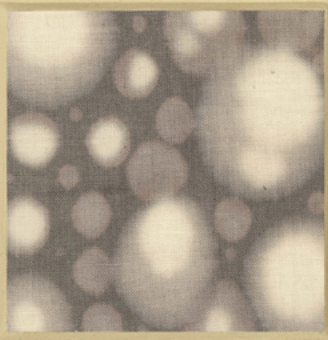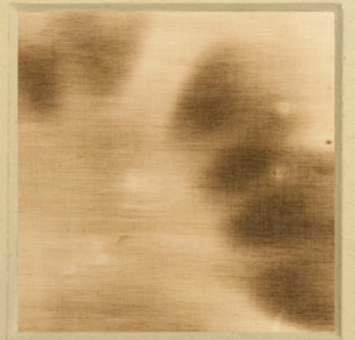
Findings

While the textures and designs produced were provocative and in line with the forms of traces that participants found acceptable in previous studies, they would not be feasible in terms of objects of daily use. Handling unfamiliar chemicals, advanced substances and possibly unsafe burning are not the most approachable means for creating material traces through use. Instead, we were particularly fascinated by the mechanical approach of scratching and engraving, the time and effort that must go into seeing a trace appear, and the careful handling required (figure 8). This emerged as the most promising design direction for our next study.
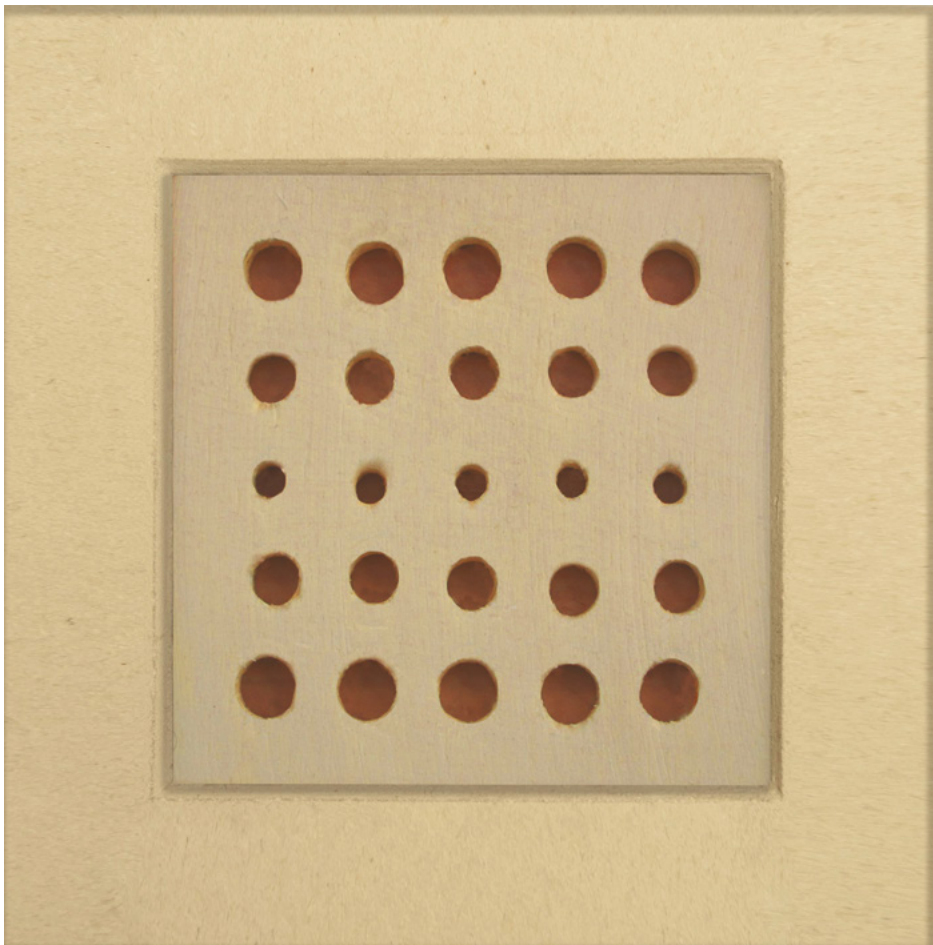

Figure 8 >
An example of our drilling design exploration on wood. This emerged as our most promising design direction.

Study 4

Concept design

Purpose

From design explorations, we transitioned into designing a product that enables people to intentionally create material traces as a means to inscribe and grow stories onto ordinary objects. With this design, we engaged with the findings from our previous studies to create a conceptual connected object.

Outcome: Chiocciola; growing a patina of deliberate traces

Drawing from inspiration for ways to enable 'acceptable' material traces to manifest on a product (Study 3), as well as previous work attempting to bridge the physical/digital divide (Rosner & Ryokai, 2008), we built Chiocciola (in Italian, "snail"). The outcomes of Study 3 led us to a more mechanical means of creating material traces. Specifically, we focused on the process of drilling, and experimented with a variety of bits on different materials. We then decided that each drill bit could represent the pixel of a computationally readable code, such as a Quick Response (QR) code. Any given pixel would be zero or one, engraved or not.

The Chiocciola is designed to use a wireless system to receive the code generated by an application and transfers it to a matrix of magnetic coils. According to the code, some coils are turned on and prevent the drill bits from leaving the base box. The rest, in the shape of the wanted code, will remain attached to the mechanical parts. And so, by using the handle, the user can engrave this matrix of bits on any wooden surface (figure 9). This device enables users to intentionally create material traces onto ordinary objects. In our conceptual design, Chiocciola allows pictures of family moments around the kitchen table to be added to the object itself and in this way to become digitally accessible via a deliberate, physical marking of important social moments (figure 10). Using Chiocciola to repetitively engrave the code into a naturally imperfect wooden surface enables this surface to 'mature' and grow a deliberate patina of material traces entangled with digital data. And so the code here is not just a marker, but an aesthetic resource for design which uses the notion of material trace as a metaphor for a newly-developed maturity of the object.
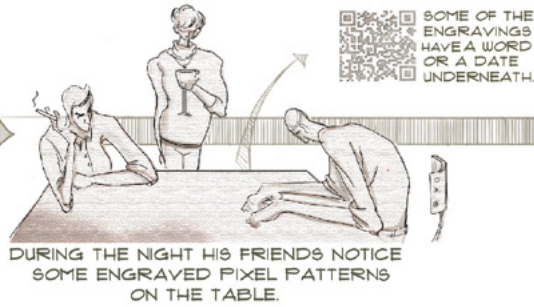
Figure 9-10 >
The conceptual design of the Chiocciola. Following pages:
_ first-page (figure 9) the top are Chiocciola's concept sketches; below, the built product.
_second-page (figure 10)a storyboard illustrating the interaction design, context, and operation of the Chiocciola.
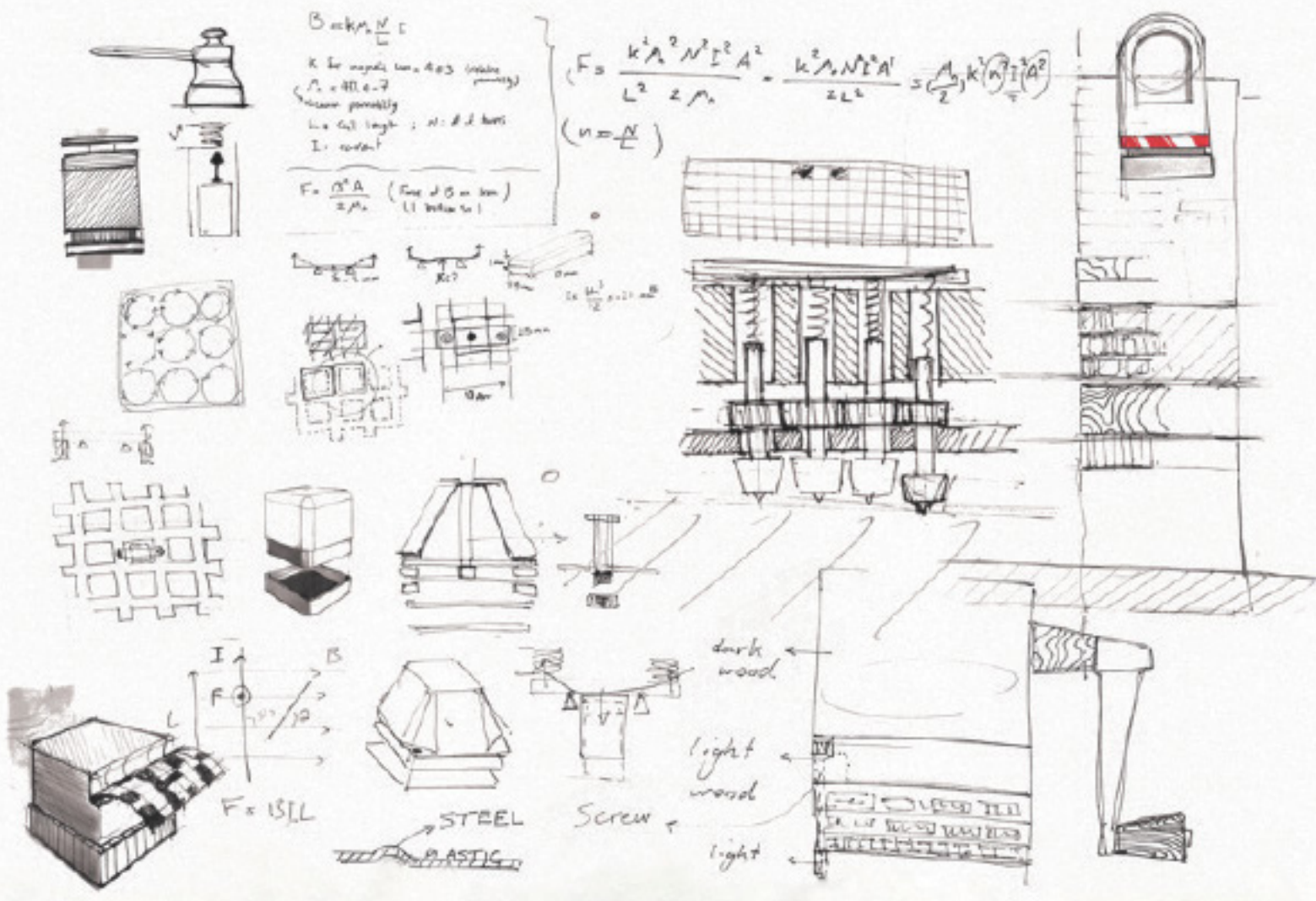
JOSH IS A YOUNG STUDENT. HE IS SOCIAL AND CONNECTED. HE USUALLY INVITES FRIENDS OVER TO HIS PLACE
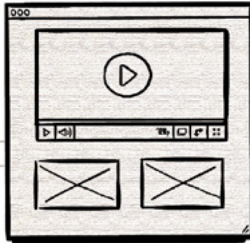
THIS IS JOSH

TONIGHT HE HAS A DINNER PARTY WITH FRIENDS TO CELEBRATE HIS NEW JOB. THEY HAVEN'T BEEN TOGETHER FOR A LONG TIME. IT'S A MEMORABLE NIGHT!

DURING THE NIGHT HIS FRIENDS NOTICE SOME ENGRAVED PIXEL PATTERNS ON THE TABLE.

SOME OF THE ENGRAVINGS HAVE A WORD OR A DATE UNDERNEATH.

JOSH:
"THESE ARE THE BEST MOMENTS I HAD AROUND THIS TABLE".

THIS IS THE APP

THIS IS THE CODE

THESE ARE THE MOMENTS

"THE APP CREATES A CODE LINKED TO THE MEMORIES"

"LET'S TAKE SOME PICTURES AND WE CAN MAKE A SIGN FOR TONIGHT!"
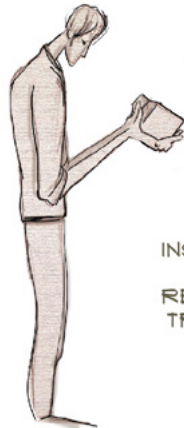
THIS IS CHIOCCIOLA

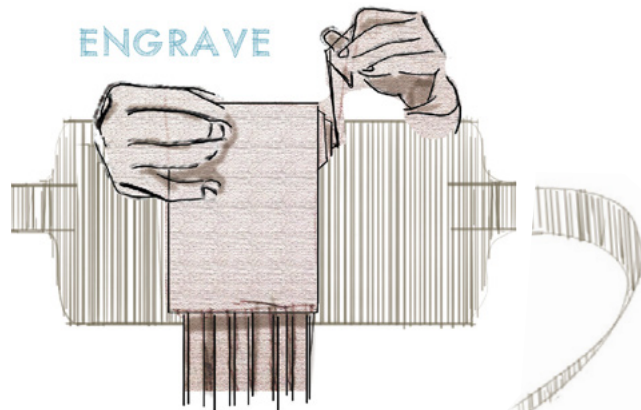"YOU JUST NEED CHIOCCIOLA AND YOUR CELLPHONE."
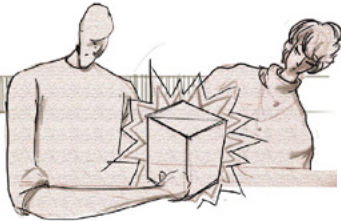
CLICK!

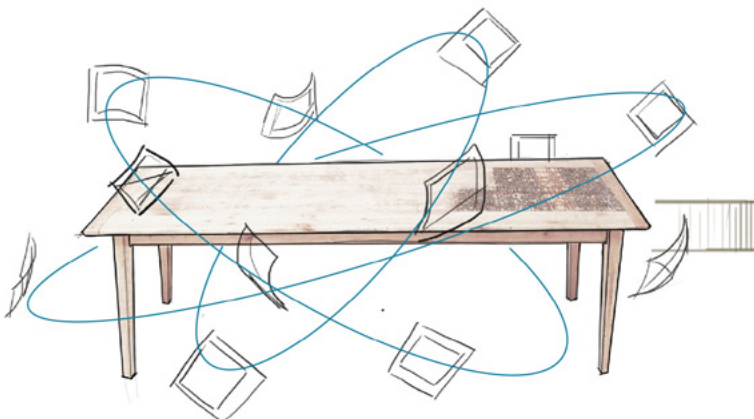"CHIOCCIOLA RECEIVES THE CODE"

"VOILÀ!"

INSTANTLY OUR CODE IS CREATED AND READY TO LEAVE IT'S TRACE WHEREVER WE WANT.

ENGRAVE

NOW LET THE OBJECT CONTAIN THE "ESSENCE OF THE PAST"

THE MEMORIES WILL CONTINUE TO LIVE ON THE OBJECT AND YOU CAN ALWAYS CHECK ON THEM, RIGHT HERE.

Outcomes and Future Work

Chiocciola is not meant to be exemplary, but an initial exploration in how to enable and use material traces as texture in the design of a new generation of digitally-connected objects of ordinary use. The core of the concept is not the technology used, but the way in which the trace or code (or any other identifiable pattern for what matters) is understood and designed as a material trace with a strong aesthetic quality. Chiocciola manifests the findings from our previous studies in an attempt to point designers in directions that utilize traces to promote objects that grow, mature and evolve with their users. Considering the various forms that traces of use come in (Study 1), we found that those indicating force and repetitive use were deemed the most acceptable (Study 3). After experimenting with how to engage with trace types for design (Study 4), Chiocciola integrated all of these discoveries in its design. Chiocciola provides users with the opportunity to engrave the QR code into the wood through a mechanical means that evokes a form of force. The intention behind the selection of the pattern of the QR code, and the interaction itself, is for the table to accumulate many of these engraved codes, simulating the appearance of a repetitive pattern. Both of these features closely echo the findings of the design exploration (Study 3).

In future work, we will take this conceptual design into the wild and see how groups of people engage with the opportunity to make traces. Given the data that we have gathered, we are interested to see how people will respond to the opportunity to make traces of their own that echo unintentional desirable traces. In particular, we will research how maturity should be understood when data are part of the materiality of the object and how the desirable aspects of traces provide digitally-connected objects with a unique character, a new form of maturity and possibly new focal practices—practices with a situated and intimate relationship to the materiality of things.

Conclusion

This paper offers a product design perspective to emerging material-oriented design methods in HCI. In HCI the category of material traces is introduced to consider the impact that traces have on an object, and how this affects the relationship that humans can have with that object (Rosner et al., 2013).

Traces have been a topic of interest within product design studies, but in the context of aging (Rognoli & Karana, 2014), patina (Rosner & Ryokai, 2008) and maturation of materials (Candy et al., 2008). This previous work brings to light the necessity for materials to age, mature, and manifest traces in a way that is aesthetically 'acceptable' (Fischer, 2007). In this paper, we are not investigating 'acceptability' as the material quality of attachment to cherished personal possessions and heirlooms. Instead, we are studying the engagement people may have with objects of everyday use, which might not be necessarily special to them (van Hinte, 1997). We conducted a series of studies to determine what those traces were, and what participants found acceptable. First we asked study participants to send us images of objects of daily use from

their lives exhibiting prominent material traces (Study 1). These traces were then represented by pictograms to provide researchers with easily readable patterns and an overview of aesthetic qualities—the pictograms later serving as a toolkit for designers to design traces themselves (Study 3). In Study 2, participants were shown a small sample of the objects collected in the previous study, and asked probing questions in order for us to understand what type of traces were perceived as aesthetically acceptable, and why. In Study 3, a design exploration, we investigated the most 'acceptable' traces identified by participants of the previous study: i.e. those that leave patterns suggesting force and repetition, and are on imperfect surfaces (of 'natural' materials in particular). Here, designers focused on how to create a deliberate and permanent trace on materials that are natural with irregular surfaces. This was to achieve a similar effect and to develop an aesthetic language for designers to implement with their work.

Lastly, a conceptual connected object was developed that enables users to intentionally create material traces as a medium to inscribe and grow memories onto ordinary objects (Study 4). This product, the Chiocciola, is a device that enables traces to be created on wooden objects in the form of an engraved code. Engraving the trace (in the form of any code) into a natural wooden surface allows this trace to evolve over time subject to additional inscriptions and environmental factors.

As designers thinking in terms of HCI, we are exploring the relationship that people have with objects and the histories associated with them. The body of work presented in this paper represents an initial attempt at understanding and designing for the impact that desirable material traces have on objects and the people that interact with them. It is a first step towards untangling how traces can be used to develop the relationship between the user and the connected object into one that grows, matures, and evolves. By facilitating a way for the desirable aspects of those traces (and their references to maturity and patina) to be made deliberately upon objects by those interacting with them, we have been exploring a new direction for rich communication through and with objects.

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