STRATEGIC DESIGN RESEARCH JOURNAL

Strategic Design Research Journal, 11(3): 254-262, September-December 2018
Unisinos – doi: 10.4013/sdrj.2018.113.10

Do you think what I think? Strategic ways to design product-human conversation

Umberto Tolino, Ilaria Mariani

umberto.tolino@polimi.it, ilaria1.mariani@polimi.it

Politecnico di Milano. Department of Design. Via Durando 38/A, 20158 Milano (MI), Italy

ABSTRACT

This contribution vets into Tangible User Interfaces (TUI) and objects' smart attitudes as emerging contemporary practices. We investigate and discuss the process behind the design and implementation of a product conceived following an idea of intuitive, gesture-based interaction, unpacking and critically analyzing how TUIs are perceived by users. We analyze what it means to experience artifacts whose interactions are triggered by an interface embedded in an object apparently static, but actually technologically augmented and interactive. Through a specific case study, we unfold the results from a qualitative inquiry conducted on a community of prosumers revealing how such interfaces can be misleading. Emerged design issues became challenges for designers and researchers, in a strategic, designerly-ways-of-knowing logic, which led to improving the product keeping into consideration users' expectancies and their actual interactions/behaviors with the product. In conclusion, we reflect on how designers can benefit from extrapolating users' habits and cognitive processes from data, in order to be strategically instrumental in defining future design implementations, features, products, services, and even systems.

Keywords. Tangible User Interfaces, IoT, interaction design, user centered design, user behaviour, design process, gesture-based interaction, embodied interface.

Technology and digital transformation alongside play a paramount role in influencing the way we live and act (Castells, 2000), simplifying our daily life and activities, and providing answers to needs that often the technology itself created (McLuhan, 1964). In doing so, technology is also significantly affecting the way in which we perceive the world. From a user perspective, it has nurtured relevant transformations providing diffused access to information as well as to skills and tools, and consequently impacting on the way we learn, share and gain awareness (Jenkins, 2006). With regard to space, time and sociality, the pervasiveness itself of information and communication has reshaped our uses and habits. In consequence, the role of technology within our society has progressively changed, from being a matter of problem-solving, to become a way to satisfy needs (Hassenzahl and Tractinsky, 2006). A process that is still ongoing, showing a pronounced tendency to include people, objects and systems into more or less complex ecosystems where they act as peers.

As a result, what we are already partly witnessing and mainly envisioning, supported by the opportunities and potentialities of the Internet of Things (IoT) and the Internet of Everything (Evans, 2011, 2012), is the presence of interconnected (eco)systems in which smart, sensory and intelligent objects communicate among themselves, as well as with people (Vitali *et al.*, 2017).

As a matter of fact, embedded technology and objects' smart attitude outline a challenging field of investigation where design meets engineering, requiring approaches that are utterly interdisciplinary. They describe a trend based on designing and envisioning physical artifacts as connected to the Internet or/and between themselves, and regulated by code for ruling their behaviours, defining how they interact with other objects and applications, also connected.

In similar conditions of cross-breeding and intersection of knowledges, the design process can be experienced at the fullest, from the idea and concept definition to the production of products, services and complex systems, including communication and marketing perspective. Indeed, as our same society constantly changes and reconfigures itself answering to the constant technological evolution (Turkle, 2012), and in particular to the ongoing digital transformation, analogously the disciplines that shape our everyday life are challenged to modify and reinvent themselves.

In the light of that, our rumination encompasses a twofold perspective: the one of the designer who designs among these boundaries and potentialities, and the one of the user who interacts with the artifact. Considering a user centered and user experience design approach[1], rather than a product-driven design perspective, we draw our attention on how contemporary objects' smart attitudes and embedded technology can be applied in the field of design, proposing experiences of products and services based on the idea of Tangible User Interfaces (TUI). Moreover, this contribution is situated in an area of further friction, where function, usability, language and meaning converge, since the object under discussion combines different approaches. It uses an invisible but tangible interface, that does not involve direct interaction of the type "what you see is what you get", but rather an interface embedded in the object (under its skin). Consequently, it uses a Tangible User Interface (TUI) that simultaneously includes some logics of Natural User Interfaces (NUI): to be used, the object requires the user to simply interact with it, mainly by moving it, changing its position in place, and tapping on specific points to activate specific functions.

That said, acknowledging the existing literature on user research and human-computer interaction and the fact "the user is not enough" anymore (Brugnoli, 2013), our aim is to dig into how users interact with artifacts employing TUIs, and hence to unpack how the norms and nature of interaction are challenged in terms of *affordance* (Gibson, 1977, 1986; Latour, 1996, 1999), keeping into consideration the ways in which users – as agents – behave and are used to behave (expectancies) with products, services and more complex systems. We follow this direction stressing and questioning the fact that a common, simple and straight-to-the-point way for describing interaction designers is as *shapers of behavior* (Kolko, 2011, p. 15).

From Nest Labs' Nest and Bang & Olufsen's Beosound Wood to Apple's HomePod, over the last years, the traditional *idea of interface* has been increasingly challenged. Benefitting of the fact that technology is getting more and more pervasive and ubiquitous, and following a tendency to get dissolved into the cloud, into the environment, and also into our bodies, what we would traditionally call "interface" is matter-of-factly progressively disappearing (Sutton, 2014). However, augmenting everyday products and services by introducing TUIs means to question implicit assumptions of common interactions with objects, and in consequence to reframe the way to build and use technological artifacts, respectively from the perspective of those who design and those who use such products/services (IoT Design Manifesto, 2016). The resulting augmentation of products and services with embedded interfaces leads to a clear shift towards engaging users with different ecologies of interaction. Artifacts become computational. In doing so, they open a set of possible kinds of dialogue between artifacts and people, or artifacts and environments – and those who populate such spaces as a result –, with challenging consequences in terms of rhetoric of communication and interaction. But what are the consequences?

Since the introduction of computing into everyday artifacts (Giaccardi, 2015; Kuniavsky, 2010), as designers, we are asked to postulate a different genre of design, which takes care of usability when new kinds of (social) interaction are required, activating new rituals with supposedly well-known products. We are asked to reshape a dialogue that goes beyond being physical and emotional, resulting from a complex interplay between natural shapes, hidden functions, and embedded technology. *But how does the user react?*

Nevertheless, to comprehend to what extent the user understands gesture-based interfaces that embed technology by remaining invisible (Krishna, 2015) and natural, and how designers can benefit from their potentialities, harnessing the kind of aesthetic experiences produced by augmented products and service, we ask ourselves: *What does it mean to design satisfying interactions (from a user perspective, rather than a designer one) with TUI? How can designers conscientiously design and embed technology in artifacts to strategically and wisely take benefit from its implications?*

Designing artifacts able to shape behaviors clearly entails a challenging level of complexity that requires to take into account multiple points of view. As shown in the case study discussed in the following paragraph, applying TUI logics, tangible and embedded interaction brings to question the traditional meanings beyond our gestures and also objects' possible uses, by affecting user expectancies, as well as the ways in which human-computer-interaction works. Tangible, embedded interfaces identify indeed the seamless integration of interaction into everyday objects.

Dealing with user interfaces, material qualities, phygital artefacts, and user experience with products, services and their inbetweens, electronic engineers, information technology engineers, product and interaction designers are concurrently asked to merge their knowledge and know-how. Especially approaching TUIs embracing a user centered approach, a further shift of perspective is required. Rather than being conceived as objects, such interfaces entail to be thought and designed as interactions between humans and invisible technology, taking into account a point of view that is in the meanwhile the one of human-computer and of human-product, paying particular attention to the aims, uses and habits, but also expectancies on the ground of the interaction itself. The interface is indeed the holistic system that dialogues with the user (Kolko, 2011) communicating product, service or system functionalities for allowing users to access informations about possible uses. This interactive and performative dimension allows objects become *products* (Bonsiepe, 1995), and usability is just a piece of a bigger amount of features that play a role in this dialogue.

Objects apparently natural and inanimate can be empowered with technology able to react to gesture, vibration, motion/acceleration, radio-frequency identification, and so on, and exchange information. Ecosystems made of products augmented with invisible compounds of sensors (Brugnoli, 2015; Sutton, 2014; Jenkins and Bogost, 2014) can allow (un)expected interactions, shaped as a sort of dialogue with the user, or with the surrounding environment. In point of fact, one of the features of products employing IoT and smart technology is their ability to fluidly react to external variables, as for example users behaviours (Yang

[1] Acknowledging the limits of a user centered approach, such a reflection has as its traditional lincipin the fact that design revolves around users, or better, their needs (Norman and Draper, 1986). Design implies indeed a deep understanding of the user, in terms of uses and habits, gestures and interactions, also rituals and aspirations. In parallel to the importance of understanding users' needs, Norman (2004) establishes the leading role of emotions in design, demonstrating the complex relation between humans and the objects of everyday life.

and Rebaudengo, 2014). In so doing they move from a state of passivity to one of activity, establishing an interaction that is a *conversation* with the subject and/or the environment. Echoing Manzini (1990), by becoming sort of virtual interlocutors with whom users are asked to confront, these objects turn into subjects able to activate *symmetrical interactions* in which both sides, namely the artifact and the user or/and the artifact and its surroundings, can act and react according to each other.

If on the one side this typology of gesture-based interaction opens *per se* a significant issue on gestures, and their being situated rather than universally spread, with meanings and interpretations rooted into culture (Norman, 2010), on the other, it spotlights the function and power of aesthetics in activating meanings that result into interactions, moving from affordances to performances, functionalities and hence usability. In point of fact, by their own nature, TUIs are tricky and different; especially when they go back to essential aesthetics, they kind of put to the test the way users dialogue with interfaces that are not really perceived as such. As a consequence, the research on users' interactions, especially when natural materials are combined with embedded technology and TUI, spotlights the need to integrate the focus on user's behaviours, to the meaning and potential interactions elicited by the artifact.

Slab! A piece of interaction

In the following, the theoretical reasoning described above is applied and explained through a case study in order to unpack and expand the logics, benefits and possibilities coming from designing a product in appearance natural-alike, but actually empowered with smart technology, following a behaviour-centered design approach. This analysis is conducted by the authors, respectively as one of the designers and researchers of Thingk (http://thingk.design), the University Spin-off that conceived and developed Slab! (http://thingk.design/slab), and a designer/researcher not affiliated with the Spin-off, whose main research focus concerns the assessment of artifacts ability and effectiveness in producing/transfering meanings, combining qualitative and quantitative approaches, and employing interdisciplinary mixed methods.

Through the critical analysis of Slab!, a smart wooden kitchen scale and digital timer (Figure 1) connected to a mobile app, we look into how users handle an artifact with a shape that doesn't suggest what it its, its functions and how to use it, and therefore posing the question of how our cultural constructions get challenged by such stealthy-augmented artifacts.

Slab! is a kitchen scale intended to result into aesthetical user experience where the digital and physical spheres overlap (Vitali *et al.*, 2017). The appearance of the scale (Figure 2) is essential and natural – high quality wood, soft and smooth outline –, but its paramount feature is that it changes, unveiling its functions, when it comes into contact with the user. Depending on its position, a LED display appears indeed from the wood surface, showing the weight of the food (when lying down) or the timer function (if standing).

However, this is the current Slab!. To get to this point it went through a process made of users and data interpretation.

Slab! uses a TUI conceived pursuing an ideal of natural and intuitive interaction, and following the criteria of aesthetics (the joy of doing), spatial-located information (objects as information), and situatedness (environmentally responsive and activator of further interaction), but challenging the criteria of direct interaction (what you do is what you get) and verisimilitude (interactions triggered

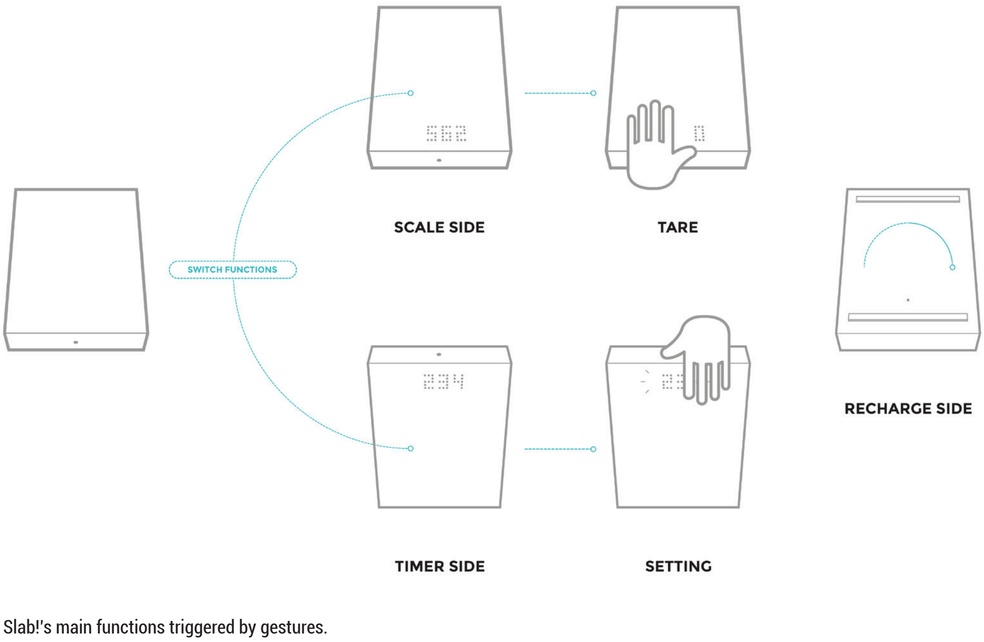

Figure 1. Slab!'s main functions triggered by gestures.

[2] In point of fact, Mann's (2003) criteria of direct interaction (what you do is what you get) and verisimilitude (interactions triggered by gestures elicited by object's affordance) are not really observed.

by gestures elicited by object's affordance) (Mann, 2003).[2] Paying special attention to understanding the pros and cons of TUIs, and how it was able to convey its functions (and functionalities), Slab! was first conceived and then implemented taking advantage of a behaviour-centered perspective – both in terms of design and research approach. Harnessed in a logic of datafication, aspects of the interaction with TUI as the way the user uses the scale and timer, and how many times s/he activates a sensor, are used to trace user's behaviour with the artifact.

Data and behaviour nurtured design. Methodology

Designerly speaking, Slab! has been developed through iterative processes of design, acknowledging the central role of the user as source of innovation rather than just needs, following the user-led innovation concept advocated by von Hippel and formalised in the user driven innovation model (1976, 1986, 1988; Herstatt and von Hippel, 1992; von Hippel and von Krogh, 2003; van Oost *et al*., 2009).

From a methodological perspective, the design research conducted on the artifact is based on qualitative and quantitative data collected from a community of early adopters, then analysed, designerly applied and implemented (Figure 3). The data collection and the research methodology are user-centered: the whole process is based on a behaviour-centered logic. Placing behaviours at the centre means investigating users in-depth, analysing the routines, patterns and distinctive features of each individual. It means therefore investigating the user with a greater accuracy in order to extrapolate habits and cognitive processes instrumental to TUI design.

As shown in Figure 3, the first prototype of the kitchen scale was subsidized through an Indiegogo crowdfunding campaign (2014) for building a community of prosumers (Gonzalez *et al.*, 2014; Brown, 2009), aiming at understanding how this kitchen scale and its TUI are used, highlighting the presence of potential design/usability ambiguity while the product is still in its prototype phase (Figure 3 – Test/Prototype). Those who partook in the crowdfunding campaign provided feedback – text and videos sent via email

Figure 2. Slab!'s main functions described through some frames from a usability test video.

Source: https://vimeo.com/211579872

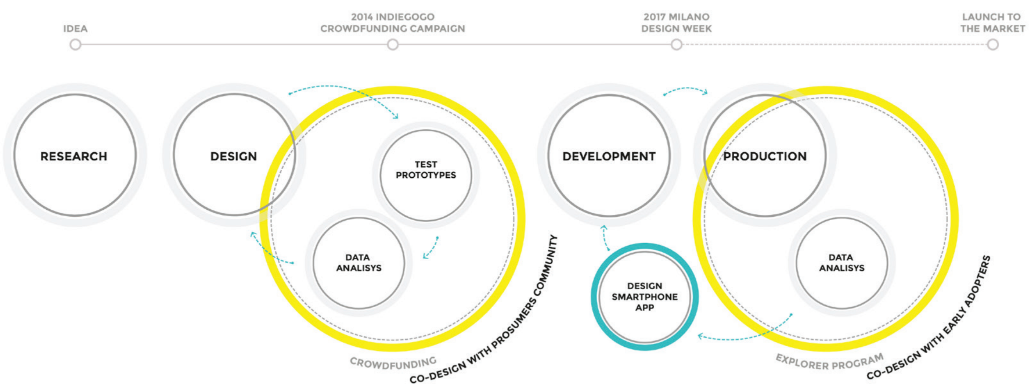

Figure 3. Research and design process map, outlining the design iterative process on the ground of the product (and then system).

– about the way in which they used the product. The data has been gathered during a six-months span from an international community from 19 Countries worldwide who received (from October 2014) and tested more than 200 prototypes, contributing with important information about how they interpreted and reacted to the artifact, and specifically how the TUI was able to communicate its functionalities and aesthetics features.

As explained below, the outcomes of this phase resulted into an improved version of the kitchen scale, then presented as an Explorer Program, that is still ongoing. In this phase, the scale is paired with a mobile app, able to track further data, as the scale uses and the user habits, and to recognise information about the interactions with the product, as well as with food (typology and quantity), cooking/culinary patterns. Quantitative data are collected by the sensors soaked into the kitchen scale, via bluetooth connection. Via a data analysis and remote ethnography, these data will be used to conduct interpretive research. In parallel, each user, as an early adopter who entered the Explorer Program, is asked to fill a questionnaire in order to provide data for enquiring further aspects on actual and expected interaction with the product and its connected system. In so doing, effective uses, expectancies and desiderata were enquired. The decision of collecting multiple forms of data, applying a triangulation of different methods, are part of a mixed methods research approach adopted for lessening those limits, biases and weaknesses that lie on the ground of each research method (Denzin and Lincoln, 2011, p. 379; Creswell, 2008, p. 14). However, since the quantitative data collection is still ongoing, in the following we focus on how the qualitative data culled until today impacted on the design of the product, as well as on its upgrade into a system (product + app).

From product to data, and backward. Results

The data collected has been used to explore and understand *if*, *how*, and also *to what extent* embedded technology can be used to lessen the threshold of access to artifacts and complex systems, opening significant design challenges, as well as to assist/guarantee to handle tasks in smarter ways, taking the interaction experience to a smoother level. To tell the truth, the analysis of the data about users' interactions revealed that some aspects of Slab! TUI fed misunderstandings, that once analysed and interpreted nurtured specific improvements.

Echoing Verganti (2009, p. 65; Norman and Verganti, 2014), *technological epiphany* happens when radical technological innovation meets radical meaning innovation, namely when technology-push and design-driven approaches overlap. IoT and technology embedded into products seem to be leading the way to answer to the radical innovation criteria of novelty, uniqueness and being adopted, as proposed by Dahlin and Behrens (2005). By making the technology as spread as integrated in our surroundings (as unpacked into experiences triggered by our interactions with the environment), IoT and embedded technology nurture their application to everyday objects via gesture-based interaction. In consequence, they tend to turn mechanics into information that can be explicitly or implicitly framed as inputs or outputs. However, as said, because of their level of innovation and embedded technology, TUI can be demanding.

> *Radical innovations seldom live up to their potential when they are first introduced. At first, they are often difficult to use, expensive, and limited in capability. Incremental innovations, meanwhile, are necessary to transform the radical idea into a form that is acceptable to the consumers who follow the early adopters. The bottom line is that both forms of innovation are necessary. Radical innovation brings new domains and new paradigms, and it creates a potential for major changes. Incremental innovation is how the value of that potential is captured. Without radical innovation, incremental innovation reaches a limit. Without incremental innovation, the potential enabled by radical change is not captured (Norman and Verganti, 2014, p. 84).*

That said, the issue that arouse analysing Slab! as a case study is that *radical aesthetical* TUI was not fully understood by users. Following Human-Centered Design and Design Research perspectives, and looking at the market logics (Norman and Verganti, 2014), the artefact was implemented: exposing certain functionalities, designers adjusted Slab!'s aesthetic, originally crafted to be so essential to look like a simple slab of wood, for increasing users' perception of the functions.

Since its conception, Slab! was born to be essential, smart and user friendly. As such it becomes the subject of an Indiegogo crowdfunding campaign (2014) during which 200 products have been delivered to early adopters to whom it was asked to use this scale and deliver information (via email) about their interaction with the artifact. Ranging from emotional and conceptual to logic and functional descriptions, from pleasant to troublesome issues, the texts and videos sent by users explored a full range of experiences and possibilities, providing crucial feedback that highlighted the existence of potential ambiguities in using the product.

With the disappearing of technology (Sutton, 2014), analysing user experience and in particular user behaviours with artifacts embedding technology assumes a pivotal role; in parallel, it becomes paramount the function played by design aspects as material, ergonomy, and so on. In our case, crucial sets of information emerged from the data gathered during the six-months span in which the prototypes were used. From a usability perspective, focusing on the descriptions about how users interpreted the product interface rather than expanding the discourse to the other points and arguments touched, the comments cluster around the two main topics of functionality and aesthetics, where functionality refers to the extent to which the artifact is able to perform desired or expected operations, while aesthetics identifies the artifact ability to enable users to sensory perceive its functionalities. According to the feedback, it was possible to understand how the product interface (TUI) activated users' behaviour in terms of affordances. It results that Slab! challenges the norms and nature of interaction, with regard to the traditional ways in

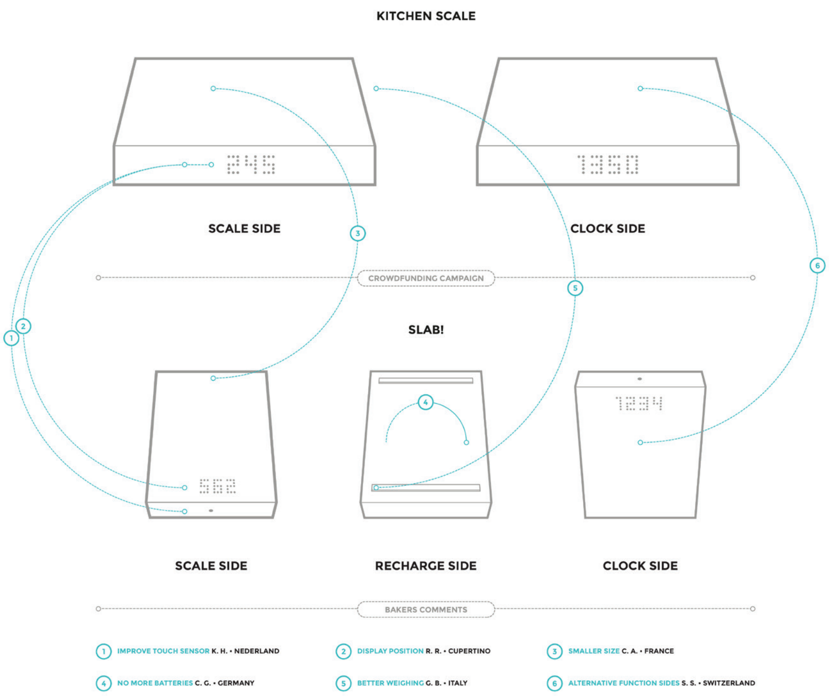

Figure 4. Results from the co-design process with a selected community of prosumers.

which users behave and are used to behave with products, services and more complex systems.

User's behaviours analysis becomes the leading strategic dimension, and the main driver in the design process. Especially the expectancies collected and feedback provided resulted as relevant to lead the redesigns of five different aspects, which have in turn been reciprocally affected, raising further implications.

(1) Timer side (Functionalities);
(2) Scale display position (Aesthetics);
(3) Object resize (Aesthetics);
(4) Tare button emphasis (Functionalities – with aesthetic implications);
(5) Power charging (Functionalities).

The following paragraphs present a critical analysis of the main issues that popped out from the prototype test with the community of prosumers.

Timer side (Functionalities)

Slab! is a smart kitchen scale nestled in a CNC-milled ash tree wooden slab, hiding just under its surface a LED display, that once activated shines through the wood. Looking at the prototype (Figure 5) and its elegant, minimal shape, it is quite natural to pose the question: how can the user know which is the correct position for activating the scale rather than the timer?

Matter-of-factly, the first comments about the product UX mainly regarded the difficulty in distinguishing the scale side from the opposite one, serving the function of timer. This recurrent comment led to a repositioning of the display with aesthetic implications in terms of visibility. Today, Slab! presents a display on it top side breaks the object' symmetry, communicating its positions of use by. Indeed, when Slab! is inlined vertically, an embedded gyroscope transforms the product into a timer, which can be easily set interacting with a touch sensor (on the small side of the scale). Visual and audible indicators will signal users when the selected time is over. These functions have been designed to be autonomous from smartphones or other devices.

The first idea, following an essential and smooth logic, was to use the two side of the artifact to carry out different tasks as scale and timer. However, the aesthetic of the artifact in terms of its TUI, and hence functionalities, were so invisible to bring to a potential design/usability issue. The implementation phase revolved around the insight that the system composed of scale and timer would have been mainly used as a scale on both its sides, since nothing was showing the difference between the two identical faces of Slab!. This supposition was confirmed by the usability tests ran with a sample of users. The way users behaved with the artifact led to reveal the rounded studs, that moved from the inside to outside of the scale. Such a change also makes evident the presence of a front and back side of Slab!, and in consequence which is the right and wrong way to position the artifact. Moreover, when the user starts the timer and then returns Slab! to its scale-position, the countdown continues to run in the background, emitting a sound when the time is over.

Scale display position (Aesthetics)

Feedback on the display legibility in different conditions of use led to an aesthetic change aimed at improving the readability. Initially, the display was placed as shown in

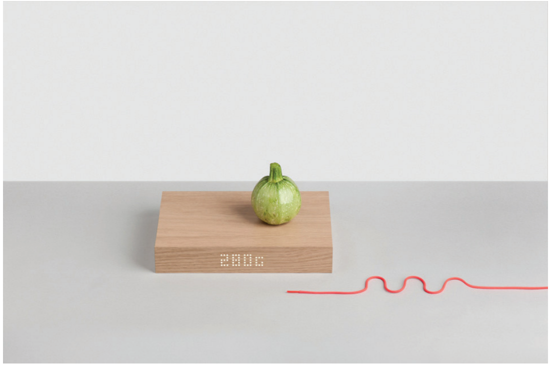

Figure 5. Prototype of the kitchen scale delivered to the crowdfunding community.

Figure 6. Slab! redesigned after the design research phase based on the crowdfunding campaign.

Figure 5, causing some issues in terms of legibility: the display position required users to take some distance from the object, or alternatively, to stoop or bend to read the weight. As a result of the new display position, when Slab! is put on the table in the scale-mode orientation (lying rather than standing), the display shows the weight on its upper side (Figure 6), rather than on the lateral side (Figure 5), so as to always provide the most favourable reading angle: the top view. This implementation also led to rethink the timer function in relation to the vertical orientation of the object.

Object resize (Aesthetics)

A less radical change, but still with a significant impact on the product ergonomics, concerns the resizing of the load-bearing structure of the kitchen scale, towards a more suitable dimension for the environment where it is used. Slab! has been reduced by about 25% of its original surface area, going through a process of reengineering of its electronic components, as well as of its CNC-milled wooden structure.

Tare button emphasis (Functionalities – with aesthetic implications)

The testing period revealed a problem among how many times the scale prototype was used and how many times the tare sensor was identified and perceived as such. Initially, the tare sensor was mainly ignored by users: it was not touched or even seen. This finding triggered the decision to use the only graphic sign on the object (the brand logo) as an indication of the very point where to touch the surface for subtracting a tare, or for setting the timer when the product is oriented vertically. If the current version of Slab! is let resting on a worktop, a simple interaction with its surface activates the weight function, and brushing the touch sensor marked on the short side enables users to weight a tare.

Power charging (Functionalities)

One of the main performance improvements proposed by the prosumer community is the transition from standard batteries supply to wireless charging with QI standard. This choice was made possible by the reduced energy consumption obtained by replacing some electronic components, taking advantage of the increasingly consolidated tendency to use this charging system in contemporary electronic objects (iPhone, version 8).

The improvements listed above have been implemented for the Milano Design Week 2017, and the product has been further augmented into a system that matches the artifact to a mobile app connected via Bluetooth 4.0.

A new phase of testing is currently in progress, involving a further community of early adopters in an Explorer Program (see Google Glass) aiming at identifying future implementations of Slab! with new functions, harnessing the app and the potentialities of the embedded technology in a IoT perspective.

The relevant benefits of having sensors (embedded technology) within Slab! and the possibility to gather data through the mobile app are the possibility to archive and interpret information about users' patterns and their habits, and in consequence the possibility to constantly update the system with new features emerging from real uses and needs. The observation and participation of a community of practice will be crucial for conscientiously exploring new application scenarios.

From an early brainstorming with a panel of selected users it already emerged the idea to take advantage from Slab!'s native functions (scale and timer) to create an interactive system that encourages a long-term engagement with the product based on cooking/culinary patterns and habits of use. Being paired with the mobile app allows to track specific data and recognise information about the interactions with the product, as well as with food (typology and quantity).

From user experience to user behavior. Discussion

From a strategic perspective, the description of the process behind Slab!'s design and implementation is a combination of research *for* and *through* design (Cross, 2006; Frayling, 1993; Forlizzi *et al.*, 2009) that leads to unpack and critically analyse two points that are central in the reasoning here presented about TUIs: their understandability and their potentialities in terms of design.

Analysing how users experienced the prototype of an artifact designed following an idea of intuitive-based interaction made evident that users actually encounter certain difficulties in grasping some functionalities activated by a TUI embodied into what appears just like an elegant slab of wood. The qualitative enquiry conducted on the prosumers involved in the crowdfunding campaign reveals that both users and sensors play the role of consistent and reliable sources of information able to prompt emerging challenges for designers and researchers, in a designerly-ways-of-knowing logic. However, further implications and insights are expected from the accurate enquiry of the patterns of use and of the interactions between users and the artefact that will start in the next future, harnessing the sensors embedded in the product sending data to the mobile app. We expect indeed to extrapolate from data habits and cognitive processes strategically instrumental, on the one hand, in the TUI implications, on the other in defining future design implementation, as well as new products. In so doing, the future design decisions will lie their foundations in the analysis of data, and hence with facts on their basis rather than aesthetics or intuitions. Gathering data and analysing user's behaviours become the leading drivers for envisioning further improvements, features, products, services and even systems, bridging innovation and experimentation, research and design.

In particular, the qualitative enquiry conducted on the community of prosumers confirms that, insofar interactions are concerned, users are used to artifacts whose shape can reveal their functions and their electronic part. However, the distinctive feature of Slab!, namely the way it uses TUI, brings to a friction between shape and function. Rather than embedding interactions into products already familiar to users, using technology to broaden their function and impact, Slab! radically changes the expected aesthetic of a scale, by taking the shape of a wooden cutting board technologically augmented with almost invisible functions. This reinforces the presence of what Kranz *et al.* (2010) named *invisibility dilemma*, namely when the physical disappearance of technology into embedded interfaces impacts on how the user perceives the product and its function.

Shapes traditionally play a paramount function in communicating possible interactions, uses and affordances to users, letting them know how to handle a product. On the contrary, Slab!'s shape doesn't suggest what it is and how to use it. Its shape required indeed an in-depth analysis with users in order to test and verify their unconventional ways of interacting with the product. As a matter of fact, it is only through the direct interaction that its surface becomes communicative, making clear that it is more than a static wooden cutting board. However, it is when Slab! is paired with the mobile app that the interaction assumes the shape of a conversation based on behaviours stored as sets of data. Such conversation is multidirectional: on the one side it happens between the product and the user when Slab! acts as a cooking assistant, on the other between the product and its designers, when transmitting data about the user's patterns of use.

As designers and researchers, dealing with a product as Slab! means put ourselves to the test in several, challenging ways, looking at strategic ways for designing and enquiring how to make users aware that apparently ordinary and common artifacts (used in everyday life) are more powerful than expected, since they are digitally enhanced.

The empirical research conducted analysing how prosumers who used Slab! outlined some limits and constraints of an interface that becomes invisible. The community of prosumers played indeed a key role in the redesign: by providing information about their interpretation of Slab!'s TUI, the users unveiled the real affordances of the artifact, explaining the actual relationship between them (as agents) and the artefact/system. They made evident what triggered potential actions, rather than what was perceived as "silent", namely non-affordances, considering Gibson's definition of affordance as "the physical possibility of an action occurring" (1986). The feedback received became the foundation for unraveling the product and conduct a critical analysis about its uses: the total amount of information collected allowed to unpack the perceptual psychology behind the users-artifact interaction, and therefore the possibilities of action that the artifact is able to communicate as if it is taking part in a conversation with the user.

As emerged throughout the entire contribution, the desire of having natural surfaces with TUI, and hence the choice of a very familiar and common material as wood (ash tree) to allow a camouflage of products in all living environments, opened a series of design issues, as interesting as challenging. Therefore, through this reasoning we intended to provide a theoretical contribution for unpacking what it means designing new ways of interacting with TUI – from a user perspective, as well as from a designer one –, and also how (Slab's) designers could take advantage of the amount of data and feedback gathered. However, since the enquiry and testing through the Explorer Program are still in progress, we do not have jet information and data from those sensors that have been embedded into the artifact. We expect data to trace, collect and archive user's behaviours and their interactions with the product. But this is our ongoing work.

Acknowledgments

This article is the result of various years of research and exploration, conducted taking advantage from the critical support and invaluable expertise of others. We discussed our ideas and challenged our insights with brilliant colleagues and outstanding professionals, as well as with highly-talented designers. Therefore, we acknowledge with appreciation those who questioned and problematized our insights, inspiring Slab!'s desgign and implementation over the years, from the Indiegogo Crowdfunding community to the professionals and designers who worked with the Thingk team. In this regard, Politecnico di Milano and Poli Hub provided a particular fertile and supportive environment, since they allowed and encouraged our researches.

A special thank goes to the team of Thingk for always pushing the line, exploring opportunities and envisioning potentialities.

References

BONSIEPE, G. 1995. *Dall'oggetto all'interfaccia. Mutazioni del design*. Milano, Feltrinelli, 264 p.

BROWN, T. 2009. *Change by Design*. New York, HarperCollins, 364 p.

BRUGNOLI, G. 2013. UX Design: The User is not enough. *Medium*. Available at: https://medium.com/@lowresolution/ux-design-the-user-is-not-enough-c90d595eb23. Accessed on: March 12th, 2018.

BRUGNOLI, G. 2015. Designing Smart Experiences: The Smart and Invisible Future of Interactions and Services. *Medium*. Available at: https://medium.com/@lowresolution/designing-smart-experiences-a6e675b414ec#.tf16wwbkq. Accessed on: March 12th, 2018.

CASTELLS, M. 2000. *The Rise of the Network Society: The Information Age: Economy, Society and Culture*. Information. New York, John Wiley & Sons, 624 p.

CRESWELL, J.W. 2008. *Research Design: Qualitative, Quantitative, and Mixed Methods Approache*s. Beverly Hills, SAGE, 260 p.

CROSS, N. 2006. *Designerly Ways of Knowing*. London, Springer, 141 p.

DAHLIN, K.B.; BEHRENS, D.M. 2005. When Is an Invention Really Radical? Defining and Measuring Technological Radicalness. *Research Policy,* **34**(2005):717-737. https://doi.org/10.1016/j.respol.2005.03.009

DENZIN, N.K.; LINCOLN, Y.S. 2011. *The SAGE Handbook of Qualitative Research*. Thousand Oaks, Sage, 784 p.

EVANS, D. 2011. The internet of things how the next evolution of the internet is changing everything. Cisco Internet Business Solutions Group (IBSG). Available at: http://www.cisco.com/c/dam/en_us/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf. Accessed on: March 12th, 2018.

EVANS, D. 2012. The Internet of Everything: How More Relevant and Valuable Connections Will Change the World. Cisco Internet Business Solutions Group (IBSG). Available at: http://www.cisco.com/web/about/ac79/innov/IoE.html. Accessed on: March 12th, 2018.

FORLIZZI, J.; ZIMMERMAN, J.; STOLTERMAN, E. 2009. From Design Research to Theory: Evidence of a Maturing Field. *Proceedings of the International Association of Societies of Design Research*, p. 1-10.

FRAYLING, C. 1993. Research in Art and Design. *Royal College of Art Research Papers*, **1**(1):1-5.

GIACCARDI, E. 2015. Designing the Connected Everyday. *Interactions*, **22**(1):26-31. https://doi.org/10.1145/2692982

GIBSON, J.J. 1977. The Theory of Affordances. *In:* R.E. SHAW; J. BRANSFORD (eds.), *Perceiving, Acting, and Knowing*. Hillsdale, Lawrence Erlbaum Associates, 504 p.

GIBSON, J.J. 1986. *The Ecological Approach to Visual Perception*. Houghton Mifflin, Boston, 332 p.

GONZALEZ, S.J.; BETTIGA, D.; SHAO, J. 2014. Crowdfunding: A New Meaning for Fundraising & User Innovation. *In:* DMI: Academic Design Management Conference, 19, London, 2014. *Proceedings…* London, p. 2683-2709.

HASSENZAHL, M.; TRACTINSKY, N. 2006. User-experience Research Agenda. *Behavior & Information Technology*, **25**(2):91-97. https://doi.org/10.1080/01449290500330331

HERSTATT, C.; VON HIPPEL, E. 1992. From Experience: Developing New Product Concepts via the Lead User Method: A Case Study in a "Low-Tech" Field. *Journal of Product Innovation Management*, **9**(3):213-221. https://doi.org/10.1016/0737-6782(92)90031-7

IOT DESIGN MANIFESTO. 2016. Available at: iotmanifesto.org. Accessed on: March 12th, 2018.

JENKINS, H. 2006. *Convergence Culture: Where Old and New Media Collide*. New York, NYU Press, 308 p. https://doi.org/10.1145/2559206.2578879

JENKINS, T.; BOGOST, I. 2014. Designing for the Internet of Things. *In:* Annual ACM Conference on Human Factors in Computing Systems – CHI EA '14, 32 Toronto. *Proceedings…* CHI EA '14, Toronto, p. 731-740.

KOLKO, J. 2011. *Thoughts on interaction design*. Amsterdam, Morgan Kaufmann Elsevier, 121 p.

KRANZ, M.; HOLLIES, P.; SCHMIDT, A. 2010. Embedded Interaction: Interacting with the Internet of Things. *IEEE Internet Computing*, **14**(2):46-53. https://doi.org/10.1109/MIC.2009.141

KRISHNA, G. 2015. *The Best Interface Is No Interface: The Simple Path to Brilliant Technology.* Upper Saddle River, New Riders Publisher, 256 p.

KUNIAVSKY, M. 2010. *Smart Things: Ubiquitous Computing User Experience Design*. San Francisco, Morgan Kaufmann Elsevier, 336 p.

LATOUR, B. 1996. On interobjectivity. *Mind, Culture, and Activity*, **3**(4):228-245. https://doi.org/10.1207/s15327884mca0304_2

LATOUR, B. 1999. *Pandora's Hope: Essays on the Reality of Science Studies*. Cambridge, Harvard University Press, 324 p.

MANN, S. 2003. *Mediated Reality: A Special Issue of the International Journal of Human-computer Interaction*. Boca Raton, CRC Press, 112 p.

MANZINI, E. 1990. *Artefatti, verso una nuova ecologia dell'ambiente artificiale.* Milano, Domus Academy Edizioni, 192 p.

MCLUHAN, M. 1964. *Understanding Media*. *The Extensions of Man.* New York, McGraw-Hill, 359 p.

NORMAN, D.A. 2004. *Emotional Design: Why We Love (or Hate) Everyday Things*. New York, Basic Civitas Books, 257 p.

NORMAN, D.A. 2010. Natural User Interfaces are Not Natural. *Interactions*, **17**(3):6-10. https://doi.org/10.1145/1744161.1744163

NORMAN, D.A.; DRAPER, S.W. 1986. *User Centered System Design*. Boca Raton, CRC Press, 544 p. https://doi.org/10.1201/b15703

NORMAN, D.A.; VERGANTI, R. 2014. Incremental and Radical Innovation: Design Research vs. Technology and Meaning Change. *Design Issues*, **30**(1):78-96. https://doi.org/10.1162/DESI_a_00250

STINSON, L. 2014. This Is What Smart Kitchen Gadgets Should Look Like. Available at: www.wired.com/2014/05/this-is-what-smart-kitchen-gadgets-should-look-like. Accessed on: March 12th, 2018.

SUTTON, T. 2014. Invisible Applications. UX Design without GUIs. Available at: https://medium.com/@thomas_thinks/invisible-applications-10501f6cfa5. Accessed on: March 12th, 2018.

THINGK.DESIGN. [n.d.]. Available at: http://thingk.design/. Accessed on: March 12th, 2018.

TURKLE, S. 2012. *Alone Together: Why We Expect More from Technology and Less from Each Other*. New York, Basic Books, 384 p.

VAN OOST, E.; VERHAEGH, S.; OUDSHOORN, N. 2009. From Innovation Community to Community Innovation: User-initiated Innovation in Wireless Leiden. *Science, Technology, & Human Values*, **34**(2):182-205. https://doi.org/10.1177/0162243907311556

VERGANTI, R. 2009. *Design-Driven Innovation. Changing the Rules of Competition by Radically Innovating What Things Mean*. Boston, Harvard Business Press, 288 p.

VITALI, I.; ARQUILLA, V.; TOLINO, U. 2017. A Design Perspective for IoT Products. A Case Study of the Design of a Smart Product and a Smart Company Following a Crowdfunding Campaign. *The Design Journal*, **20**(sup1):S2592-S2604.

VON HIPPEL, E. 1976. The Dominant Role of Users in the Scientific Instrument Innovation Process. *Research Policy*, **5**(3):212-239. https://doi.org/10.1016/0048-7333(76)90028-7

VON HIPPEL, E. 1986. Lead Users: A Source of Novel Product Concepts. *Management Science*, **32**(7):791-805. https://doi.org/10.1287/mnsc.32.7.791

VON HIPPEL, E. 1988. Lead User Analysis for the Development of New Industrial Products. *Management Science*, **34**(5):569-582. https://doi.org/10.1287/mnsc.34.5.569

VON HIPPEL, E.; VON KROGH, G. 2003. Open Source Software and the "Private-Collective" Innovation Model: Issues for Organization Science. *Organization Science*, **14**(2):209-223. https://doi.org/10.1287/orsc.14.2.209.14992

YANG A.; REBAUDENGO, S. 2014. When Objects Talk Back. Design Mind. Available at: http://designmind.frogdesign.com/2014/10/when-objects-talk-back. Accessed on: March 12th, 2018.

Submitted on March 23, 2018
Accepted on June 26, 2018