SOCIOTECHNICAL
ENVIRONMENTS

PROCEEDINGS OF THE 6TH STS ITALIA CONFERENCE 2016

EDITED BY
STEFANO CRABU
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Interaction Matters. A Material Agency's Perspective on Materials Experience

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Materials are not inert substances. They can act, change, behave. It is acknowledged by both the Materials and Design community and the Human–Computer Interaction community, which recently are merging their interests into the engagement of users with physical matter, through the experiential qualities of materials. Taking into consideration the fundamental role of materiality in the definition of the product experience, the concept of Materials Experience emerged. Nevertheless, since it is restricted to a human–centered view, the framework of Materials Experience does not contemplate the relations between non–human subjects, i.e. the interaction between the materials and other artifacts, substances, organisms, and environments. The concept of material agency in non–human relations might offer a new perspective to Materials Experience.

Recently, materials with a high degree of interactivity are emerging, showing unusual properties and establishing unique relations with users, designers, artifacts, environments. They are connected, computational, augmented, smart, self–healing, aging, and growing materials. A selection of best practices and case studies is presented, highlighting their involvement in non–human relations. As a result, we propose an expansion of the framework of Materials Experience and a paradigm that highlight the autonomous, provoked and interpreted components of materials agency.

***Keywords**: Materials experience; ICS materials; material agency; non–human relations; interactive materials*

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Introduction

Materials are not inert substances, but entities able to act, change, behave, i.e. they have ‘Material Agency’. They also influence the experience that people have with artifacts through ‘Materials Experience’. Nevertheless, the notion of Materials Experience appears to explicitly consider only relations between human and non–human entities, i.e. between people and the materials. It does not contemplate the role of material agency in establishing non–human relations between the materials and other non–human entities. In this paper, we focus on expanding the framework of Material Experience through the lens of Material Agency in non–human relations, and on identifying a paradigm that considers the role of material agency in defining the autonomous, induced and interpreted components of Materials Experience.

In state of the art, we introduce the most relevant theoretical contributions about the topic, and we address the research question: *how is the Materials Experience framework influenced by materials agency in non–human relations?*

To answer, we examine examples and case studies of interactive materials. We use the term ‘interactive materials’ with a broad meaning, including not only computational, electronic, and digital materials, but all the materials that can establish a two–way exchange of information with other human and non–human entities.

As a result, a paradigm arises, and an expansion of the Materials Experience framework is proposed and discussed. This early investigation relates to a research project about the relation between design, materials, and interaction, also referred as ‘ICS_Materials’, i.e. interactive, connected and smart materials (Rognoli, Arquilla and Ferrara, 2016).

State of the art

In the panorama of design, materials are a fundamental element of products. In the last 30 years, scholars moved their attention from technical properties of materials to the sensorial and experiential qualities of them (Ashby and Johnson, 2002; Cornish, 1987; Karana, Pedgley, and Rognoli, 2014; Manzini, 1986; Rognoli, 2010). Nowadays it is known that material not only needs to meet practical demands. It also offers intangible features that captivate people’s appreciation and that affect the experience of an artifact beyond its functional assessment. In a few words, these can be called 'intangible characteristic of materials' (Karana, Hekkert and Kandachar, 2007; 2010), 'intangible sparks' (Karana, Pedgley and Rognoli, 2015), and 'expressive–sensorial characteristics' of materials (Rognoli, 2010).

Since materiality contributes to the definition of Product Experience (Desmet and Hekkert, 2007) the concept of Materials Experience arises as 'the experience that people have through and with the materials of an artifact' (Karana, 2009; Karana, Pedgley and Rognoli, 2014; 2015). In its very first definition, Materials Experience has been framed in a framework of intertwined and interdependent layers:

- the sensorial experience, related to how user senses materials. *We find materials cold, shiny, etc.*
- the affective experience, related to emotions elicited by the material. *Materials cause us to feel surprised, bored, etc.*
- the interpretive experience, related to the meanings evoked by the material. *We think materials are modern, cozy, etc.*

Materials Experience arises autonomously and is interpreted subjectively by people. Nevertheless, when designing a material or embodying it into an artifact, the role of designer appears to be fundamental in understanding, envisioning, and creating the Materials Experience, to provide meaningful material and product experiences to users.

Similarly, Human–Computer Interaction (HCI) community is moving its interests toward interaction and experience with materials. After having focused its investigation on the dematerialization of technologies, it is re–valuing the importance of the sensorial involvement of the user with physical matter. It is demonstrating interest towards materiality of devices, interactive artifacts, and tangible interfaces, promoting the notion of 'material turn' (Robles and Wiberg, 2010), 'material move' (Fernaeus and Sundström, 2012) and 'material lens' (Wiberg, 2014). It would be helpful to mention the research projects and studies by Anna Vallgårda about 'Computational Composites' and 'Material Programming' (Vallgårda, 2015; Vallgårda and Redström, 2007; Vallgårda and Sokoler, 2010; Vallgårda et al., 2016), Vasiliki Tsaknaki and Ylva Fernaeus about imperfection in HCI (Fernaeus et al., 2014; Tsaknaki and Fernaeus, 2016; Tsaknaki, Fernaeus and Schaub, 2014), Daniela Rosner (Ikemiya and Rosner, 2013; Rosner and Ames, 2014; Rosner and Taylor, 2012; Rosner et al., 2013) and Holly Robbins, Patrizia D'Olivo, and Elisa Giaccardi (Giaccardi et al., 2014; Robbins, Giaccardi and Karana, 2016; Robbins et al., 2015) on the topic of aging and of traces, Jenny Bergström about 'Becoming Materials' (Bergström et al., 2010) and the research of Hiroshi Ishii on 'radical atoms' (Ishii et al., 2012).

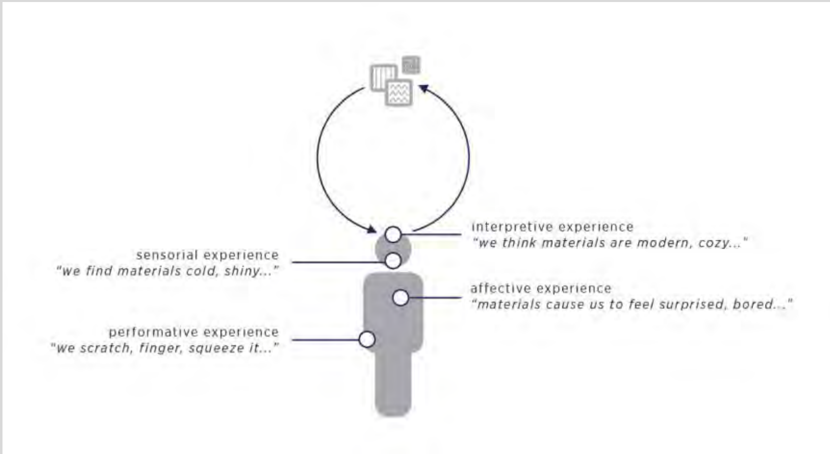

Figure 1 A conceptual framework of the levels of Materials Experience according to Karana and Giaccardi's definition (2015).

According to HCI notions and focusing on the interaction between people and things, the framework of Material Experience was recently extended by Giaccardi and Karana (2015), by adding a new level. This level is named 'performative experience' and acknowledges the active role of materials in shaping *ways of doing*, physical actions and practices. *We scratch, finger, squeeze it, etc.* (fig. 1).

The introduction of this level in the framework of Materials Experience opens to considerations on materials as a part of social and cultural practices. Indeed, this leads to a shift for designers from considering individual relationships between people and material artifacts to a whole experience, where the experiential qualities of materials allow encounters, performances, and social practices. Designers should anticipate, envision, and create a situation in which desired practices may arise and people may assimilate the material artifact, and its behavior, into their ongoing performances (Karana et al., 2016). Through this, materials are 'co–performers' of practice with people in the 'socio–ecological context' (Robbins et al., 2016).

Giaccardi and Karana's contribution to Materials Experience grounds on a non–anthropocentric or 'thing–centered' approach to design (Cila et al., 2015; Giaccardi et al., 2016), which considers the human as an element in a broader system of relations between humans and non–humans, and non–humans playing an active role in action and experience. This perspective takes into consideration the notion of agency, that, according to Karana and Giaccardi, is not the attribution of intentionality to materials, but the acknowledgment of how humans and materials interact relationally in a productive entanglement and a mutual relation. According to Giaccardi and Karana (2015) 'neither people nor objects, but instead the mutual interaction between people and objects, gives rise to particular materials experiences.' Agency is the result of the relation between human agency, i.e. the ability and power of people to control, shape and use materials on their purpose, and material agency, i.e. the power of the non–human entities to facilitate, suggest, provoke or prevent actions. This position on the argument about where agency is situated states that agency is neither only in human nor only in material, but in both of them and in the relation between them. This is close to the positions of many authors as Merleau–Ponty (1962), Dewey (1980), Miller (1987), and on the 'theory of imbrication' (Taylor, 2001) and of 'diffused agency' (Gell, 1998).

We can state that the concept of Materials Experience grounds on the relationship between humans and non–humans. On the contrary, the concept of Agency implies also non–human relations and social interactions without the presence of human actors (Latour, 2005). As a matter of fact, 'Agency is often understood simply as the ability to act. The agent is someone, often recognized as a subject, who can undertake action' (Borgerson, 2005). The material agency is the capacity for non–human entities to act on their own, apart from human intervention (Leonardi, 2011).

From these observations, we raise a research question. *How is the Materials Experience framework influenced by materials agency in non–human relations?* To answer this question, we introduce a list of classes of interactive materials. In these materials, non–human relations through materials agency are evident. Observations on their behaviors, properties, and performances could bring to insights to answer the research questions.

Classes of interactive materials

We selected a list of interactive materials that can establish non–human relations, communicating and exchanging data with other non–human entities, i.e. other materials, technologies, artifacts, organisms and the environment. We use the term 'interactive materials' with a broad meaning, including not only computational, electronic, and digital materials, but all the materials able to respond and establish a two–way exchange of information with other entities, influencing each other, through chemical, mechanical, electronic, and biological means. Among these materials, there are both conventional and low–tech materials, and emerging and technological ones. These materials are described in an order based on traditional classification by literature. For each of these classes of materials a description of their peculiar properties, thanks to which they can relate to non–human entities, will be provided, and examples of applications and experimentations will be described through best practices and case studies. To answer the research question, we examined the physical and temporal behaviors of these materials, their properties, and performances, highlighting their materials agency in non–human relations and considering their autonomous, induced, and interpreted components.

Aging materials

'Aging' is the natural dynamic behavior of materials due to environmental factors. It is a process that changes the physical and chemical structure of substances through time, or a whole of physical–chemical phenomena that alter properties of materials, according to specific mechanisms related to material properties. From a technical and engineering perspective, the measurement of aging and degradation is a conventional practice to define durability of materials. Durability is described as the conservation of physical and mechanical characteristics of materials and structures, and as the capacity to last through time resisting to aggressive actions of the environment, without degradation (Ostuzzi et al., 2011).

Some materials, more than others, have peculiar and unique ways to age that are evident and expressive, like patina, i.e. copper oxidation (Fontanille, 2002). *Stain Cups* are partially glazed ceramic cups by Laura Bethan Wood (www.bethanlaurawood.com/work/stain) that create a relation with the drink they contain by absorbing it in some portions of the surface, changing color through time and revealing a designed pattern. *Verderame* by Odoardo Fioravanti (www.fioravanti.eu/project/verderame) is a set of copper tiles that due to oxidation shows through time a graphic pattern.

This kind of behaviors is slow, difficult to control and to design by the human, because latent in the material and subjected to the randomness of environmental factors. Some contemporary designers have decided to embrace materials aging, by giving value to the mutations of materials provoked by time and by environmental factors and designing a graceful manner to age (Rognoli and Karana, 2014).

Figure 2 The materials of Sui Bag are able to interact with the environment with two contrasting behaviors and qualities. Master thesis project by Giulia Ardenghi, supervisor: Valentina Rognoli (Ardenghi, 2014).

Smart materials

'Smart materials' is an expression used to identify functional materials that have changeable properties, and that can reversibly change some features like shape or color in response to a physical or chemical influence, e.g. light, temperature or the application of electric field. Some of these materials are shape memory alloys, thermochromic and photochromic polymers, photoluminescent materials (Addington and Schodek, 2005; Cardillo and Ferrara, 2008; Ferrara and Bengsiu, 2013; Ritter, 2006; Rognoli, 2015). This behavior is designed, reversible, very fast in its manifestation, and repetitive.

A case study is *Sui Bag* (Ardenghi, 2014; Rognoli, 2015). Sui Bag is a project that aims to manifest the qualities of the interactive behavior of smart materials in contrast with aging materials. It is a bag conceived as a personal object accompanying the owner in daily life. Due to its materials changing over time, it elicits in the user the awareness of the incapability of controlling and predicting its changes. The concept of the bag is based on the difference of reaction to the passing time of the inner and of the outer parts of the bag, thanks to the use of two different materials. The first one, leather (Tsaknaki, Fernaeus and Schaub, 2014), is slow and irreversible. The second one, a photochromic smart yarn, is fast and reversible. The outer part was realized in vegetable–tanned leather, which ages and lasts over time, recording and accepting in an irreversible manner all the alterations, evidence, traces and imperfections due to the passage of time. Through this, it enables a slow and continuous mutation of the artifact itself. On the contrary, the inner part of the bag changes over time in a rapid and reversible manner, eliciting temporary changes, thanks to the use of photochromic materials, i.e. smart materials able to change their chromatic optical properties according to light exposure. The final design solution of the bag can interact with the environment by receiving an irreversible and slow accumulation of traces and patina, and temporary and quick color alterations (fig. 2).

Self–healing materials

'Self–healing' or 'self–repairing materials' are synthetic substances with the ability to automatically repair any damage to themselves without an external diagnosis of the damage or human intervention. In contrast to conventional materials that degrade over time due to fatigue, environmental conditions or damages, self–healing materials counter degradation through the initiation of a repair mechanism that responds to micro–damages. This healing mechanism varies from an intrinsic repair of the material to the addition of a repair agent contained in a microscopic vessel inside the material structure. Self–healing materials cover all classes of materials, i.e. metals, ceramics, concrete, but the most common types are polymers and elastomers. In some cases, the healing process activates in response to an external stimulus, i.e. light, temperature change. One example of these materials is a self–healing Concrete developed by TU Delft (www.citg.tudelft.nl/en/research/projects/self–healing–concrete) able to repair its cracks, by embedding calcite–precipitating bacteria in the concrete mixture.

Augmented, computational and connected materials

Nowadays and even more in the future, computation surrounds us in our daily lives. Technologies are unobtrusive and seamless, almost disappearing. Thanks to the embedment of technologies and computers, materials can obtain the ability to act and to interact not only with users but also with other objects or with the environment, i.e. *machine–to–machine* behavior. The term 'augmented materials' (Razzaque, Delaney and Dobson, 2013) denotes a family of materials with general physical and computational properties, in which electronics are seamless and embedded during the fabrication of the material. Similarly, the term 'computational composites' (Vallgårda and Redström, 2007) identifies composite materials in which at least one of the components has computational capabilities. This definition acknowledges computer as a material, with specific computational properties, which might be included in a composite material to become useful in design. In a similar way, due to the diffusion of 'Smart Objects' and the 'Internet of Things' (Giaccardi, 2015; Kuniavsky, 2010), 'connected materials' that might act through a *machine–to–machine* behavior might emerge. Specifically, one of the aims of the *ICS_Materials* research project (Rognoli, Arquilla and Ferrara, 2016) is to investigate on this class of materials and develop a definition, framework, and strategies for them. Thanks to sensors and actuators, these materials can have a broad range of behaviors and qualities that should be decided at first stage by designers through 'material programming' (Vallgårda et al., 2016).

Growing materials

'Growing materials' are living materials or composite materials based on living organisms that use the growth of their living substrate, e.g. bacteria, microbes or fungi, as manufacturing and shaping process, i.e. 'Biodesign' (Van Der Leest, 2016; Myers, 2012). This definition covers a broad range of materials. The designer of *SuperOrganism* (www.uovodesign.com) established a close collaboration with bees in the manufacturing of small artifacts and packaging. They are made of beeswax and propolis, by providing a shape suggestion, and letting the bees build the artifact. *Bicouture* (www.biofabricate.co) is a leather–alike material obtained by bacterial cultures.

A case study is *A Matter of Time* (Parisi, 2015; Parisi, Rognoli and Ayala, 2016). A Matter of Time is a research and experimentation project on a growing material based on mycelium – also known as the roots of mushroom – and a natural substrate made of agricultural waste fibers. The project aims to understand, exploit, and implement the inner and spontaneous mechanism of growing of the material. Its manufacturing and shaping process is based on the growing of mycelium that acts as a binding agent to the natural substrate, inside a mold, for several days. The only task for the designer is to assist the material during its growing stages, e.g. by preparing a proper environment for the material to grow. Since it is a living organism, it is spontaneous, and it is not possible to have full control of it during its growing, bringing each time to different results (fig. 3).

Figure 3 The project a Matter of Time explores the potentialities of mycelium–based growing materials highlighting its spontaneity and autonomy. Master Thesis project by Stefano Parisi, supervisor: Valentina Rognoli (Parisi, 2015).

Other materials

Finally, other materials show interactivity without being part of the previous categories. One example is *Transformative Paper* by Florian Hundt, a layered structure, that reacts to environmental conditions by changing its shape thanks to the anisotropic properties of moisture expansion of papers.

Results and discussion

Although these classes of materials appear to be very different and with their own characteristics and behaviors, observing them it is possible to identify a common paradigm.

- First, the human entity sets the beginning of the process by programming, guiding or facilitating the material in its action.
- Then, the non–human entity – both the material and the environment or other non–human entities – expresses itself as actant and produces a result thanks to a latent performative pattern, which is partially innate and partially induced by the human entity.

- Finally, this behavior and its effect are perceived and interpreted by people, i.e. a human entity that have experience of it as observers.

It is evident that when designing a material or embodying it into a product, the designer's vision for the desired Materials Experience manifests through experiential qualities of the material, as well as technical properties. With interactive materials, it expresses also through the qualities of their dynamic and active behavior, in particular through their non–human interrelations. By materializing their vision of materials experience, designers transfer a set of values, beliefs, aspirations, and ideas into the materials, and, through the materials, they communicate them to society. This observation is connected to the metaphor of technology–as–text (Joerges and Czarniawska, 1998). Designers exploit the inner dynamic mechanisms of materials to convey a vision that reveals itself through the qualities of their active behavior. Materials tell us something through changes and traces. 'If no trace is produced, they offer no information to the observer and will have no visible effect on other agents. They remain silent and are no longer actors: they remain, literally, unaccountable' (Latour, 2005). Through changes and traces materials express themselves, as well as people that produced them and that use them do (Parisi and Rognoli, 2016; Robbins, Giaccardi and Karana, 2016; Robbins et al., 2015; Tsaknaki and Fernaeus, 2016).

Thus, the physical and temporal behaviour of materials and the results have peculiar features that influence the material experience. Thanks to this observation we propose to expand the framework of Materials Experience by adding another level that demonstrates the relevance of material non–human interactions in the creation of the Materials Experience. The level of Materials Experience here proposed answers to the following questions: 'How do the materials interact with the environment and other things? In which manner and with which behavior? Which are the results?' (fig. 4).

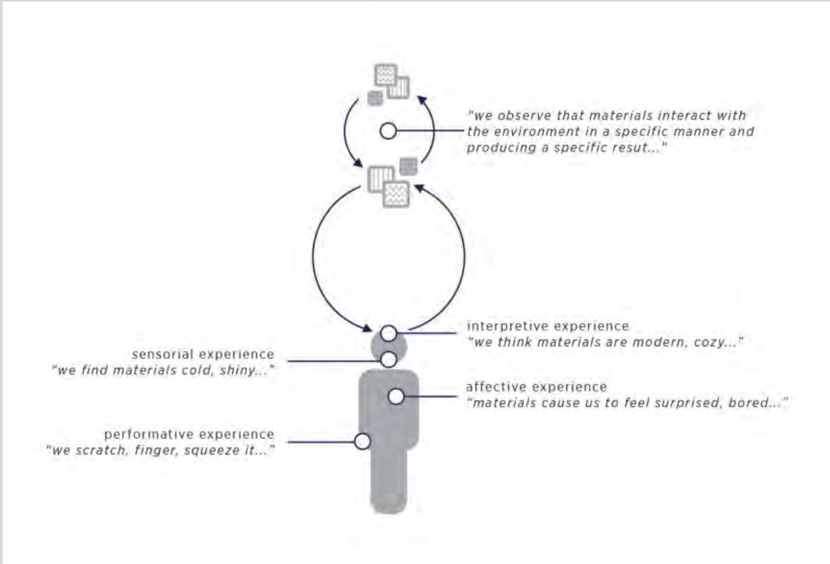

Figure 4 A proposal for expanding the Materials Experience framework by adding a level related to non–human relations of active materials.

Observing the described classes of materials, we can state that they have different behaviors and results and that we might identify a range of qualities characterizing them. These qualities are related to diverse criteria that need to be further investigated and classified:

- the speed of action
- the regularity or irregularity of actions
- the reversibility or irreversibility of mutation
- the predictability or unpredictability of actions
- fuzzy behaviors
- the repetition
- the autonomy of automatism of action
- the modality of transformation and expression, e.g. stratification, reduction, movement, sound, light, etc.

Although with interactive materials all these observations appear very evident, they may also be applied to conventional materials with a lower degree of interactivity.

In addition, we argue that it may be required to rename the levels of materials experience to make it more clear and consistent with classical terminology and avoid misunderstanding, introducing the term 'aesthetic' instead of 'interpretative', and the term 'aesthesic' instead of 'sensorial'.

Finally, observing the paradigm, it is evident that matter is active, but cannot be independent of human intervention and interpretation. In particular, the designerly intentionality of humans appears to have the fundamental role of giving a purpose to the actions of non–human entities – by programming, designing, guiding and facilitating – transforming active matter into purposeful and specialized interactive materials, through the design process. As Manzini (1986) stated, 'matter becomes material when it is included in a design project and becomes part of a product.'

Conclusions

The aim of this research was to investigate how materials agency in non–human relations influences the framework of Materials Experience. To answer, we considered interactive materials, i.e. emerging and traditional families of materials that have the ability to establish non–human relations with other substances, organisms, and environments. These families of interactive materials were described including best practices and case studies of research projects, highlighting the different types of material behaviors, their qualities, and the results of interactions.

As a result, we identified a paradigm that puts human and non–human entities in relations, and an expansion of the Materials Experience framework, by considering non–human interactions of materials and how people perceive them through their qualities. This new experiential level, its qualities, and the paradigm need to be further developed and studied in the in the scope of the *ICS_Materials* research.

Furthermore, it contributes to the *ICS_Materials* research project examining some case studies of materials through the lens of Material Agency and Materials Experience.

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