DIGITALLY ENHANCED DESIGN

Breakthrough tools, processes, and expressive potentials

edited by Maurizio Rossi and Davide Spallazzo

D.I. FrancoAngeli DESIGN INTERNATIONAL OPEN ACCESS

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Contents

6. From smart materials to Animate Objects. Reframing smartness through behavior exploration

Marinella Ferrara, MADEC, Department of Design, Politecnico di Milano
Alessandro Squatrito, Alessandro Squatrito Design

Abstract

Today, a new class of materials and objects are entering our daily lives, giving interest in smart devices research and robotics in our societies. As a result, we are experiencing a renewed interest in "material agency" and the reconfiguration of our environment through the hybridization of physical matter and digital performance.

The purpose of this paper is to highlight the research direction of MADEC - the Material Design Culture Research Center in the Design Department of the Polytechnic University of Milan - on the *phygital* evolution of product design and the design implications of *animate objects*, which we will define. Since technology has allowed the transition from graphic interfaces to shape-shifting ones, designers are experiencing new challenges. We frame the topic of smart evolution of objects through the existing literature, and investigate issues like their new features, behaviors, and aesthetic implications. Then we analyze a few case studies to stress the fundamental aspects to consider when approaching the design of animate objects.

We believe it is time to strengthen design-led research on behavior of animate objects. Their qualities cannot be detached from design aspects inherent to their tangibility during interaction, such as form in time and expressiveness. These aspects shape users' behaviors in terms of new functions as well as cultural, social, and ethical dimensions that are at the basis of collective meanings and values.

6.1 The new *phygital* materiality

Materials, one of the fundamental elements of design culture (Manzini, 1986; Raimondo, 2006; Ferrara, 2017), have today acquired new importance in qualifying the intelligence of artifacts.

Recent advancements in the materials field - rapid manufacturing, electronics miniaturization, computational tools, programmable matter, modular micro-robots, and integration - are introducing new design variables, enabling researchers not only to apply advanced materials but also to conceptualize, program, develop, and then use new smart material systems.

Conventional materials (fabric, plastic films, leather, wood, etc.) tightly integrated with interactive technologies (sensors and actuators; connection modules; inexpensive, small microprocessors, etc.) have given birth to, what we define as, a new *phygital materiality* (phygital comes from physical + digital), which in a previous study we named "ICS-Materiality", where ICS stands for interactive, connected, and smart (Ferrara *et al.*, 2018).

Mainly applied in robotics, smart material systems affect the design of new artifacts thanks to their abilities to sense, actuate, and perform local computing, as well as their communicating elements (McEvoy and Correll, 2015). Moreover, these materials have been shown to have a certain intelligence and autonomy, as well as a special formal performance, i.e., the ability to change shape and appearance and thereby impact applied research, generating "Shape-changing Material Interfaces" (Coelho and Zigelbaum, 2011). This ability generates an effect that, if it not the same it is at least comparable whit what in context of the performance art, dance and theater has been defined "digital performance" (Dixon, 2007, p. 3), i.e. a performance where technology «play a key role […] in content, techniques, aesthetics, or delivery forms».

The phygital materiality with its behaviors, i.e., its diverse forms in temporal and spatial structures, has a fundamental role in "material agency"[1] (Van Oyen, 2018) as an active player in the interactive

[1] The concept of agency is vital to understanding the productive nature of material-discursive practices, including technoscientific ones.

process. Agency is not a property of each user, and neither is it a pre-given property of an artifact or material. It doesn't merely depend on material and sensorial qualities either; rather, agency is an emergent relationship from the unfolding of transactions between humans and object materiality (Tholander *et al.*, 2012), for instance in the case of "Ultra-Surfaces" developed by a MADEC team (Ferrara and Pasetti, 2020). Ultra-Surfaces ability to perform dynamic behaviors while interacting depends on their phygital materiality, applied in specific configurations. It appears that they have a form of agency that allows them to achieve a certain goal while developing closer relationships with users. The user's actions and the object's materiality together contribute to a unique relational experience.

We consider this particularly important for what we will examine in depth later: the behavioral and animacy aspects of *animate objects*.

6.2 The discourse on objects' smartness

Since computing and the digital revolution entered everyday life in the late 80s, concepts such as "ubiquitous computing" (Weiser, 1993), "internet of things" (Ashton, 2009), and SPIMES (Sterling, 2005) have stimulated reflection on scenarios about features of spaces and artifacts. Recently, Mike Kuvniasky (2010) has talked about "smart things", things that are embedded with smartness or intelligence, identification, automation, monitoring, and controlling functions.

In the industrial design community, the issue of objects' evolution has been faced by the scholars Ezio Manzini (1990) and Giovanni Anceschi (1993), who added to the literature on "Ambient Intelligence" (Aarts and Marzano, 2003).

While Manzini developed a theoretical reflection on "cognitive artifacts" (1990), Anceschi (1993) developed a reflection on interfaces. For Manzini and Anceschi, the fundamental transformation affecting design is the entry of the fourth dimension: time. According to Manzini (1990), to design the interactivity means

dare al tempo il valore di parametro organizzatore [...] occuparsi dell'interattività significa dunque avventurarsi su un territorio del tutto nuovo, i cui riferimenti

culturali vengono [...] dal cinema, dal teatro, dalla musica: da attività, cioè, in cui la qualità si produce organizzando sequenze di eventi (Manzini, 1990, p.140).[2]

Together with time, Manzini identifies another relevant characteristic: «il modo in cui gli attori coinvolti nella generazione dell'evento collaborano per raggiungere il risultato previsto»[3]. This vision seems to us to successfully frame the concept of agency as an emergent relationship from transactions between humans and objects.
The Ambient Intelligence vision emphasized the qualitative features of sensitive, responsive, intelligent scenarios in order to support the design of user-friendly and unobtrusive artifacts for humans in their everyday lives, offering at the same time a more fulfilling user experience. Similarly, the literature on "Calm Technology" (Weiser and Brown, 1997) has contribute to spread an approach to humanly fit technology.

In the late 80s, the HCI and Interaction designers community began to address interactivity by focusing firstly on technical aspects and then on usability. Recently, several authors have shifted their focus toward an "aesthetics turn". The contribution of Donald Norman (2002)[4] is one of the most incisive in overcoming the paradigm of efficiency and functionality by including reflections on usability and also emotions, feelings, relationships, and psychological and semiotic aspects of objects and their behaviors, all as elements that improve usability.

The current "material turn" in interaction (Robles and Wiberg, 2010), related to material interfaces, has accelerated a return to basic design (Hallnäs, 2011) as well as a move toward "pragmatic aesthetics". The latter allows researchers to focus on the aesthetics of behaviors, the finality of design, and new artifacts (Russo and Ferrara,

[2] Translation: «giving time the value of organizing parameter [...] dealing with interactivity means therefore venturing into an entirely new territory, whose cultural references come [...] from cinema, theater, music: from activities, that is, where quality is produced by organizing sequences of events».
[3] Translation: «the way in which the actors involved in the generation of the event collaborate to reach the expected result».
[4] Norman states «attractive things make people feel good, which in turn makes them think more creatively. How does that make something easier to use? Simple, by making it easier for people to find solutions to the problems they encounter».

2017). In this scenario, we think it is time to strengthen design-led research on phygital design, because the quality of any object cannot disregard those design aspects inherent to their materiality, nor the cultural, social, and ethical dimensions that are at the basis of objects' meanings and values.

6.3 Animate objects: an attempt at definition

Coming from the Italian Design Culture that has developed in a strict interplay between humanities and technology, we choose to adopt the term *animate objects* for those emerging intelligent everyday objects that are able to perform behaviors thanks to their phygital materiality.

The adjective *animate* was first used by Anceschi in his previously cited book to describe the fundamental novelty of "colloquial objects" (p. 9), i.e. objects' «new ability to interact with us»[5] (Anceschi, 1993). Highlighting the phenomenon of new technical objects' status and abilities, Anceschi adopted a bio-constructive perspective, the same applied to the development of artificial intelligence with reference to the intelligence of nature. In line with this perspective, we also use the term "animate", which derives from the Latin *animat* and indicates something «alive or having a life»[6]. Already, in a previous study, we used the expression "almost-living objects" to define the same category of everyday objects implemented with emerging technologies. These are «capable to somehow interact with human beings, determining interesting connections and emotional responses in terms of what can be defined as a sub-branch of the applied aesthetics domain, smart aesthetics» (Russo and Ferrara, 2017).

With their "behavior", animate objects modify the relational space, modulating their connection by following users or other objects.

Through analyses of case studies, including those that we will present later on, we have identified and characterized animate objects

[5] Anceschi derived this term from anthropologist Franco La Cecla's (1991) neo-animist theory of objects.
[6] From the Oxford dictionary.

according to their main features. This allows us to highlight which aspects we believe must be taken into consideration when approaching their design.

- **Shapeshifting**
  This is the capability to change state and appearance thanks to phygital materiality. The activation of light signals, sounds, colors, temperature, movements, and even smells are changes that show the capability to respond to stimuli and interact.
- **Data processing**
  This is the capability related to the Internet and computational processes. Animate objects can, through the Internet, collect, process, and exchange data and information, affecting objects', and consequently users', behaviors.
- **Independence and pro-activity**
  A certain degree of independence and pro-activity contributes to animation. This is critical to shifting from a purely functionalist and passive view of objects' performing a specific function toward an active behavioral function view.

These capabilities contribute to objects' shaping, expressing, and performing behaviors, and stimulating responses to users or other objects which in turn can further influence users and stimulate new behaviors. These are the fundamentals for a smart experience and aesthetics.

6.4 The role of aesthetics in the design of animate objects

According to the designer Yves Béhar:

> aesthetics is the support of experience both from the appearance and the functional side of an object, driving one's eyes or hands toward the product so as to strengthen the temporal and structural logic of the project (Béhar, 2020, p. 234).

In the last decade, the scholar Lars Hallnäs (2011) has launched a proposal for a revision of the aesthetics of interaction at a fundamental level. He suggests taking a step back from the perspectives of experiential design and design for emotion, and to revisit the elementary notions of form and expression based on design fundamentals (form,

color, texture, sound, smell, and behavior), rather than focusing on behavioral and social sciences as is common in HCI. He relies on an approach that focuses on the "act of use", "interface", and «processes of learning how to use given things», with strong relation «function and interaction in space and in time». He defines the central design dimensions for the classification of interaction design variables as the following:

- Timing - the rhythm and meter of use we introduce.
- Spacing - the space of use we introduce.
- Connectivity - the connections of use we introduce.
- Methodology - the ways of use we introduce (Hallnäs, 2011).

Other scholars maintain a double focus on expression and experience, meaning the aesthetics of interaction remains somewhat different from the aesthetics of traditional product design (Petersen *et al.*, 2008). Thus, despite the abundance of studies, HCI has not yet been able to achieve a clear and convincing aesthetic perspective.

We believe that today it is essential to recover a basic design approach. We also believe that it is important to articulate a perspective capable of incorporating contributions from other disciplines to structure design purposes in terms of method and ethics.

Currently, one of the most respected perspectives on aesthetics is Richard Shusterman's pragmatism. Briefly, an "aesthetic experience" has a practical use as well as an intrinsic value. It «invigorates and vitalizes us and thus helps us achieve the ends we pursue» (Shusterman, 2000). It relates to a user's experiences and is linked to the sociocultural context because the meanings and values we attribute to objects constantly change as cultural groups change. It has an ethical and social dimension.

Form, which is "a dynamic interaction of elements" (Shusterman, 2008), is closely related to the aesthetic experience and is strongly linked to the body (its senses and movement) and the social conditions that helped structure it. Finally, Shusterman's "somaesthetics"[7] puts the body and its movements back at the center as fundamental parts of feeling and thinking (Shusterman, 2011). The human participates and structures the aesthetic experience with his body and mind.

[7] Somaesthetics combines the terms "soma" and "aesthetics".

These concepts are particularly relevant for the design of animate objects because they reveal the wide potential for interacting with them. Their shapeshifting in time makes them agents of "kinesthetic interaction" (Fogtmann *et al*., 2008), including multisensory stimulation and excitement, movability, implicit and explicit motivation, and empathic response related to the body. Emotional, affective, social, and cultural stimuli are added to the body stimulation process, leading to cognition, reasoning, and judgment.

6.5 The behavior of animate objects

In neuropsychology, behaviors are the externalizations of emotional processes, associated with bodily movement and certain orchestrations of reactions to given causes, within a given environment (Damasio, 2000). Regarding objects, behavior is related to action and reaction, to what happens in a particular context, and to a change of state or a movement in time that occurs in the object itself. We refer to behavior as an orchestration of dynamic sequences of physical movements or a change of state in the material world (in form, color, light, density, sound, etc.), making an explicit link between form and expression, the abilities to stimulate relationships with users and create specific experiences.

In biology, a behavior is a neural response that results in a stimulation of the senses and an effect on motor activity.

We can then define the behavior of an animate object as the production of transformations that we can observe and promote or that are implemented in response to an environmental change - but always self-generated toward a specific goal or as a reaction to an external event.

Animate objects are sources of change through their behavior according to a principle of intentionality, i.e., a design.

On the behavior of objects, there is also the recent literature on "behavioral objects" that connects art, robotics, and cognitive psychology to emphasize a double point of view: the agency of behavioral objects and the cognitive faculties of the observer (Bianchini *et al.*, 2016; Levillain and Zimbetti, 2017). Firstly, this focus recalls

anthropomorphism, i. e. the innate tendency to readily attribute formal and mental states (emotional, intentional, behavioral, etc.) to living and nonliving entities. Animate objects, having the ability to interact with the external world, suggest living-being-like (anthropomorphic, zoomorphic, or even plant-like) traits to an observer, as well as mental traits. When this happens, the relation of the user with the non-living entity manifests an affective state.

We believe that the behavioral characteristics of animate objects must be studied and designed in the light of physical variables that relate to changes of state (form, dimension, density, light and color effects, movement, etc.). There are already some guiding principles around this, for instance regarding movement.

The "12 Principles of Animation", which were developed by Walt Disney Studio in the 1930s (Johnston and Thomas, 1995), are still a valid tool for designing movement as transition from one shape to another, adhering to basic laws of physics as well as emotional timing and character appeal. More recently, Strohmeier *et al.* (2016) have explored the link between the shapes of a flexible surface and emotions, demonstrating that movement might be used to convey messages with emotional content. Similarly, design guidelines can be formulated for light and color shape changing.

Secondly, the behavioral focus recalls the human capability for signification and assignment, known as "attribution" and defined in social psychology as the faculty of being able to explain or infer a behavior (Malle, 2011). Through attribution, humans are able to accurately assign and predict certain psychological attributes to external entities which then determine specific social characteristics such as intention, motivation, and purpose.

At a deeper level then touching the affective aspects related to behavior, it is necessary to mention our tendency as observers to place ourselves in an empathic relationship with others, that is, our ability to understand and respond to the emotional states of other agents.

6.6 Exploring the behavior of animated objects: case studies

After defining animate objects and describing our thoughts on the existing literature, we move to the current scenario of research practices to analyze some case studies that fall under this new class of objects. The chosen case studies contain the features we previously identified. The projects were analyzed including interviews with the designers. We have reported on aspects such as the technologies and materials applied, the form and expressivity, the behaviors, as well as the designers' intentions and narratives. Moving beyond pure appearance, we have identified these objects as agents of smart aesthetic experiences, which include augmented perception, relational communication, and empathy (Russo and Ferrara, 2017).

6.6.1 Lift by the design studio Patten Studio, 2017

Let's take a close look at Lift[8] (Fig. 6.1) designed and produced by James Patten and his team. This is an interactive, heat-sensitive, motorless light feature consisting of 24 LED petals attached to a spine. Each petal embeds a microcontroller that receives data from one of six thermal imaging cameras (infrared sensors) in Lift's ceiling mount.

Lift is a good example of system design that applies a smart material (wires of Nitinol, a shape memory alloy commonly called *muscle thread*) and microelectronics jointly to consolidate materials (metals and polymers for the lamp body).

Moreover, it is a good example of smart aesthetics. This animate object has a high expressiveness, mediating animacy through its computational power and material performance. Lift's petals respond to human presence with a movement that looks more natural than mechanical in terms of fluidity and timing. Each petal works in a coordinated way with the others: it reacts to nearby people by fluttering slightly if someone walks beneath it or moving more dramatically in response to wild movements. In these instances, the closer petals move

[8] Lift received the Core77 Award 2017 in the Furniture & Lighting category.

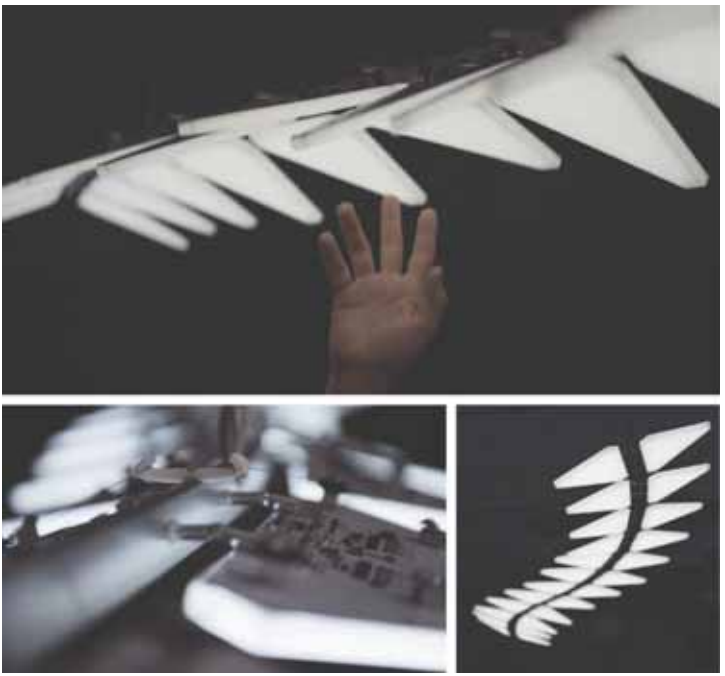

Fig. 6.1 - Lift, interactive light by Patten Studio. Courtesy Patten Studio.

away, as if communicating a feeling of fear. The long central spine of the lamp is composed of pieces like vertebrae, and extends smoothly and asymmetrically, like a snake, resulting in a fluid, organic-looking, and completely silent movement imbuing spaces.

With some of the richness, nuance, and immediacy - the same we would expect from the natural world. […] It will respond as long as those people continue to move around. If those people stop moving, it will gradually return to an idle state, even if they do not leave the room.

Essentially, Lift is seeing human activity by noticing changes in heat in space. […] Environments that acknowledge our presence within them help us to relax - to feel that we belong. Interactivity engages us, helping us to tune into our surroundings, embrace the present moment, and connect to the people we share physical space with (Patten Studio, 2021)[9].

[9] From the interview with James Patten.

In Lift's behavior, we recognize the will to engage the observer in a kinesthetic experience. The smooth shape of the spine from one side to another involves the observer under the petals, who follows the fluent curves and movement. Like a vegetal organism turning its head toward the sun, Lift orients itself toward the people entering its environment (Pattern Studio, 2017).

6.6.2 Opale by Behnaz Farahi, 2017

Opale is a shape-changing interface, also defined as an "emotive garment" (Farahi, 2018) (Fig. 6.2). The focus of this project is the dynamics of social interactions. Opale's behavior is based on its recognition of the basic human emotions that are considered universal and physiologically associated with facial expressions. We normally respond intensely to the expression of an onlooker by adapting our emotional expressions to others' (whether happiness, sadness, surprise, anger, or a neutral expression). This is a neuropsychological process led by mirroring neurons that works as a communication channel.

> The design challenge was to critically explore whether emotions expressed in our social interactions could be represented in a non-verbal way through the motion of a garment (Farahi, 2018).

In technical terms, Opal uses a facial tracking camera that captures the facial expressions of people around and a microcontroller to activate a mechanical system. It is equipped with a pneumatic actuation system capable of generating patterns and various inflation speeds to mimic emotions, thanks to small inflatable silicone pockets. On top of the pockets, thousands of thin fibers are embedded and move by following the pockets' expansions. The movement is inspired by the behavior of animal fur, to which the designer dedicated an attentive study so as to accurately decide the location and orientation of fibers and shape an effect not dissimilar to nature. Subsequently, the fiber distribution on the wearable surface was adapted to the biological structure of the human body and refined in density and weight to make the effect more realistic. The object's behavior-changing creates an aesthetic-emotional experience and influences the behavior of the observer.

Creating a system of exchange «the material then responds physically to the detected emotion in order to establish an effective loop with users» (Farahi, 2017 and 2018).

Fig. 6.2 - Opale by Behnaz Farahi, 2017. Courtesy Behnaz Farahi.

6.6.3 Pinokio by Shanshan Zhou and Adam Ben-Dror, 2012

Pinokio (Fig. 6.3) is an experimental attempt to transform a common artifact into an animated object by designing a behavior through movement. Designed by Shanshan Zhou and Adam Ben-Dror, an anglepoise-type table lamp uses a wide camera to track a user's movements, which are then transformed into the object's movements via a microcontroller. Conceptually, the two designers used body storming and role-playing to analyze and understand the object's possible movements. They then translated the desired behaviors into movements in the joints of Pinokio's arm using inverse IK kinematics[10].

The central concept is to explore if we can evoke empathy in humans when they interact with a machine. We wanted to subvert our "relationship" with a tool from being purely functional, to be empathetic and emotional instead. We wanted to

[10] This is a technique that uses trigonometry to define the spatial movement of multiple parts, commonly used in animation and robotics.

experiment and explore which type of interaction can help to develop a connection between a human and a machine (Zou and Ben-Dro, 2021)[11].

Fig. 6.3 - Pinokio, 2012. Courtesy Shanshan Zhou and Adam Ben-Dror.

Object and user find themselves equal, as the movement of one influences that of the other (Ben-Dro, 2012). The designers add:

> The behaviors we worked on were very simple, they are just enough to give you a sense that this character has some personality, and we didn't want to create a narrative because then it becomes deterministic and more like animatronics that plays a routine.
>
> We worked on simple behaviors such as curiosity (looking around randomly), research (looking for faces, and focusing on people's faces), shyness when people look at Pinokio too long (looks away, ducks down as if to hide), tiredness or boredom (looks down lazily), relaxing (turns off the switch, covers the switch). The key to this aliveness comes down to Pinokio's interaction with humans and the environment: a living creature that responds to random events in the environment (Zou and Ben-Dro, 2021).

[11] From the interview with Shanshan Zhou and Adam Ben-Dror.

6.6.4 Addicted Products, by Simone Rebaudengo with Haque Design + Research, 2012

The last project we are going to present explores gestures and the implication of animate objects being connected. Like in the case of Pinokio, Addicted Products (Fig. 6.4) applies technologies to common objects like toasters, lamps, etc. Using a microprocessor and an Internet connection, the objects become animated and capable of providing a service. The designer imagines a series of toasters connected to a network making decisions autonomously: sending the shopping list to the nearest store, communicating with each other by exchanging information about their use, and even deciding to look for a new user by posting a message on a social network, if they are not suitably used. The designer explains:

> People would apply to an online site for the opportunity to host a toaster, and then the objects themselves would decide where to live based on their perception of being used enough. By being connected their perception of being used, a sort of rudimentary happiness from an object's perspective, was influenced by all the other toasters in the network, creating a sort of peer pressure for objects. Based on their happiness I then programmed a series of behaviors, from a simple toggle movement to attract attention, to tweets to complain to the most extreme behavior for an object: breaking the user/object bond and asking a better user/object to leave and sending a messenger to take it to its new and potentially happier home (Rebaudengo, 2021)[12].

Addicted Products become social agents. Through the movements of the toaster, the user can assign an initial series of behavioral parameters to which are then added all the other relational capacities of the object that manage to influence, not only the nearby environment, but other agents (Rebaudengo, 2012).

[12] From the interview with Simone Rebaudengo.

Fig. 6.4 - Addicted Products by Simone Rebaudengo with Haque Design+Research, 2012. Courtesy Simone Rebaudengo.

6.7 Discussion

From the analysis of the case studies, taking into account the design intention, the user's involvement, and the context in which the objects act, a variety of aesthetic experiences emerge. The relational experiences between user and animate objects mainly refer to:

• The sensory-motion dynamic that happens when behavior primarily affects the senses and the body, stimulating perception, motion, and motivation.

• The sensory-emotion dynamic that overcomes the body stimulation with an empathic relation and emotions coming from the process of attribution, and mainly depends on the coordination of shape-changing in time and space.

• The cognitive-behavioral dynamic, which no longer concerns just the relationship with the object through motion, but also affects cognitive processes.

• The ethical dynamic related to sense-making and reasoning that arrive at ethical judgments.

The dynamics presented are actually various traits of the entire user experience, which contains sensory and ethical traits on opposite sides. In fact, the aesthetic experience is like a continuum in which those

dynamics are all present to different degrees, creating an impact at an emotional and a cognitive level, encoding new attitudes, feedback, gestures, and communicative issues.

A similar distinction can be made with regard to the spheres involved, namely the individual and the social.

In the individual sphere the process of adapting behaviors and the relational experience are primarily binary between users and objects and vice-versa. The social sphere involves multiple agents, both human and other animate objects. The process of adapting behaviors is no longer binary but relates to a wide network.

For instance, in the case of Lift and Pinokio, the aesthetic experience involves sensory-motor and sensory-emotion dynamics in the surrounding space, although in different ways.

Lift richly occupies the surrounding space with its presence and behavior, interacting with the observer, who is quickly emotionally caught up in the game between fluid forms and the coordinated time of movements. The kinetics of Lift is linked to that of people in the surrounding space. Each petal responds by moving according to the movement of the observers and reacting sequentially. The design of the long central spine sinuously accompanies the movement of the petals and distributes them within the space. Lift seems to understand and communicate emotions of happiness and fear through its petals' kinetic speed. Shapes and movements together recall natural organisms and provoke empathy in the user, who becomes almost a playmate.

Pinokio involves the user's personal space in a more invasive way, acting out a binary sensory-motor dynamics. The object, initially quiet, starts to move when turned on. Its kinetisms appear like a waking-up and then a seeking of an intimate relationship with the user, who is also influenced by the object's animacy. Moreover, Pinokio expresses curiosity about its user and even demands attention, modulating movements through its articulated arms and the rotation of its head. It extends and contracts, depending on the proximity of the user's face. Even in this case, shape-changings create an empathic response from a user who looks like a shy and curious playmate.

In the case of Opale and Addicted Products, a critical intent involves the body, mind, and society. In these projects the cognitive

dynamics seem to be stronger, and the involvement shifts from the individual sphere of a user toward a social sphere.

Emotions seen as social dynamics are the focus of Opale. The designer reflects on the effects of our unconscious facial expression and our body movements related to emotions and imagines a wearable appendix that can empathize with the onlookers.

Emotions are detected and expressed by the object, and through them, Opale involves the user and people around in a behavioral loop with their bodily reactions and, consequently, their minds. Movement depends on perceived emotions and their expression in turn influences movement again.

In the Addicted Products experiment, we recognize a strong ethical-social dynamic. In this project, the designer imagines a society in which there are self-motivated objects with independence, considering both the positive and problematic aspects. The objects' behavior consists in gesture-like movement able to communicate emotion to users, such as moving its lever frantically to complain. This makes objects capable of organizing themselves to respond to problems of consumption and circularity. The designer uses them to try to give an answer to a social and ethical problem, that of production and waste. We add a scheme to visualize the relational dynamics that characterize the aesthetic experience with animate objects referred to in the four case studies (Fig. 6.5).

6.8 Conclusions

Through the analysis of the aforementioned theories and case studies, it has been possible to define the new class of *animate objects* and characterize behavior as a new parameter for reframing objects' smartness in the ongoing process of *phygitalization* of our ambient.

Animate objects, with their capability for shapeshifting, processing data, independence, and pro-activity, express behaviors. These directly influence human behaviors, including our perception, attention, motivation, and, in general, our decision-making capabilities.

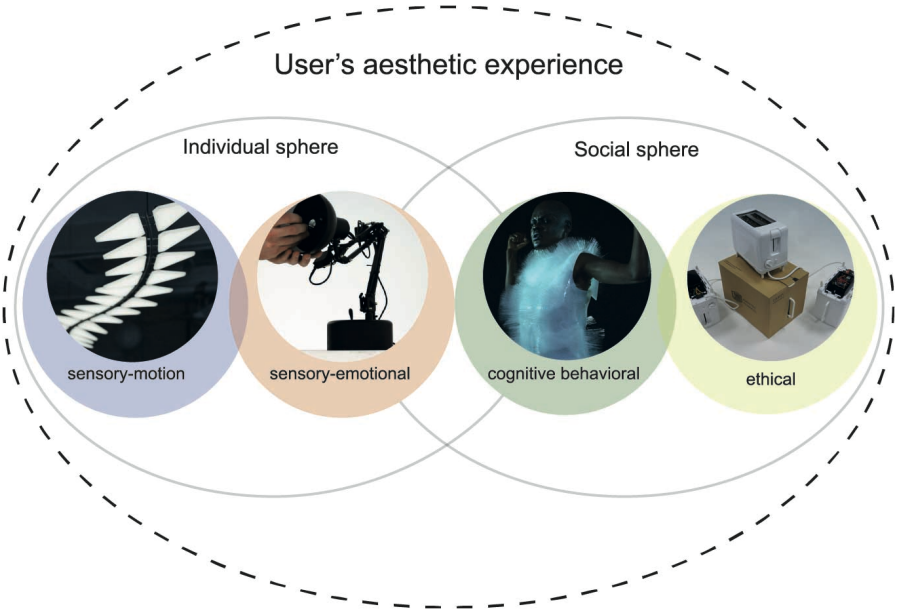

Fig. 6.5 - Scheme of relational dynamics that characterize the aesthetic experience with our four chosen animate objects.

This means that they both stimulate our senses and our cognition, establishing relational qualities in which objects' meaning and value are built.

Through the case studies, we tried to offer a phenomenological taste, albeit minimal, of the current research practices on animate objects. These include common objects (toasters, lamps, clothes, etc.) with a primary function accompanied by a second one that adds qualities to the experience resulting from the object's presence and use.

This scenario is comparable to neither computers nor robots in terms of complexity of the technical functionality or efficiency of the tasks. From Alain Turing's (Turing, 1950) foresight that machines would become more effective if they became credible companions, we shift to the philosophy of "meaningful presence", in which common everyday objects become machines to improve our lives from an ecological point of view. Their presence is «part of who we are, how we live and how we express ourselves» (Hallnäs and Redstrom, 2002, p. 121) - and not just. Animate objects carry affective relationships in the

everyday experiences through which we assign meaning as well as value to life.

We believe that the aspects presented so far are of considerable importance, in view of wider reflections on product innovation. They can help us understand the phygital evolution of our environment, with its strengths but also difficulties, and open possibilities of choice.

Today's, objects' behaviors, jointly with the use of time and space, are the central parameters for designing animate objects. The latter represent a design challenge that requires further interdisciplinary research. We believe that the behavioral characteristics of animate objects must be explored and designed in the light of physical variables that relate to shape-changing, in terms of changes in form, dimension, density, light, and color in time.

We strongly encourage further exploration of behaviors in future research.

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Authors

Henriette Bier. After graduating in architecture (1998) from the University of Karlsruhe in Germany, Henriette Bier has worked with Morphosis (1999-2001) on internationally relevant projects in the US and Europe. She has taught digitally-driven architectural design (2002-2003) at universities in Austria, Germany, Belgium and the Netherlands and since 2004 she mainly teaches and researches at Technical University Delft (TUD) with focus on Robotic Building. She initiated and coordinated (2005-06) the workshop and lecture series on Digital Design and Fabrication with invited guests from MIT and ETHZ and finalized (2008) her PhD on System-embedded Intelligence in Architecture. She coordinated EU projects E-Archidoct and F2F Continuum (2007-10) and led 4TU projects RDCB and Adaptive Joints (2015-18). 2017-19, she has been appointed professor at Dessau Institute of Architecture. Results of her research are internationally published in books, journals and conference proceedings and she regularly lectures and leads workshops internationally.

Mauro Ceconello. Architect and Associate Professor, Product Design, School of Design, Politecnico di Milan. He focuses his research activity on tools and apps to enhance cultural heritage and tourism using mobile technology, serious games, and interactive systems. He held courses about augmented reality and mobile experience. He is a scientific coordinator of many research projects concerning valorization of culture through digital technologies and interaction tools.

Marinella Ferrara. PhD, Associate Professor of Industrial Design at Politecnico di Milano, Head of MADEC, the Material Design Culture Research Centre (www.madec.polimi.it). Her research aims to clarify the relationship between design and materials, and to contribute to design theories and teaching methodologies. She developed the theory of the Material Paradigms (2004), founded MAD (University of Palermo, 2006), one of the first Materials Library of the Italian Universities. Following, she published the first Italian design-led study on Smart, Sensible and Interactive Materials (Lupetti, 2008), defined the Italian Way to Material Design (2015) and developed the Design-driven Material Innovation Methodology (2015-2017).

Gianluca Guarini. Adjunct professor at Politecnico di Milano and research fellow. Engineer and freelance expert in 3D modeling and rendering techniques aimed at photorealistic Architectural Visualization. Since 2000 he has been teaching Autocad 2D/3D and 3D Studio Max in IT training companies, for individuals and companies. He teaches at Politecnico di Milano, in Interior Design bachelor's degree courses concerning two-dimensional CAD technical drawing, three-dimensional modeling and photorealistic rendering. He teaches courses on BIM in lighting project within the international Master in Lighting design and technology of Politecnico di Milano.

Attilio Nebuloni. PhD, is assistant professor in Architectural and Urban Composition at the Design Department of Politecnico di Milano. He teaches architectural composition at the School of Architecture, Urban Planning and Construction Engineering. His research interests are the relationship between architecture/nature, sustainability, physical interaction and computational design. He has been director of workshops on digital design tools and editor in chief of several architecture journals.

Alice Plutino recently obtained a Ph.D. in Computer Science at Università degli Studi di Milano. Her research interests are: Color Science, Colorimetry, Image Enhancement, Image Digitization, and Archiving with a particular interest in Cultural Heritage applications. She is the author of the book "Tecniche di Restauro Cinematografico" and

different journal and conference papers of national and international relevance. She is Adjunct professor at Università degli Studi di Milano and Centro Sperimentale di Cinematografia, teaching digital film restoration and digital media conservation. She is part of AIC2021 Organizing Committee and member of the Italian color group (Gruppo del Colore).

James Postell. Architect and Associate Professor, Product Design, School of Design, Politecnico di Milan. Professor Emeritus, College of DAAP at the University of Cincinnati. He has taught architecture, interior design and product design at: Texas Tech University, University of Cincinnati, DIS in Copenhagen, and the Politecnico di Milano. He focuses his research activity on links between design, technology, and methods of production, with focus on furniture design. As a practicing architect (www.designstudio161.com) he has designed and written about interiors, furniture, craft, and materiality.

Maurizio Rossi, MSc, PhD. Full professor of Design at Politecnico di Milano where he is the scientific manager of the Lab. Luce, the director of the Master program in Color Design & Technology and the Master program in Lighting Design & Technology. He is the editor-in-chief of the Color Culture and Science Journal. From 2012 to 2018 he was the President of the Associazione Italiana Colore. Since 2018 he is member of the Executive Committee of AIC (International Colour Association).

Beatrice Sarti is currently a Ph.D. student at the University of Milan (Italy) at the Department of Computer Science, after obtaining a Master's degree in Cultural Heritage Conservation Science. She performed a master's degree thesis in collaboration with the Xlim research institute (Poitiers) concerning the Hyperspectral Imaging characterization for pigment identification on ancient paintings. Her Ph.D. research is focused on film restoration with a particular interest in Chemical and Physical Diagnostic Analyses, Data Digitization, Image Processing, and Image Enhancement.

Martina Sciannamè is a PhD student in Design at Politecnico di Milano. She investigates how AI and ML can be meaningfully included in Design education with a multidisciplinary approach. Her aim is to produce theoretical knowledge and practical tools to enable designers to exploit the opportunities offered by this technology and to communicate with ML experts, being aware of its actual capabilities and limitations. Her hope is that the intersection of Design and ML, within the frame of Ethics, will finally steer the development of ML systems towards real-world problems and responsible innovation for the flourishing of humans.

Gabriele Simone received his BIT in 2005 and his MSIT in 2007 both at University of Milan-Department of Computer Science, Italy. He accomplished a PhD in Color Imaging in 2016 at University of Oslo-Department of Informatics, Norway in collaboration with the Norwegian Colour and Visual Computing Laboratory at NTNU i Gjøvik, Norway. His main research interests are HDR Imaging, Image Quality, Image Enhancement, Color Perception and Colorimetry. He is adjunct Professor at Master in Digital Humanities and collaborator with the Multimedia Interaction Perception and Social Lab at University of Milano. Today he is working as Software Engineer at Elica-ASM.

Andrea Siniscalco. MSc in Industrial Design in 2002 with a thesis on lighting for windowless spaces. PhD in Design of lighting product in 2007. At Politecnico di Milano he is an adjunct professor of "Lighting theory" in MSc course in Interior and deputy director and teacher in the international master in Lighting design and technology. Since January 2003 he actively collaborates with Laboratorio Luce of Design department. Vice president of Gruppo del Colore - Associazione Italiana Colore. His main research interests are product design, CAD for lighting, visual perception and human-material-light interaction.

Davide Spallazzo, Ph.D. in Design is an Assistant Professor at the Department of Design of Politecnico di Milano. Active in Interaction Design and Human-Computer Interaction, his main research interest is the human-centered approach to digital innovation and meaning-

making, applied to diverse fields of inquiry. Over the years, he coordinated and took part in several national and international research projects concerning digital technologies in the Cultural Heritage field, serious gaming, and AI. He is now coordinating the Meet-AI research project, aimed at creating a new UX assessment method for AI-infused products.

Alessandro Squatrito is an experienced product and interaction designer. After studying industrial design (University of Palermo) and product design with a final master thesis mentored by Aldo Cibic (IUAV, Venice), he moved to Rotterdam (NL), where he worked for several international studios such as Minale-Maeda, and Richard Hutten. In 2015 came back to Italy where he worked for Arduino and Carlo Ratti Associati as product and interaction designer. On the same time thought at several university such as Abadir Academy (Catania), IED Torino, and UniRSM. At the moment he is guest lecturer at HfG Karlsruhe and teaching assistant at Polimi.

The book explores evolving perspectives on furniture, interior, spatial and architectural design, providing a multifaceted view of how the design discipline and practice deal with the complex and ever-evolving interplay between the physical and the digital realms. It explores the new frontiers of digitally enhanced design, investigating how computation capabilities impact the design discipline and designers' thinking and practice. Today more than ever, the design discipline must cope with the need to absorb technical skills and dialogue with traditionally distant domains. The core competencies in the Human-Computer Interaction field are becoming essential to every design branch: the computational power is entering the design process, modifying how products and spaces are designed, how they are produced, and how they will impact the daily life of users.

The book explores these novel frontiers, proposing captivating portraits of digitally enhanced design possibilities, from tools and processes to expressive potentials.

Industry 4.0 and traditional craftsmanship hybridize in view of a circular and just economy for the furniture sector, imagining new approaches towards the European Green Deal. The sensing capabilities are intertwined with the materials to create a new form of animated objects, proposing a novel design approach beyond the user-centered one. The computational power of lighting design tools is entering the complex BIM methodology, exploring the problematic integration between the two worlds, and proposing solutions to support the design activity. Artificial Intelligence reframes the domestic landscape, thanks to Science Fiction Scenarios, to stimulate reflection on the designer's role in framing utopic/dystopic futures. Finally, data drive the design of adaptive morphologies, exploring the context of computational design with a conceptual framework and reflecting on how robotic design can contribute to architecture.

FrancoAngeli
La passione per le conoscenze