


# The contribution of Design Thinking to the R of R&D in technological innovation

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Literature on Design Thinking has mainly focused on whether its key principles enhance performance in the development phase (the D of R&D) of the technological innovation process. However, it has dedicated scant attention to the earlier research phase (the R of R&D). This aspect is surprising, given that many innovations fail as a result of early research actions and decisions. This article examines how it is possible and desirable to apply Design Thinking to the research phase of the technological innovation process. How can Design Thinking support innovation, even when advanced breakthrough technologies are at stake, the market is distant, and product applications and specific user needs have not been identified yet? To respond to this question, we investigate the research work of the design center of a global electronics company that uses a design approach called Proxemics to envision future interactions between bodies (people), objects (technology), and spaces (context). Although Proxemics is consistent with and implements the human centeredness and experimentation principles of Design Thinking, results of this study show that its logics and tools are different from those used in Design Thinking in the D of R&D due to the more abstract nature of the tasks in the R of R&D.

## 1. Introduction

A significant number of product and service innovations fail (Cierpicki et al., 2000) for reasons related to the innovation process, organization, resource endowment, and commercialization strategies, among others (Montoya-Weiss and Calantone, 1994; Evanschitzky et al., 2012; Kahn et al., 2012). These reasons mostly refer to the design and execution of the development process, the D of R&D. Design Thinking is a formal creative

problem-solving method based on the application of the mindsets and tools of designers to the business context (Dewett, 2007; Brown, 2008). According to early empirical works, the constituent principles of Design Thinking, such as human centeredness and experimentation, are adopted to address recurring syndromes in innovation projects, thus increasing the likelihood of success (Carlgren et al., 2016).

However, there is evidence that new products and services might also fail due to actions and decisions taken in early stages, before the development process

begins (Von Hippel, 2007; Cavallo et al., 2020). Even if the decisions taken in the research phase, the R of R&D, have little or no direct influence on the innovative output, they create path dependency and may act as constraints to the work of developers in downstream stages (Watanabe et al., 2001). For instance, in the 1980s, Motorola heavily invested in satellite technology to create a new global telephone network. Iridium, the resulting phone and infrastructure launched 10 years later, was extremely expensive, impractical, and suffered from technical issues. Eventually, the satellite technology was leapfrogged by the GSM system, which offered sufficient performance to the mass market at a fraction of the cost (McGrath and Keil, 2007).

The inherent technological orientation of research and its distance from the market might foster decisions and behaviors that lower the innovation's chance of commercial success (Kakati, 2003). Elsbach and Stiglian (2018) propose that human centeredness should characterize innovation work whatever the phase of the process or the radicalness of the project. This would contribute to reducing the overcrowding phenomenon, namely, users are overwhelmed by the large number of technological options that deliver little or no value (Verganti, 2017). Moreover, advancements in prototyping and simulation technologies as well as novel management concepts, such as 'pretotyping' (Furr and Dyer, 2014; Savoia, 2019; Magistretti et al., 2020), allow anticipating the moment in the innovation process of how ideas can be transformed into tangible artefacts and used to gather user feedback (Thomke, 1998).

In light of the above statements, we enquire how it is possible and desirable to apply the principles of human centeredness and experimentation to the research phase of the technological innovation process. Put differently, how can the Design Thinking approach be applied in the R of R&D? The present study is a first attempt to address this question. Research on Design Thinking has predominantly focused on the development context (Brown, 2009; Martin, 2009), largely overlooking the management challenges and success factors in the research phase (Micheli et al., 2019). This gap, which also emerges in the literature on other flexible innovation models, such as Agile and Lean, is a significant issue because the high level of uncertainty and ambiguity in research renders decision-making particularly complex (Alvarez and Barney, 2005; Reymen et al., 2017; Pellizzoni et al., 2019).

The opportunity to improve innovation performance through a more proficient management of the research phase, in contrast to the development phase, is significant (Stokes, 1997, p. 196). For instance,

Liedtka (2020) advocates the need for new approaches able to anticipate the desires and lifestyles that people will have in the future. Van der Bijl-Brouwer and Dorst (2017) argue for a stronger focus on the human role in the dialogue between technologies and people if firms want to design meaningful technological interactions, and this focus should characterize technological innovation from the start.

On the other hand, there are fundamental differences between research and development activities that might advise against the application of Design Thinking in earlier stages. Research-related decisions have a longer-term time horizon, which might transcend the lifecycle of a specific new product or service. Research activities might begin before the identification of a specific market, let alone the user segment (Magistretti et al., 2020). Design Thinking emphasizes the observation of current user behaviors through ethnography, and although this might offer managers a better understanding of the existing reality, it might also constrain envisioning future realities (Norman and Verganti, 2013). Furthermore, in Design Thinking projects, user desirability takes precedence over technological feasibility, in line with a market-pull approach.

To shed more light on these aspects, we carry out an exploratory empirical investigation. In this study, we use the case study method to examine the application of Design Thinking to research projects at the design center of a leading high-tech electronics company that we call TechInteract for confidentiality reasons. Through interviews with the center director, managers, and project team members, and the analysis of archival documents on different projects performed by the organization, we document the nature and use of a design approach in research, based on Proxemics. Proxemics is the study of the nature, degree, and effect of the spatial separation that individuals naturally maintain (as in various social and interpersonal situations) and of how this separation relates to environmental and cultural factors. Proxemics contributes to the study of non-verbal communication along with haptics (touch), kinesics (body movement), vocalics (paralanguage), and chronemics (structure of time). The anthropologist who initiated this discipline in 1963, Edward T. Hall, emphasized the use of space on interpersonal communication. Proxemics is commonly adopted in the field of interaction design, i.e., the practice of designing interactive digital products, environments, systems, and services (Cooper et al., 2014) because it provides a set of tools to envision future interactions between bodies (people), objects (technology), and spaces (context). As it supports research work based on the principles of human centeredness

and experimentation, among others, Proxemics is a potential way to apply Design Thinking in the R of R&D, emphasizing the centrality of interactions as a possible equivalent for empathy in the development process, and extensively using speculative prototypes to envision futures differently from high-fidelity or minimum viable prototypes that are used for testing products and services (Furr and Dyer, 2014). Although this study does not offer a definitive answer on the viability and desirability of Design Thinking in early innovation stages, it illustrates how a method consistent with the Design Thinking approach can contribute to the proficiency of the research phase. Moreover, this study provides insights about the reinterpretation of the human centeredness and experimentation principles required by the peculiar nature of research projects.

## 2. Conceptual background

This section discusses and develops the key concepts that are relevant for the purpose of this research. We specifically focus on human centeredness and experimentation among the multiple principles underlying the Design Thinking approach, as they recur in all the overlapping conceptualizations of Design Thinking (Carlgren et al., 2016; Micheli et al., 2019), and are at the heart of the way designers approach problem-solving, sensemaking and ultimately innovation (Liedtka, 2015; Beckman, 2020).

### 2.1. Design Thinking is human centered

In the last decades, the emergence of Design Thinking (Brown, 2008; Martin, 2009) and related approaches, such as human-centered design (Buchanan, 2001) and participatory design (Sanders and Stappers, 2008), have highlighted the transformational role that design can play in innovation. Design Thinking has grown into a strategic innovation approach, as it is evident in both the practitioner (Brown, 2008; Knapp et al., 2016) and academic literature (Cross, 2007; Brown and Wyatt, 2010; Dorst, 2011).

Design Thinking is conceptualized as a multidisciplinary, iterative, human-centered approach inspired by designers that leads to transformation and innovation (Giacomin, 2014; Carlgren et al., 2016). Human centeredness in Design Thinking means that what drives the entire innovation process is the identification and satisfaction of user needs (Thomke and Von Hippel, 2002; Norman, 2005; Brown, 2009). The success of any innovation depends on simultaneously achieving user desirability, technology feasibility, and financial viability, yet Design Thinking almost

prescriptively instructs innovators to address desirability first (Brown, 2008). By continuously involving end users in the iterative co-creation and testing of ideas and prototypes, design thinkers ensure that the outcomes of their innovation effort add value to the human experience, that they are meaningful and affordable (Norman, 2017). In so doing, Design Thinking overturns the technology-driven perspective that recurs in many innovative organizations: firms first determine what is feasible for them to develop, given the work and the outcomes from their R&D labs, and then push their new products and services through marketing campaigns hoping that they address people's needs (Verganti and Dell'Era, 2014; Artusi and Bellini, 2020).

The relevance of a human-centered approach also stems from the wicked nature of the problems addressed in Design Thinking projects (Buchanan, 2001; Camillus, 2008). Wicked problems are defined as a class of social problems that are ill-formulated, where the information is confusing, and where many customers and decision-makers have conflicting values (Rittel and Webber, 1973). These types of problems should be addressed with a human perspective to grasp their complexity, make sense of them, and make them tractable (Liedtka, 2015).

Human centeredness in Design Thinking is achieved through an innovator's empathy with users. Empathy refers to the willingness and ability to adopt the perspective of other persons and recognize their perspective as their truth, be open to various inputs, suspend judgment, sense other people's emotions, and communicate by mirroring back (Brown, 2009). The way the innovator 'puts herself in the user's shoes' is by conducting ethnographic research: immersing in the user's natural habitat, replicating and observing user behaviors that might reveal their thoughts and feelings, questioning motivations through deep, contextual interviews to infer 'the intangible meaning of those experiences' (Sanders, 2006). Inspiration from people also comes from co-creation sessions and tests (Dahan and Hauser, 2002).

A still limited number of empirical studies investigate the relationship between human-centered design and innovation performance. Rosenthal and Capper (2006) show that the integration of ethnographic research at the front end of the product development process may yield insights well beyond what the researchers originally set out to explore, thus contributing to product innovativeness. Based on four cases from manufacturing and service sectors, Goffin et al. (2012) find that ethnographic techniques reveal issues with existing products, facilitating understanding of customer attitudes, perceptions, and needs, both rational and emotional. Leonard and Rayport

(1997) assert that empathic design pushes innovation beyond just producing the same artefact better, by challenging industry assumptions and stimulating radical innovation. Based on an empirical study of six large organizations, Carlgren et al. (2016) argue that human centeredness also entails involving users in the co-creation and exploration of ideas.

## *2.2. Design Thinking is experimentation based*

Experimentation is a fundamental trait of Design Thinking (Carlgren et al., 2016; Micheli et al., 2019). In their creative problem-solving initiatives, designers create and process information and make decisions by designing and running experiments (Brown, 2008). These experiments generate knowledge about the unknowns underlying an innovative idea, its desirability, feasibility, and viability (Thomke, 1998; Hampel et al., 2019).

Experimentation in the context of an innovation process means using prototypes, i.e., incomplete and approximate representations of the innovation output under development, to actively intervene on reality and manipulate it (Bogers et al., 2010). Testing prototypes with target users serves to create a realistic experience of what the innovation might be so that users can provide reliable feedback (Pisano, 2019). Such feedback is fundamental for innovators to make accurate design decisions as the projects unfold.

In conditions of high uncertainty and volatility, experimentation is deemed a superior information creation and processing approach than more passive methods, e.g., analytics and desk research (Felin et al., 2019; Thomke, 2020). Experimentation is not a new Design Thinking principle brought to the practice of corporate innovation. Although testing prototypes are also an important phase in the traditional, linear Stage Gate and Waterfall frameworks (Cooper, 2008), the logic significantly differs (Bianchi et al., 2020). In Stage Gate, experiments take place late in the process to validate the innovative output before its deployment, hence they are optimized to succeed. The historically high cost of prototyping limit the number of tests, which are characterized by high fidelity and integration. Garvin (2003) defines this approach to experimentation as hypothesis testing, as opposed to the exploratory experimentation that characterizes Design Thinking. In this latter approach, the rationale for experimentation is discovery: multiple, partial, 'fast and frugal' prototypes are used to 'see what would happen if' (Garvin, 2003, p. 142), namely, to search the solution space to identify promising new concepts (Carlgren et al., 2016).

On the one hand, advancements in simulation and rapid prototyping technology, such as 3D printing, have reduced experimentation costs, allowing for an early set-based testing strategy (as opposed to the late point-based in Stage Gate) (Sobek et al., 1999). On the other hand, tools like minimum viable products, smoke tests, and prototypes (Eisenmann et al., 2012; Furr and Dyer, 2014; Magistretti et al., 2020) have pushed innovators to test their ideas without necessarily having to build the 'real thing'. A 'fake it before you make it' approach can flash-forward users into the future at a fraction of the cost and time compared to traditional prototyping. Of course, these tests are likely to fail, but this is not deemed negative due to the valuable information that early-stage failures provide (Edmondson, 2011).

Besides acting as tools that elicit user feedback, prototypes facilitate communication and coordination across team members (Hargadon and Sutton, 1997). They support the construction of new understandings and prospective sensemaking (Stigliani and Ravasi, 2012). Moreover, Liedtka (2015) argues that experiments help reduce individual cognitive biases that hinder innovation. A growing number of studies investigate the impact of experimentation on innovation performance. MacCormack et al. (2001) document the performance gains of software firms that launched early beta versions of their products. Candi and Beltagui (2019) show that 3D printing enhances innovativeness in turbulent environments. Recent studies find significant benefits from disciplined experimentation-based decision-making in innovation processes (Camuffo et al., 2019) and from combining an experimentation orientation with a less formal organizational structure.

## **3. Research method**

Notwithstanding its limitations in terms of reliability and validity, a single case study is considered as an appropriate empirical approach to answer 'why' and 'how' questions (Yin, 2011). In this article, the case study has an illustrative function: to investigate complex phenomena under insightful circumstances and clarify ill-defined relationships between constructs (Siggelkow, 2007). To achieve this aim, the selection of the case is critical and should be 'very special in the sense of allowing one to gain certain insights that other organizations would not be able to provide' (Siggelkow, 2007, p. 20). Thus, in line with both theoretical and convenience sampling (Dubois and Gadde, 2002; Eisenhardt and Graebner, 2007), we focus on a pioneering technology supplier, the Design Center of a global high-tech firm



in the electronics industry that we call TechInteract for confidentiality reasons. The firm adopted Design Thinking since early 2000s to conduct both research and development work. In particular, TechInteract's Design Centers (TDC) conduct exploratory research on new ways through which people and technologies interact, as well as on new color, material and finish for its products. We selected this company due to its worldwide presence and attention to design as a source of competitive advantage. Indeed, the company has won several iF Design Awards for product design, concept design, communication design, and packaging design. In terms of research outputs, TechInteract has more than 50,000 active patents, clearly a technological leader in its field. In the last two decades, TechInteract has opened several Design Centers around the world, including one in the United Kingdom in 2000 with the aim of creating modern and revolutionary experiences embedding European culture and diversity. This cross-disciplinary Design Center preserves and celebrates the finest aspects of European design, while foreseeing future needs by questioning the norms and the conventional thinking around using electronic products. In 2005, a Design Center was opened in Milan, Italy, to harness the flow of creativity that pulsates through the Italian capital of design and fashion. Specifically, both Design Centers carry out studies on new materials emerging in the electronics industry, investigating the new sociocultural behaviors and lifestyles that inform the development of innovative products. As a consequence of digitalization dynamics, the focus of the projects progressively moved from ergonomic product performance to digital system features. Although the interaction between humans and objects has

always been central, the advent of digital technologies required and allowed to significantly reframe the ways humans rely on their senses to access, handle, communicate, and receive feedback from digital objects.

To collect and analyze the empirical data, we followed a two-step exploratory process that lasted almost 2 years (see Table 1). First, we conducted three semistructured preliminary interviews with the Director of TDC in Italy. Each interview lasted on average 3 hr and aimed to gather information on TDC's structure, organization, and activities. In a second phase, we conducted more structured interviews with TDC directors and managers, focused on the understanding of the process followed by the TDC group. These seven interviews lasted around three and half hours on average and investigated six research projects conducted by TDC between 2013 and 2016. Please refer to Appendix A for an overview of the research goal, composition of the team and the steps followed by the TDC research group. In addition, we interviewed three design managers to examine the techniques and tools adopted in their research on new interactions between humans, objects, and spaces. We also interviewed one manager from the TDC in the United Kingdom, as he was involved in these projects too. Interviews were recorded and transcribed, leading to more than 33 hr of recorded material and over 1,200 pages of transcripts. This information was triangulated with data from secondary sources and from archival documents, such as internal reports and presentations on the projects performed by the TDC between 2013 and 2016. In particular, we reviewed documents for a total of 1,000 pages and examined around 40 different prototypes.

Table 1. Data sources

Type of data source	Data source	Time	Evidence analyzed
Preliminary interviews	TDC Director – Italian Office	21/04/2016 25/05/2016 21/06/2016	3 Interviews, 9 hr
In-depth interviews	TDC Director and Design Managers – Italian Office	02/11/2016 20/12/2016 15/02/2017	7 Interviews, 24 hr
	TDC Manager – UK Office	20/03/2017 14/06/2017 15/11/2017 20/12/2017	
Archive documents on research projects developed in the period 2013–2016	Documentations shared among participants in the projects (e.g., videos, slides, reports)	2013–2016	
Prototypes developed in the research projects in the period 2013–2016	videos and real mock-ups	2013–2016	

In the data analysis phase, we performed content analysis and coded the adopted design practices to explore TDC's application of both the human-centered and the experimentation-based principles in its research projects. We analyzed the qualitative data prior to categorization and contextualization to extrapolate insights related to the approach adopted to envision future human–technological interactions (Miles and Huberman, 1984; Eisenhardt and Graebner, 2007). In particular, we categorized the identified design practices according to the two Design Thinking principles investigated in this study: human centeredness and experimentation. To increase the robustness of our findings, the interpretations were validated by recontacting the interviewees by phone and sharing the preliminary results to obtain their final approval (Goffin et al., 2019).

## **4. Empirical results**

This section illustrates the approach that TDC adopts in the early research phase of the technological innovation process. First, we provide a description of the nature of the research work carried out by TDC. Then, we analyze the results in light of the two Design Thinking principles (human centeredness and experimentation) and examine how TDC applies these in the R of R&D.

### *4.1. Research at TDC*

TDC's mission evolved over time. In the first 5–10 years from its establishment, TDC mainly focused on research projects aimed at discovering color trends and new materials able to support innovative product interfaces. Since 2010, TDC began to carry out research projects aimed at investigating interactive technologies, such as haptic or motion sensing. Before digital transformation became an established trend, interaction projects primarily dealt with human–computer interactions (design and use of computer technology, focused on the interfaces between users and computers). The advent of a large variety of digital devices (e.g., smartphone, tablets, wearables, digital surfaces) increased the relevance of interaction design and the development of more advanced frameworks and methodologies. TDC has significantly contributed to this research and to the resulting technologies that today allow the natural interaction with smartphones, tablets, or smart appliances (page flipping, picture zooming, image rotating, etc.). The main aim of the research projects performed by TDC is to explore new interaction modes between humans, objects, and spaces. Indeed,

the advent of digital technologies (e.g., motion sensors, internet of things, haptic technologies, LED) combined with their pervasive connectivity has led to innovative interaction modes.

At the beginning, TDC focused on Color, Material and Finish research projects. I have to admit that my colleagues in the Italian office and I were more than enthusiastic to progressively dedicate significant effort to exploring digital technologies that were almost unknown, but that enlightened radically new interaction modes. I was personally fascinated by the various interpretations people could give to new 'objects', able to interact with them in a completely different way. Because of this intuition, we created completely new research dedicated to human-object interactions enabled by new technologies. (TDC Director – Italian Office)

It should be noted that, whatever the focus or the scope of the projects, TDC performs only research tasks and does not develop end customer products. TDC stimulates and informs several product lines by writing reports on emerging sociocultural trends and suggesting new interaction modes through technological prototypes. Both contributions aim at envisioning new ways that humans can interact with objects equipped with sensors like touchscreens or voice recognition. For example, TDC has deeply studied the sociocultural trend of haptic sensing, i.e., the science of sensing through touch, to better understand its potential. Haptic technology offers humans a truly immersive experience when using touchscreen interfaces, in the form of direct information transfer between the display and the fingertips. Tactile haptic feedback recreates the sense of touch, detecting forces and tactile stimuli in the form of vibrations, texture rendering, simulated clicks, pulses, and buzzes.

The interviews shed light on the way the projects are conducted in the particular context of the R of R&D. They allowed researchers to delve deep and unveil the underpinning elements characterizing how these innovative projects were conducted early in their lifecycle. TDC research projects have a dual nature: developing a core annual research project on advanced physical interactions aimed at scouting new technologies able to support novel interaction modes and discovering emerging human lifestyles that represent weak signals about future behaviors. Data show that the six research projects between 2013 and 2016 investigated in this study (see Appendix A) exhibit this dual nature and adopt a similar process based on five steps (see Figure 1).

We always start with research; we need to be sure that all the different socio-cultural trends are mapped before

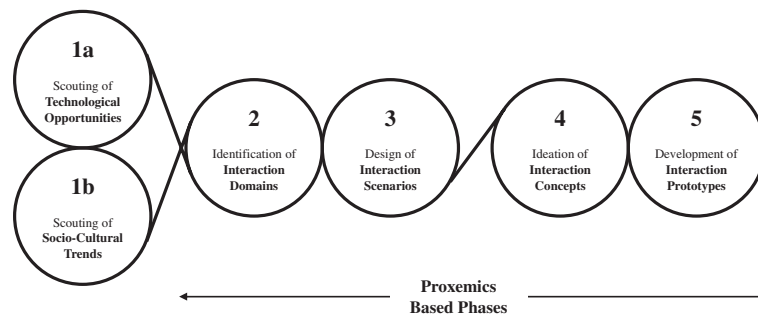


Figure 1. The research process adopted at TDC.

trying to envision possible future scenarios for technologies. Then we cluster them in subsequent stages, and we start to research on new ways humans can interact with objects in the space by leveraging the newly discovered tech solutions. (TDC Director – Italian Office)

The first step in this process consists of an outward-looking scouting activity. It aims at understanding what kind of novel interaction opportunities emerging technologies might offer, and the growing sociocultural trends that influence human behaviors when interacting with objects. This step provides the fundamental premises for all the projects performed by TDC. It draws on curiosity-driven exploration that typically leads to outcomes that were not envisaged at the outset of the project.

The subsequent four steps in TDC's projects are based on Proxemics. Proxemics is an approach that studies the human use of objects in the spaces, and the associated effects on behaviors, communication, and social interactions. Humans can interact with objects and spaces relying on both primary and secondary senses (see Figure 2). Proxemics supports the conceptualization of interactions among humans (through their body), objects, and spaces. In doing so, it can stimulate the experimentation of innovative interactions enabled by emerging technologies.

The research projects carried out at TDC are significantly distant from the market, they are pure research projects. For this reason, we need to conceptualize the interactions between humans, objects, and spaces in an abstract way; Proxemics helps us in framing various interaction opportunities. It is fundamental to interpret all new technologies that we periodically scout by considering the inputs they require and the outputs they provide. In this way, we can imagine innovative interactions independently from the products already available on the market. (TDC Director – Italian Office)

The Proxemics approach is realized in TDC's projects as follows. It starts with the identification

of interaction domains based on combining the data collected in the preceding scouting step. Interaction domains refer to general contexts such as user experiences or product categories, where new technologies can innovate the way humans interact with objects. This step is followed by a design activity, as researchers envision new interaction scenarios to imagine how the relation between humans and objects might change by adopting emerging technologies. Compared to an interaction domain (e.g., human in a domestic space), a scenario has a narrower scope, it is more specific and detailed (e.g., human interacting with a screen that displays images). The next step entails the ideation of novel interaction concepts based on the previously designed scenarios. These concepts go beyond simple ideas as they specify technology requirements and possible features; however, like ideas, they have a mental, cognitive nature. The final step, development, adds physicality and resolution as concepts are embodied and transformed into interaction prototypes that concretely deliver the novel interaction in an experimental way. It should be noted that although human centeredness is the driving principle early in the process as researchers adopt an explicit human perspective to identify domains and design scenarios, the experimentation principle later becomes predominant to explore alternative concepts and to make them concrete into prototypes, apt for exploring and for stimulating conversations.

#### 4.2. Proxemics as a human centered approach for the R of R&D

The initial scouting of emerging technologies and the possibilities afforded by them provides inspiration to the Proxemics-based work, by suggesting how objects and spaces can interact with humans in the future. In parallel, making sense of sociocultural trends offers insights on the interactions that might be desired and appreciated by humans. Differently put, technologies identified during the scouting step

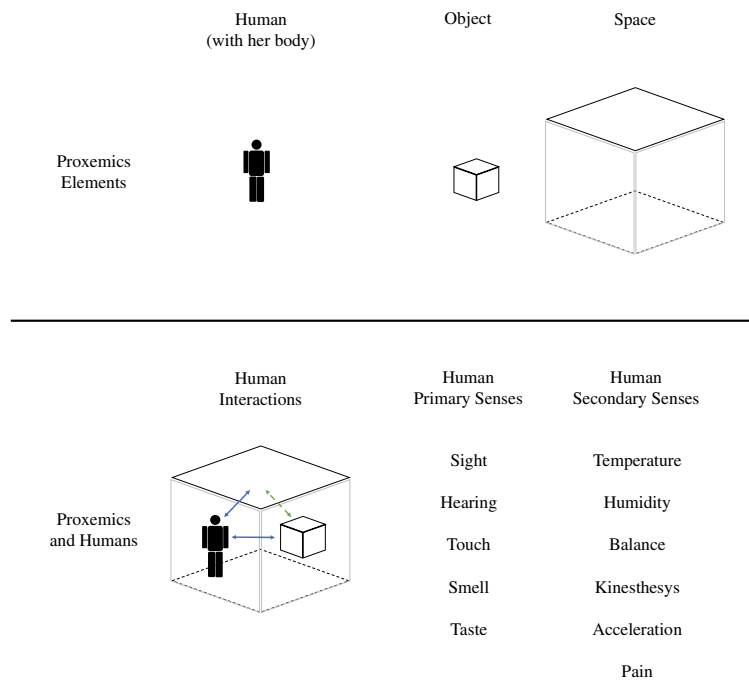


Figure 2. The Proxemics approach. [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

define the boundaries of the interaction domains, although human desirability, suggested by environmental trends, represents the key criterion to rank, and subsequently focus on, the most promising interaction domains.

Scouting socio-cultural trends is fundamental because it provides those inspirations that allow us to reinterpret the features provided by emerging technologies; it reinforces those weak signals that, properly decoded, allow imagining the adoption of existing technologies to provide completely different interactions. (TDC manager – UK office)

As an example, the research project performed by TDC in 2013, named Project A, began with and drew on the scouting of technologies like voice and image recognition, eye tracking, advanced haptics, and of trends, such as multisensoriality, simplicity, and contextualized personalization. These insights were combined, clustered, and interpreted along dimensions such as ‘adaptivity’ (i.e., the degree to which objects adapt their features to user needs through, e.g., mechanical transformation, flexibility, or programmable behavior) and ‘immersivity’ (i.e., the extent to which a sensorial experience attracts the user in another dimension).

Based on this work, the research team identified distinct domains where new interactions could be generated. One interaction domain formulated in Project A was named ‘people in the space’ and

was meant to include all the plausible interactions between a human and her surroundings made possible by wearing passive and active objects equipped with sensors (see Appendix B). Human metrics and surround data are other domains identified in Project A and indeed represent broad contexts, user experiences or product macrocategories, whose boundaries and units of analysis are defined by the crossing of technological opportunities with sociocultural trends. Nevertheless, domains do not provide any further detail on the possible interactions included in the domain’s boundaries.

Each interaction domain is then deeply investigated and made sense of, giving birth to one or more scenarios. For instance, the four interaction domains in Project A were articulated into 40 scenarios (see Appendix A) that visually represent a specific set of interactions between humans and objects in a well-defined context. For instance, the interaction scenario ‘fully integrated TV experience’ deriving from the ‘people in the space’ domain, describes the possibility to create a digital continuum between the user and the TV by using the smartphone as a gateway. The resulting interactions provide more detail and clarity about the possibilities afforded by digital connectivity when it is brought to a more integrated level (see Appendix B). In this design step aimed at generating scenarios, TDC’s researchers use two tools from the Proxemics approach: (i) interaction maps that analytically outline the possible ways through which



human, objects, and spaces can interact in that particular scenario and the technological sensors needed to enable those interactions; (ii) feedback loops that schematically visualize the aforementioned sensors, the inputs necessary to activate them and the outputs they generate. Another interaction scenario in Project A, noting and sketching, was meant to describe a possible seamless experience in which humans take and read notes on both physical and digital surfaces, e.g., paper and screen. Thus, the scenario included information on the interactions involved in multimodal noting, and the necessary sensors, inputs, and outputs to enable bridging from physical to digital supports, and vice versa, e.g., strain/pressure sensors and intuitive layering.

In the research projects carried out at TDC, the novel interaction modes being conceived in the first steps of the process apply to different user segments, experiences and product families. Therefore, it is not possible nor desirable to predefine the target audience. Instead, generating a broad variety of interaction scenarios (almost 60 scenarios generated by TDC between 2013 and 2016) is fundamental to (i) trigger and leverage different, complementary perspectives to improve the ideation of interaction concepts and to (ii) expand the potential market for products that eventually will draw on the same interaction mode. The intrinsically conceptual nature of the Proxemics approach allows to think creatively about human interactions, free of the constraints imposed by the products currently available on the market. Paradoxically, one might argue that humans are more central in these research projects than in downstream development projects because their primary and secondary senses, often overlooked in the latter category of projects, are pivotal elements around which innovative interaction concepts are ideated.

Because of the absence of target users, the creation of the interactions domains according to technological opportunities and emerging lifestyles allows us to speculatively and rather 'wildly' reflect on the potential areas where new interaction modes can emerge. (TDC design manager 2 – Italian office)

#### 4.3. *Proxemics as an experimentation-based approach for the R of R&D*

After performing the steps described above, researchers at TDC shift their focus on the ideation of interaction concepts and then on the development of interaction prototypes (see Figure 1). The previously envisioned scenarios serve as springboards to imagine new concepts, i.e., concrete means to deliver a

set of new interactions by drawing on elements, e.g., sensors, inputs, outputs, from one or more scenarios. Indeed, there is no 1:1 correspondence between scenarios and concepts, as one concept can embody inputs from multiple scenarios. As researchers move from scenarios to concepts, there is a creative leap as well as a change of focus from what the interactions between humans, objects, and spaces might be to how they can be delivered, i.e., to concrete objects that can act as interfaces.

At the concept level, the outcomes of the researchers' ideation effort have a mental, cognitive nature. Concepts are indeed detailed descriptions, consisting of words, sketches and diagrams, of a possible artefact and of the particular interaction modes it can enable. One example of an interaction concept ideated in Project A is the smart pad. In the researchers' minds, the smart pad would be a layer like an A5 paper equipped with sensors, haptic, flex, and positions that would recognize people and objects in the space and would be activated when something, e.g., a smartphone, is laid over it (see Appendix B).

Following this ideation step, a subset of concepts are transformed into interaction prototypes. They take a concrete, tangible form that realizes the proposal that was just 'on paper' and allows stakeholders, not only project team members but also possible internal customers, such as the product managers of different business units, to try out the new interactions. The experimentation orientation in this latter part of the projects is evident and predominant.

Compared with the traditional product prototypes used in development projects for testing hypotheses with target users, interaction prototypes at TDC are highly speculative. Their purpose is not to stand in for the 'real thing', i.e., to approximate a specific commercial product application or use case, as these fall outside the scope of research projects and thus have not been envisioned yet. Instead, interaction prototypes are used to facilitate imaginings. These props have just enough resolution to show stakeholders what the combination of sensors might enable. For instance, one of the interaction prototypes in Project A, which was named the hub and incorporated some insights from the smart pad concept, was a cylindric object equipped with Wi-Fi, near-field communication, LED, and other technologies to recognize objects that were laid over it as well as other objects in a room. The prototype's only job was to make objects in the room vibrate when it sensed a phone being put on it. The low resolution of interaction prototypes invite stakeholders to actively engage with the object and 'fill the blanks', exploring the meaning and implications of the proposed interactions, entertaining alternative behaviors not

identified at the outset, and challenging preconceived notions and schemas. Their tangible nature provokes conversations between researchers and stakeholders who debate about ‘what might happen if’.

One of the seven interaction prototypes developed in Project C in 2015 was able to dim the light intensity according to the pressure applied through the haptic technology and to add vibration feedback when the pressure persisted for several seconds. Even if the prototype was apparently simple, the first time it was shown to some managers at TDC’s business units, unexpected applications were identified, from safety to medical, from education to entertainment.

The interaction prototypes are not products, but only probes that concretely demonstrate the innovative interactions allowing both project team members and internal stakeholders to imagine its adoption in different contextual settings. Even if it may imply some initial difficulties in properly understanding the interaction, the use of this type of prototype frees the imagination of internal stakeholders and allows overcoming the stereotypes usually associated with the good or bad results of past products. (TDC design manager 1 – Italian office)

Indeed, as researchers prototype a concept, they deliberately avoid using a specific product language. A product language is the set of signs and symbols (e.g., color, material, surface, form, style), that supply a product with a distinct character and help communicate its use (Dell’Era and Verganti, 2007). The goal of TDC’s researchers is instead to create ‘vanilla’ prototypes, whose proposed interactions can be exploited in different product categories and for different user experiences. Project D, carried out by TDC in 2016, aimed at exploring how different wave technologies like sounds, air movement and gesture could control human interaction with objects. By experimenting with five different prototypes, the project team was able to propose an innovative way for people to interact with smart objects even without using voice or touching them, that was eventually picked up in downstream development projects across product lines.

The ideation and especially the development steps allow us to rapidly and concretely gather the feedback from different business units in terms of their future desires, and derive the technological requirements for the subsequent development projects. (TDC Director – Italian Office)

## 5. Discussion

The adoption of the Proxemics approach in the research projects at TDC illustrates one possible

way companies can adopt Design Thinking in the early research phase of the technology innovation process, to generate ideas of novel interactions among humans, objects, and spaces. This study, thus, responds to recent calls on the potential of Design Thinking in relation to addressing long-term strategic objectives and not only solving current, specific user needs (Holloway, 2009; Johansson-Sköldberg et al., 2013; Micheli et al., 2019; Verganti, 2017). Our findings contribute to the ongoing debate on the core principles of Design Thinking, highlighting the fundamental role of human centeredness and experimentation in research projects (Kolko, 2015; Elsbach and Stigliani, 2018), showing that the adoption of Design Thinking at an early phase might differ from that in a later development phase (Carlgren et al., 2016).

The analysis of the application of Proxemics by TDC shows that, although this approach is human-centered and experimentation-based, it implements these principles through logics, techniques, and tools that differ from mainstream Design Thinking methods for new product or service development and instead fit with the specificities of research tasks. The absence of predefined target users implies the need to investigate human desirability at a conceptual level and to consider a broad variety of user experiences. The longer-term and more general-purpose perspective of research suggest researchers to produce innovative outcomes able to nurture several product lines or even to create new ones.

Following Modig and Åhlström (2012), this result can be interpreted by conceptualizing management paradigms, like Design Thinking, as trees of concepts at different levels of abstraction. At a high level of abstraction, *principles* are the foundations of the paradigm and define how operations should be; in the case of lean, which is the paradigm investigated by Modig and Åhlström (2012), just-in-time and *jidoka* are the principles that guide managers’ decisions in manufacturing. Although the principles are valid across different environments, this is not the case for *methods* and *tools*, which are at a lower level of abstraction and are context specific. Methods and tools define how different tasks are performed in line with the above principles, considering the particular contextual conditions. One way to apply the just-in-time principle in lean is through the pull method, consisting of tools like *kanban*. Pull and *kanban* are concrete practices that Toyota developed to address specific issues in their production line. In the attempt to apply the lean principles to a context other than production, e.g., innovation processes, it would make little sense to set up a *kanban* system due to significant differences in lead times, tasks, and goals. Following this reasoning, we argue that the

application of the Design Thinking principles to the R of R&D, although possible and desirable according to our exploratory study, appears to require different methods and tools that account for the specific nature of research vis-à-vis development. In this sense, Proxemics appears to be a sound method, together with its tools, including interaction maps, feedback loops and speculative prototypes.

According to the most diffused models of Design Thinking for new product or service development, e.g., the Double Diamond by the British Design Council and the five hexagons by Stanford's d.school (Liedtka, 2015), human centeredness is achieved by building empathy with the users and through the implementation of ethnographic methods, which are borrowed from anthropology (Carlgren et al., 2016; Dell'Era et al., 2020). Developers work in an outside-in fashion to unearth latent user needs, immersing in the user context, observing their behaviors as they experience products, and interviewing them about motivations and pains (Verganti and Dell'Era, 2014). Developers are invited to adopt a beginner's mindset and to be as factual as possible, to avoid biased interpretations and fixation (Brown, 2008).

Conversely, the analysis of Proxemics at TDC suggests that the application of the same principle, human centeredness, in research work and projects can occur in a diametrical way (see Table 2) (Wang and Horng, 2002). Because target users cannot and should not be specified at an early phase, researchers follow an inside-out and conceptual approach. They envision possible scenarios and novel interactions by combining predictions about emerging lifestyle and technological trends, with insights stemming from their individual experience, background, and motivations (Verganti, 2017). Interaction maps are a Proxemic tool to design scenarios that conceptualize humans in an abstract, stylized way, as bodies that can interact with objects and spaces through primary and secondary senses. Feedback loops, another Proxemic tool, model interactions through general concepts like sensors, inputs, and outputs. Design Thinking in the R of R&D appears to move from its consolidated role of solving wicked problems (Brown, 2008) to that of abductively imagining scenarios that might be meaningful for humans in the future (Alvarez and Barney, 2007; Kolko, 2015).

The analysis of TDC projects also highlights a shift in how the experimentation principle is pursued in the research phase of the technological innovation process (see Table 2). More specifically, experimentation is no longer aimed at testing desirability, feasibility, and viability hypotheses inherent in the products and services under development. For instance, minimum viable products, A/B or smoke

Table 2. Design Thinking differences in the D and in the R of R&D

Principle	Design Thinking in the DEVELOPMENT phase of the technological innovation process		Design Thinking in the RESEARCH phase of the technological innovation process	
	Logic	Methods/tools	Logic	Methods/tools
Human centeredness	Outside-in Empathy building	<ul style="list-style-type: none"> <li>Ethnography (immersion, observation, contextual interviews)</li> </ul>	Inside-out Abstract conceptualization of users	<ul style="list-style-type: none"> <li>Scouting sociocultural trends</li> <li>Proxemics               <ul style="list-style-type: none"> <li>Interaction maps</li> <li>Feedback loops</li> </ul> </li> </ul>
Experimentation	Testing products under development	<ul style="list-style-type: none"> <li>Minimum viable products</li> <li>A/B test</li> <li>Smoke test</li> </ul>	Exploring future interactions	<ul style="list-style-type: none"> <li>Proxemics               <ul style="list-style-type: none"> <li>Speculative prototypes</li> <li>Internal test audience</li> </ul> </li> </ul>

tests are categories of prototypes that are used in development projects to verify the effectiveness of the product innovation in satisfying user needs (Ries, 2011; Ghezzi et al., 2020).

Instead, interaction prototypes should be seen and classified as speculative prototypes (Dunne and Raby, 2013; Pilling et al., 2019). They are not meant to be viewed as real, i.e., as proxies of products or services that eventually will be launched on the market. They actually might not fit into today's world. Instead, they are incomplete fictional props that, in a basic form, suggest possible future interactions in settings that might not exist yet and leave much room for imagination by the audience (Dunn and Raby, 2013; BenMahmoud-Jouini and Midler, 2020). Especially in research projects, these prototypes act as 'playgrounds' for conversation (Schrage, 2000) and sensemaking (Stigliani and Ravasi, 2012), as they allow stakeholders to explore alternative understanding of future scenarios. To support meaningful verbal exchanges and cognitive processes, interaction prototypes should be concrete enough to let the audience perceive the experience in a similar way, yet partial and elementary so that each viewer can develop her own narrative around the prop.

It should be noted that the test subjects that engaged with interaction prototypes at TDC were not end users, as these were not identified yet, but internal customers of the Design Center, i.e., product managers from different business units in TechInteract who might eventually use the outcomes of the research projects as inputs to their own development efforts. Hence, the interaction prototypes had a general-purpose nature that cut across product families.

## 6. Conclusions

The case study of the application of Proxemics at TDC provides insights on the role of Design Thinking in the R of R&D. This study provides three main contributions to the vibrant debate on Design Thinking informing both the practitioner and academic communities. First, the particular nature of research challenges requires carefully adapting the consolidated Design Thinking paradigm. Proxemics is an interesting approach to apply the core principles of human centeredness and experimentation to the R of R&D. Second, if the human centeredness principle applied to development projects is mainly aimed at creating empathy with users, it has to be reinterpreted in research projects which require the analysis of socio-cultural trends and the abstract conceptualization of humans and of interactions that might be desirable for them in the future. Third, the experimentation

principle applied to research challenges is aimed at exploring future alternative scenarios and requires ad hoc tools such as speculative prototypes.

Our findings have implications for academics as well as practitioners. On the one hand, we enrich the discussion in the Design Thinking literature on the applicability of this approach to contexts that do not involve development or problem solving. Our case study suggests that Design Thinking can also work in longer term technology-oriented research projects. On the other hand, practitioners can find inspiration in our investigation of how an innovative leading firm in the electronics industry explores and envisions new systems through Design Thinking.

Our study has limitations that provide opportunities for future research. First, given the approach used, this study does not allow statistical generalization, for example, inferring conclusions about a population (Harrison and Kjellberg, 2010). Second, although the focus on a single case study of a multinational company is relevant, it calls for more quantitative analyses to further validate the insights reported. Third, it would be interesting to verify the suitability and efficacy of Design Thinking in other kinds of research projects. The Proxemics approach focuses on interactions and on human senses in the context of product innovation. More research is needed on how human centeredness and experimentation can be pursued in other research environments.

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## APPENDIX A

Information about the research projects at TechInteract's Design Centers (TDC) investigated in this study

Project name	Goal	Team	Start year	Project phases				
				Step 1. Number of sociocultural and technological trends considered	Step 2. Number of Interaction Domains identified	Step 3. Number of Interaction Scenarios designed	Step 4. Number of Interaction Concepts ideated	Step 5. Number of Interaction Prototypes developed
A	The aim of this first project performed by TDC was to discover how emerging technologies and sociocultural trends could have unveiled new interactions among human, object, and space	<ul style="list-style-type: none"> <li>• 1 Director – Italian Office</li> <li>• 2 Design Managers – Italian Office</li> <li>• 1 Manager – UK Office</li> <li>• 1 external supplier for the sensors</li> </ul>	2013	55	4	40	16	10
B	This project leveraged the trend scouting step conducted in Project A to investigate on how new technologies could enhance the interaction between a human and an entertainment system (e.g., TV, Audio system, etc.) in a space	<ul style="list-style-type: none"> <li>• 1 Director – Italian Office</li> <li>• 2 Design Managers – Italian Office</li> <li>• 1 Product Manager from TDC headquarter</li> </ul>	2014	55	4	40	6	3
C	Project C is the follow-up of Project A: its aim was to better discover the potential of the haptic technology and understand how this way of sensing objects could enable a different human–object–space interaction	<ul style="list-style-type: none"> <li>• 1 Director – Italian Office</li> <li>• 3 Design Managers – Italian Office</li> <li>• 1 Manager – UK Office</li> <li>• 2 external suppliers</li> </ul>	2015	61	4	40	21	7



## APPENDIX A Continued

Project name	Goal	Team	Start year	Project phases				
				Step 1. Number of sociocultural and technological trends considered	Step 2. Number of Interaction Domains identified	Step 3. Number of Interaction Scenarios designed	Step 4. Number of Interaction Concepts ideated	5. Number of Interaction Prototypes developed
D	In this 2016 project, the focus was on waves and how this way of transferring information in space could have impacted the way people interact with objects in the space. Wave technology has been explored and discussed within and outside the TDC	<ul style="list-style-type: none"> <li>• 1 Director – Italian Office</li> <li>• 1 Design Manager – Italian Office</li> <li>• 1 Manager – UK Office</li> <li>• 1 external artist</li> </ul>	2016	71	4	17	13	5
E	Project E leveraged the sociocultural and technological trends scouted in projects C and D, to experiment how new interaction concepts could change the way humans interact with smartphones, white goods, and other smart objects by squeezing and pressing objects due to the haptic science researched in Project C	<ul style="list-style-type: none"> <li>• 1 Director – Italian Office</li> <li>• 2 Design Managers – Italian Office</li> <li>• 1 Product Manager from TDC headquarter</li> </ul>	2016	71	4	17	25	11
F	Project F leveraged the trend scouting effort performed in Projects C, D, and E to understand how the adoption of wave technologies can enhance interaction with smart objects. The research aimed at discovering how people interact with technology not by touching but just by interacting with the space around them	<ul style="list-style-type: none"> <li>• 1 Director – Italian Office</li> <li>• 2 Design Managers – Italian Office</li> <li>• 1 Product Manager from TDC headquarter</li> </ul>	2016	71	4	17	15	8

## APPENDIX B

Examples of the application of the Proxemics approach by TechInteract's Design Centers in Project A

Proxemics-based step	Example of output in Project A
2. Identification of interaction domains	<i>People in the space</i> is the name of one of the four interaction domains developed during Project A. It consists of the definition of the spatial proximity between users and objects in a delimited area. Objects can be recognized or worn, and being passive or active enable the extension of the power of interaction of people within the area. Within this domain are encompassed all the interaction technologies that enable the domain of a digital continuum.
3. Design of interaction scenarios	<i>Fully integrated TV experience</i> . This scenario encompasses the possibility of expanding the power of the TV with the connection of the device with a smartphone to leverage its sensors and enable a digital continuum interaction between the user and the TV by using the smartphone as a gateway. The main gain of this scenario is the possibility to leverage all possible devices as fully integrated in a bigger system of connected appliances.
4. Ideation of interaction concepts	<i>Smart pad</i> . This is the concept of a smart pad, a layer of sensors that recognize what is position over it and reinforce the input and output sensors of that device, connecting it with other appliances in the space. It leverages haptic feedback and flex sensors to enhance human interactions with objects in the space.
5. Development of interaction prototypes	<i>Hub</i> . It is a prototype that leverages Wi-Fi, LED, microphone, speaker, and NFC technologies to recognize what is leaning over it and interact with it to reinforce its sensors' power and interact with the surrounding space in a brand-new interaction modality. The object has a simple shape because the prototype aims are the technologies inside and the interaction design rather than aesthetic.