

5. Prototypes of tangible interactions

Venere Ferraro, Susanna Testa

Abstract As authors of this chapter, we aim to analyse the role of prototypes in the research area of interaction design. We selected three Case Studies involving tangible artifacts in the context of academic research. We interviewed Livia Tenuta, assistant professor at the Design Department of Politecnico di Milano, who shared a Case Study of research in innovative jewelry for an Italian company. We interviewed Olga Noronha, designer, artist and visiting lecturer at the Royal College of Arts and Central Saint Martins. She shared her doctoral thesis findings about an Investigation into the Possibilities and Affordances of Medical Jewellery. Thirdly we interviewed Tom Jenkins, assistant professor at IxD Lab IT, University of Copenhagen. He shared with us the Case Study of research on alternative modes of living thanks to domestic Internet of Things devices adopted in co-housing communities. All examples refer to research developed in an academic context, where external partners are involved at different levels and for various purposes. In the chapter, firstly we illustrate the selection criteria adopted for three Case Studies. Then we describe compare and discuss them through the lens of the prototypes' categorisation criteria and interviewees' feedback on our theoretical concepts.

Venere Ferraro, Susanna Testa (✉)

Politecnico di Milano, Dipartimento di Design

Milan, Italy

e-mail: venere.ferraro@polimi.it; susann.testa@polimi.it.

5.1 Prototypes in design research of tangible interactions

The present text focuses on the analysis of the role of the prototype in the domain of interaction design, which is the process in which technology, products, and solutions are designed and shaped to centre on the human behaviour, interaction, and utilisation of a system(s) (Benyon et al. 2005; Moggridge and Atkinson 2007; Rogers et al. 2002; Saffer 2010).

In the disciplinary area of interaction design, there are no more boundaries between the traditional disciplines of product, fashion, communication, and interior/spatial design since we refer to systems crossing smart products and clothes, digital and visual interfaces, and responsive environments. More in detail, the Case Studies here described and explored focus on the design of interactive experiences enabled and mediated by both analogue means and digital technologies between users and their bodies, users and other users, users and objects, and users and environments (Desmet and Hekkert 2007).

While dealing with human behaviour and users' dialogues with others and the surroundings, the role of the prototype in the design process becomes crucial. Indeed, the prototype is used to implement ideas into tangible forms, from paper to digital (Wiberg and Stolterman 2014) and to explore and assess new experiences (McElroy 2016).

When selecting the Case Studies, we kept in mind the four theoretical concepts concerning the use of the prototype in design research defined in Chapter 2. To recap, concept 1 "Transition" described the prototypes as "the fundamental need to make magmatic and conceptually embryonic ideas manifest through fathomable forms of representation" (Sect. 2.2.4.1). concept 2 "Making theory" described the prototype's role as means for reflecting on the design process. In that perspective the specific prototype(s) becomes proxies of theoretical instances to be put to the test to understand the dynamics related to the use of, e.g., materials, technologies, social interactions. Concept 3 "Evolution" related to the emergence of new prototypes and ways of prototyping connected with the technological digital revolution. Concept 4, "Milieu", described the relevance of the context in which the research takes place and highlights the academisation of the design research.

In light of such a theoretical framework, we selected the relevant Case Studies that could let us test such findings. We interviewed three colleagues in charge of their research and asked them to share their thought about our theoretical findings and the details of the case Studies.

We interviewed:

Livia Tenuta, assistant professor at the Design Department of Politecnico di Milano, Italy, she shared the case of the design project "SmartJ. for Baraka";

Olga Noronha, designer, artist and visiting lecturer at Royal College of Arts and Central Saint Martins, who shared her doctoral thesis "Becoming the Body: An Investigation into the Possibilities and Affordances of Medical Jewellery,".

Tom Jenkins, Assistant Professor, IxD Lab IT, University of Copenhagen about the research project "Cohousing IOT".

While selecting those case studies, besides using the four concepts related to the use of prototypes, we also considered what we, the group of researchers participating in the Project PARIDE, meant with the term *advanced* prototypes, that is “prototypes - resulting similar, in terms of aesthetics and functionality, to a finished artefact - that allow a researcher to test user experiences, providing helpful information for designing future scenarios” (see Sect. 1.1).

The first two Case Studies belong to the area of wearable devices defined as discrete electronic hardware mounted on objects designed to be “worn” (e.g., glasses, headgear, footwear, skin patches, handbags) (Ferraro 2021). In particular, they belong to those classes of fashion products that accompany people in their daily lives and have a strong link with the body. Therefore, the term *fashion* is understood in those case studies as “equipment for the body,” (Farren and Hutchinson 2004).

In this view, the term *fashion* no longer alludes to the clothing industry but includes a broader number of categories of enabling products that act as body extensions.

The Case Study “Cohousing IoT”, apparently distant from the first two, uses research through design to probe alternative modes of living and prototype domestic Internet of Things devices and propose new roles for internet-connected things to support and sustain the social life of a co-housing community.

The three explored Case Studies, therefore, in our opinion, well represented the broad view of interaction design and some of the contemporary trajectories for the sector as:

- they arose from the intersection of fashion/product and technological progress (enabling and requiring the creation of new types of prototypes);
- they operated experimentally in a dimension of complexity at the boundaries of heterogeneous disciplines, describing realities that are sometimes at odds with traditional practice (broadening its perspectives, fields, research methods, and uses of prototypes);
- they were projected towards a practice aimed at integration between disciplines, approaches, different skills and professionals, between products, enabling technologies and spaces, between products and the human body;
- they were targeted to improve human-human experiences (Case Study “SmartJ. for Baraka”) and social aspects such as disability (Case Study “Becoming the Body”) and co-housing (Case Study “Cohousing IOT”).

Once the objectives and themes were defined, the three Case Studies were first described in terms of time frame, partners (institutions, companies, and organisations), people involved and their role in the project/research, overall research description, context, and disciplinary area definition. Secondly, we investigated the role of the prototype in the three studies through an interview addressed to the reference person and a description of each Case Study.

The first part of the interview explored the four theoretical concepts related to the use of the prototype (Transition, Making theory, Evolution and Milieu) and how those concepts can be reflected in the research practice.

The second part was based on a questionnaire that framed: the research phase(s) in which the prototype was used and aims for which they were made.

5.1.1 Integration of digital technology for a jewellery company

The combination of digital technologies and fashion has enabled a new lever for companies' success: creating an experience for consumers, who can acquire an active role by interacting in the process (Testa 2019). Livia Tenuta's research activity was set in this framework and, in particular, had the objective of defining a methodology able to combine the processes of fashion design and the engineering approach (Tenuta 2016). According to her research in the field of fashion technology, fashion design and engineering methods are currently applied alternately or in an imbalanced way, showing a lack of integration and dialogue between the two fields. Therefore, Livia Tenuta's work aimed to develop a fashion-wearable design methodology that could potentially embody authenticity. Her research indicated and analysed the limits of wearable technologies intended not only as products but also as a systemic and procedural dimension offered by a design-oriented approach. The experimentations on the methodology to design wearable devices gathered different workshop activities and industrial partnerships run at Politecnico di Milano. The Case Study here presented is part of the "SmartJ." project (Cappellieri et al. 2020) took design research out of the academic context to respond to market demands.

Interview on Theoretical Findings In relation to the first concept, "Transition" from abstract to concreteness, Livia Tenuta confirmed that, in her research practice, the prototype is the tool that allows magmatic and conceptually embryonic ideas to be made manifest through forms of representation that can be sounded out. Indeed, for Livia Tenuta, the prototype is the means by which to verify that all the characteristics and specifications identified in a conceptual phase can be applied to an actual physical product. Since this is a type of research aimed at investigating the relationship and interaction between body equipment and the body, the prototype takes on the role of a tool which, within the research, facilitates not only the transition from chaotic, confused and sketchy to clear and defined but also from abstract to tangible. Within her research, the prototype facilitates the transition towards materiality and realism: "We tend to make prototypes that are not 100% functional but realistic. Even if the final materials are not used, the experience of contact with the prototype must represent the real final experience". Although in this research the prototype describes this kind of transition, Livia explained that she is interested in and recognises the value of using the prototype as an enabling tool for a transition to the speculative and immaterial dimensions as well, especially

concerning future scenarios and trends definition. In the concept “Making Theory”, Livia Tenuta recognised within her research practice the importance of the prototype as a tool capable of going beyond its function of supporting the initial technical development phases. For example, the prototype becomes a useful tool for preliminary verification of the functioning of certain elements of the concept (going beyond materiality), but also a tool for making theory. According to Livia, prototypes are the result of a methodology that starts with research, goes through concept definition and ends with realisation. Learning by doing activities of carrying out practical actions contributes to creating theories and generating theoretical content - as in the case of the “SmartJ.” project. With respect to the concept of *the emerging of new prototypes and ways of prototyping*, Livia explained that in her opinion the digital technological revolution has had an impact on the development of prototypes, this does not only concern the product, as in the case of integrated technologies, but also the production processes: she referred in particular to the technologies that allow interaction with virtual products thanks to augmented or virtual reality, or products with integrated technologies that generate physical responses and stimuli. On *the influence on the context on research activity*, Livia acknowledged that the role of the prototype is influenced by the context in which it is used. As a result, academisation and doing theory through practice have influenced the characteristics of the prototype itself and the research activity. This evolution has led to a more complex role for the prototype that can evoke discussion and reflection and can be used to test a theory and ultimately create new knowledge: Livia explained that in her practice the prototype is a tool not in itself but functional to something, it refers to the initial stages of research or concept development, and experimentation may not necessarily lead to a positive result. So, this iteration and validation through a physical or virtual prototype also helps to create knowledge through experimentation and testing.

5.1.1.1 Case Study SmartJewellery for Barakà

Description In 2015, Alberto Muraro, CEO of Barakà, an Italian company that caters to a male audience, turned to the research group of the Design Department of the Politecnico di Milano to develop a connected quantified-self bracelets collection. The group specialising in wearable technologies was coordinated by Prof. Alba Cappellieri and composed by Livia Tenuta, Valentina Bruzzi, Secil Ugur. The project involved a tech company responsible for the engineering part of the process. In particular, the brief of the project was to create a collection of technological jewelry pieces for people in business over 35, including mainly small-sized and precious bracelets without having the appearance of a gadget. For the Politecnico di Milano research group, it was an opportunity to test the co-creation methodology between fashion designers and engineers in actual practice. The

research was organised in the following phases: (i) the brand study, encompassing formal and material aspects, product type, and target audience hallmarks; (ii) market analysis and potential competitors; (iii) identification of existing technologies that could be combined with jewelry; (iv) scenarios and concepts development; (v) design of the products of the collection and their features; (vi) products realisation. After the first preliminary phases (i and ii), available technologies on the market were investigated and divided into three categories to simplify the approach to technology: input, output, and data transmission. Instead, more challenging research was carried out for batteries representing one of the most significant limits in size and duration.

Based on existing technologies, three possible scenarios were identified:

- Bracelet>smartphone>bracelet: the bracelet was the tool that received inputs from the environment or the body, transmitted the data to the smartphone reworked them, and sent the output to the bracelet. For example, the jewel monitored the heartbeat, the mobile phone stored the received data, recorded that the beat was regular, and sent the signal to the bracelet that communicated information to the user through a sound, a vibration, or a light signal.
- Bracelet>smartphone: the bracelet was the input to activate a function on one's smartphone. For example, by contacting the bracelet and the smartphone, one could access private data.
- Smartphone>bracelet: the phone received the input, displaying the output on the bracelet. For example, the user could get a call on the smartphone, and the signal was also sent to the wearable device.

Based on the analysis, a collection in which all the products had common characteristics was designed. The technology part could be easily removed and replaced to be updated directly in Barakà boutiques, making the user-brand connection increasingly closer. All scenarios relied on the Barakà app to alert the user when a new product and latest updates were released. All jewels were thought not to have a seasonal duration but to resist the passage of time, be updated and customised according to the tastes, but always following the brand's aesthetic. From the direct experience of the physical realisation of the design, some difficulties in developing miniaturised technology on a small scale emerged. Because of the challenges mentioned above, the product did not reach the market right away (but only a few years later). Indeed, it required more investment to solve miniaturisation challenges. The process led to consideration in terms of methodological approach, and a clarification of the roles and expertise needed. This project, together with other experiences in the field, led to the tentative development of a hybrid methodology that combined some elements from both the fashion design and the engineering methods. The two approaches were combined to tackle problem definition and investigate user needs and desires, the fashion market, current trends, and innovative technologies that were ready to be applied to industrial production.

The initial definition of basic requirements was followed by the most creative part of the project, in which brainstorming led to the generation of a specific future scenario. Products were centre stage and become the focal interaction point between users, the environment, and other objects. Equally important, nonetheless, was the correct identification and analysis of specific personas on whom to tailor the project. These steps were crucial to set the project on the right course: the procedure enabled designers to identify with a specific set of users and understand their needs and issues to develop the original project. The proper management of the two stages positively affected the following definition of a precise concept. It also eliminated the widespread inclination to equip objects with too many functions and even enhanced the relationship between their shape and function. The concept stage witnessed the identification of materials, shapes, and interaction dynamics by means of technical sketches. Later experimental prototypes were completed, tested, and evaluated. Qualitative checks, typical of the engineering approach, were in place and matched by a qualitative assessment that tested user experience by measuring the intensity of the users' emotional response to product interaction. All these steps had to be managed by designers and technology experts, as only the joint application of their respective skills may lead to successful products.



Fig.5.1 Project SmartJewellery for Barakà

Data Collection and Analysis The principal investigator of the project, Tenuta, told us that no other term was used by the research team to refer to prototypes. Regarding the project phases, she highlighted that prototypes were mainly used in the conceptualisation and design development stages. The concept of “Fidelity” in describing the prototype was applied and referred to as medium fidelity.

The specific aims selected by the interviewee applied to the use of the prototype within the research ‘SmartJ. for Baraká’ were the following ones: develop (finalise design and resolve), assess (test, evaluate/analyse, improve), communicate (persuade/reassure, show, get feedback), represent (visualise), comprehend (understand, collect (data)), research (produce (knowledge), translate (abstract to concrete)), identify (problems), investigate (issues), explore (experiment, experience), provoke (discuss (critical)), foster (imagination/creativity), anticipate). When later we asked to group prototypes with similar aims in different stages of the research process (see Sect. 3.1.3.4) Tenuta highlighted three groups. The *first group* consisted of 3D models and realistic rendering of the object used within a scenario (however they were defined with the term ‘models’ not ‘prototypes’) with the aim of fostering imagination (envision). They could be digital and visual, virtual and fictional. Indeed this group was displayed in the IV Quadrant of the interactive tool (dot 5.1 Fig. 5.2). These were employed in an intangible phase of the research with a speculative scope. The *second group* referred to aesthetic prototypes by verifying that all features and specifications identified at a concept stage can be applied to an actual product (therefore to finalise design). These prototypes were not 100% functional, but they were physical and realistic. They were made from materials that were not the final ones but resemble them, and the experience of contact with the body had to represent the actual final one. They were used in a tangible and concrete phase. The *last group* dealt with physical prototypes that provided for technological integration. Therefore, as in the previous group, the phase in which they were used in it was tangible and concrete. These two groups were displayed in the III Quadrant of the interactive tool (dot 5.2 and dot 5.3 in Fig. 5.2).

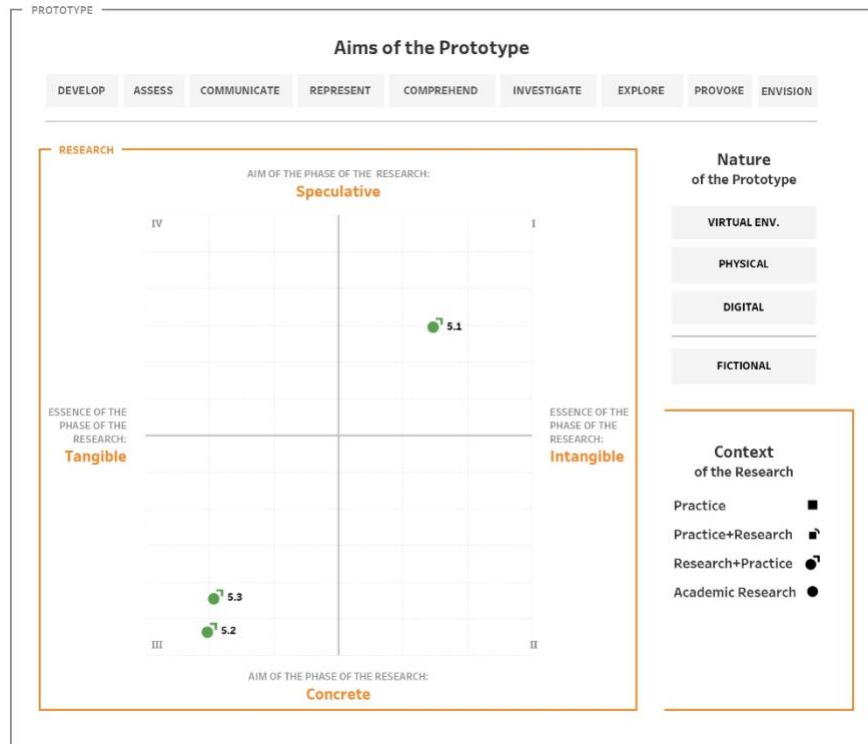


Fig.5.2 Case Study “SmartJewellery for Barakà” displayed in the interaction tool

To summarise, ‘SmartJ. for Baraka’ research moved in a tangibility dimension and had concrete objectives: developing an innovative project for an actual company. Even though a speculative phase was held to envision possible solutions before the design. The prototypes were essentially physical and used in the project development phase.

5.1.2 Exploring possibilities and affordances of “Medical Jewellery”

The multidisciplinary research areas that animate the complexity of contemporary fashion include the scenario arising from the integration of medicine, orthopaedics, and projects investigating the relationship between disability and aesthetics. The results are objects suspended between ornament and medical function and define a new relationship between the traditional image of illness and physical defect and a unique, intimate idea of beauty. Olga Noronha’s research

practice analysed the intersection between anatomy, medicine, and ornamentation and explored the concept of “jewellery as prosthesis.” In “Becoming the Body: an Investigation into the Possibilities and Affordances of ‘Medical Jewellery,’” (2018), she proposed a vision of implanted prostheses being transformed into intra-body jewellery.

Interview on Theoretical Findings With respect to the first concept, *the transition from abstract to concreteness*, Noronha recognised in her research the role of the prototype as an instrument capable of making magmatic and conceptually embryonic ideas manifest through forms of representation that can be fathomed. It is a process of ideation and materialisation, and therefore a path towards the tangible. In particular, for ‘Medically Prescribed Jewellery’, she talked about ‘advanced and accurate prototyping’, which can be computerised or manual. Noronha has a particular schematic that she follows, and she needs to base her prototypes on the dimensions of medical products, on the application of those medical devices and the anatomy of the human body. So, tangibility here is not conceptual but technical because she produces something that then has to be tested mathematically, quantitatively and qualitatively. When asked to place her research activity in the realm of ‘material and realistic’ or ‘speculative and immaterial’, or crosswise - she replied that with Medically Prescribed Jewellery she created speculative objects that are prototypes for realistic approaches. She recognised the value of a type of approach linked to the use of intangible prototypes, as in the case of using the telling of a story (intangible and imaginative) as a form of prototype for testing with possible patients - but said that most of the time she would show an image, so the impact is different, and the tangible aspect is on an image. Reasoning on the second concept, Noronha argued that *making theory* is a prerequisite for her prototypes because they are epistemic objects, they are enriched when they gather knowledge. They present knowledge and frameworks that then allow her to further develop a project through those objects. With respect to *the emerging of new prototypes and ways of prototyping*, Noronha acknowledged the impact that the digital technological revolution has had on the development of prototypes at different levels. However, she claimed to have no particular knowledge of 2D or 3D projection. She prefers to represent things in drawings and modelling to actually have the dynamics of touching perception. She does not use these types of technologies for most of her work. As for “Medically Prescribed Jewellery”, she has not yet tested the products, but they have to be tangibly tested in the laboratory. Noronha pointed out that these are complex prototypes and because of their nature they require the coordination of different professionals: from a technical point of view, the medical jewellery has to go through a laboratory, engineering universities and biomechanical engineers. The consumer experience was very difficult to test: Noronha said that, within medical products, when you think about health recovery, you can’t really talk about consumerism and experience. In fact, the aim was to achieve a balance, in this case, between the aesthetic and psychotherapeutic aspects of what she was offering, and the fact that it actually worked as a real medical

device: the aim was to heal - to help mentally and to heal physically. It was not within her competence to be able to test them, but it required many other professionals. Olga Noronha's objects are unstable objects because they can be seen in different ways depending on the context: they can be seen as medical prototypes, sculptures that talk about medical devices and the body, or design products. They tell a story and can be exhibited in a gallery or a museum, in which case they can be taken either as finished objects or as prototypes. At different times, they can be suitable for different purposes: aesthetic prototypes and functional prototypes where functionality requires much more expertise than just the person who created that idea. Lastly, Olga recognised *the influence on the context on her research activity*: there are places that consider design research as a mathematical production process, and other places that take design research as a creation of philosophical knowledge about the object and the user experience and the way people act and interact with design. Olga said that she developed the concept independently, and developed the aesthetics and materialised the concept influenced by the field and context she was in. And then, while doing her MA and PhD, she was influenced by a College context that was much more into anthropology and philosophy.

5.1.1.2.2 Case Study “Becoming the Body”

Description The research was developed between 2011 and 2018. It took place at the Arts and Humanities Research Council. It started at Central Saint Martins for one year, and then it went on at Goldsmiths University. Noronha was the design researcher and head of the project. To develop the research project, she collaborated with patients (physically vulnerable people), doctors (such as orthopaedic surgeons), and mechanical engineers in Portugal. The research investigated the social and psychological aspects of body modification and medical interventions on and in the body by analysing biomedical research into the repair of the body, surgical procedures, material compatibility, and prosthetic design. Noronha then outlined the theoretical underpinnings of the work, the necessary practical-material considerations in producing ‘viable’ medical jewellery, and the understanding of its reception in different contexts (medical and jewellery). She suggested an alternative way jewellery could operate by adapting the perception of medical repair (from wound stitching to joint replacement) and inquiring about the feelings/perspectives of the body when repaired. The work had come about by considering sites on and in the body at different ‘archaeological’ layers (from outer to inner physical space), namely orthotics subdermal, exodermal, exo-corporeal intracorporeal jewellery. These layers presented a series of “medical jewels” that recognized science, jewellery, and technology as accomplices to repairing and enhancing the ‘self’ while adding value to the mended body. Rather than only a medium for expression, the repaired or fixed body became a locus for experience, symbolism, and aestheticization. The jewel is understood to both aestheticize the body (it becomes you) and become integrated and integral to the body. In this research, “becoming the body” indexed an aesthetic enhancement of the body; naturalisation in the body

- as a body replacement or part of it; completion or repair of the body, and a prosthetic enhancement. By moving jewellery into this space (namely surgical repair), the research and its practices tested the boundary/edge of what jewellery is and is not, what it may mobilise, and how it may perform. Also investigated how different publics received the work and how it moved through and across different epistemic constructs (art and science). The *discursiveness* of the practice was defined by understanding how the different designs performed in different situations, provoking and raising questions that were both specific to and cross-contrasting scenarios. The research had a twofold objective by intending to minimise or deflect the negative and mutilating effect inherent to medical repair. From one side it aimed to comprehend how the speculative medical jewellery - seen as tangible results of the aestheticized scientific technology and medical knowledge - was emotionally and physically experienced; from the other, to understand the knowledge they could gather and convey. During this doctoral academic research, Noronha was not fully developing the artefacts/medical objects but was doing research led by practice. She was reflecting on the practice she had already carried out to understand the response from different fields toward the concept and objects she had created. So, it was understanding how those objects of medically prescribed jewellery could open many other possibilities in science, design, and art.

Fig.5.3 Project Becoming the Body



Data Collection and Analysis Olga Noronha, when asked about the terminology adopted to refer to prototypes, stated that she would call them ‘prototypes’ only at a very high stage of inquiry. She would refer to these also with the term ‘models’: rough and simple paper models to catch dimensions and material tension. However,

instead, she would call them ‘artefacts’, because that was actually how they were sold to clients, ‘limited edition artefacts.’ These ‘final artefacts’ were anatomically perfect items but not implantable and usable as medical devices.

The prototypes in the mentioned research were usually used in the design development phase, while fidelity was an implicit attribute for her.

The aims for which prototypes were used ranged from developing (finalising design, creating/designing), assessing (testing, evaluating/analysing, validating, improving - she would pick something that already existed and then adding something new), to communicating (getting feedback, conveying), representing (simulating, visualising), comprehending (understanding), researching (producing (knowledge)), exploring, provoking (investigating, speculating), and envisioning (anticipating).

When later we asked to group prototypes with similar aims in different stages of the research process (see Sect. 3.1.3.4) Noronha highlighted four groups of prototypes. The *first group* consists of realistic photomontage or realistic 3D generated images together with a story (conceptual tangibility). This first group of prototypes helps in gathering responses, and then the research continues with the project development and the creation of the “final artefacts”. The aim of this first group of digital (and visual) and fictional prototypes is to get feedback (communicate). The essence of the phase of the research is mainly tangible and its aim is speculative. Indeed, this group was displayed in the IV Quadrant of the interactive tool (dot 7.1 Fig. 5.3). The *second group* (conceptual tangibility) is represented by study-sketches and drawings - physical prototypes that are used to support the creation within the development phase. The essence of this phase is tangible and mostly concrete. Moving to the *third group*, this relates to model making: rough and simple paper models just to catch dimensions and the material tension to actually have the dynamics of the touching perception (conceptual and technical tangibility). They are physical prototypes used with the scope of finalising the design. As in the case of the second group, the essence of the phase in which they are used is tangible and mostly concrete (technical tangibility). These two groups were displayed across the III and IV Quadrant of the interactive tool (dot 7.2 and 7.3 Fig. 5.3). Lastly, the *fourth group* is represented by physical realistic final artefacts with accurate aesthetic qualities, such as the weight and the way it is positioned as an object in terms of scale or dimensional balance. It might be in that case computerised or manual, but usually manual. They are adopted with the purpose to evaluate/analyse (asses) in a tangible and concrete phase of the research. This group was displayed again in the IV Quadrant of the interactive tool (dot 7.1 Fig. 5.3).

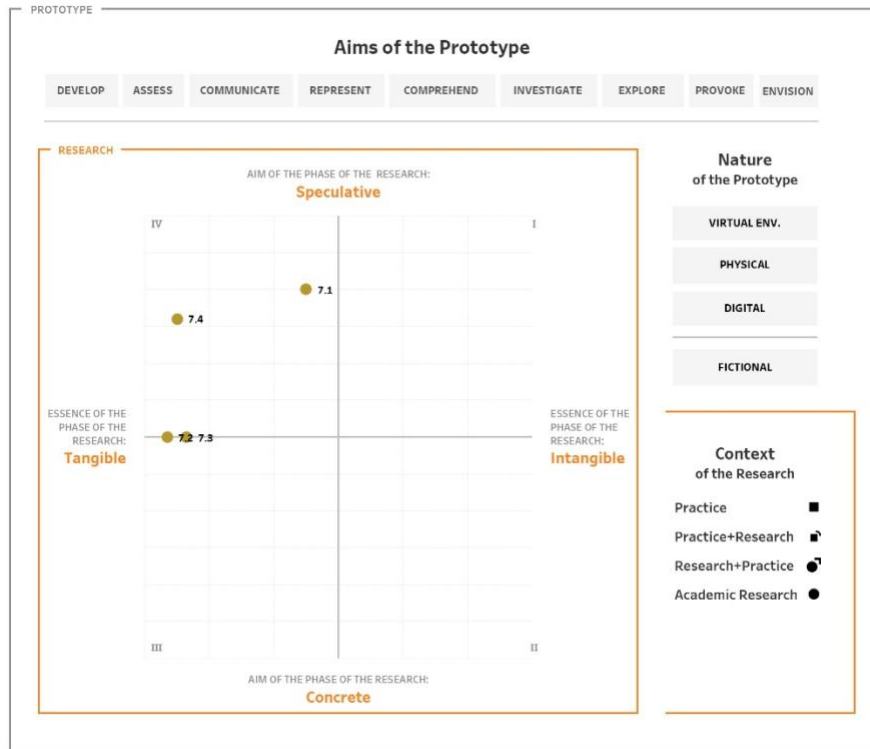


Fig.5.4 Case Study “Becoming the Body” displayed in the interaction tool

Olga Noronha’s practice, presented a type of research with a tangible essence (investigation and design in the field of medical jewellery), characterised by both speculative and concrete objectives: on the one hand, to investigate, envision and speculate on possible future scenarios for medical jewellery, to generate knowledge and provoke, but also to develop aesthetic and plausible artefacts in their functionality, to test the emotional and physical response of possible patients. The prototypes she used were mainly physical (she called them ‘artefacts’) and used for developing, assessing, and communicating during the research's development phase.

5.1.3 Prototyping Internet of Things (IoT) devices for co-housing communities

Interview on Theoretical Findings Tom Jenkins explained how the four theoretical concepts interlaced his research. Concerning the first concept, “Transition” from abstract to concreteness, he said that in his opinion, being the prototype a filter for the design activity- it embraces the concept of transition, and its nature (physical-digital) depends on the type of the idea you are developing. For instance, it could be a sketch, a collage of images or a rough model to explore the form giving. Moreover, according to him, the nature of the prototype depends on its purpose so that it could be an image, a tiny model, or even a material sample.

Concerning the topic of the research placement, if in the material and realistic realm or the speculative and intangible one, he stated that his research is across the two words. From his point of view, the prototype objects represent “matters of concern” (i.e. a social one): they tell a story, and by doing so, they are an expression of reality. That said, they could both be used to be a manifestation of an idea or to speculate. For instance, if “we prototype to speculate existing technologies, we create new configurations of infrastructures and materials. Indeed, the prototype generates new contexts for existing products and services as well as new understandings of how they might operate in different social worlds”.

Moving to the concept of “Making Theory” through prototyping, Jenkins explained that, in his opinion, the prototype is a valuable “thing” to carry on theory but also to concretize it. Besides, the prototype is useful for adding and generating theory/unique knowledge. About the knowledge, he believes that it is encapsulated into the prototype itself that being unique is a demonstrator of new knowledge (i.e. understanding how to change user behaviour).

While discussing the topic of *the emerging of new prototypes and ways of prototyping*, he confirmed that the role of the prototype has certainly evolved thanks to the digital revolution and that it is now part of each design activity (both in practice and in research). In light of the technological signs of progress, he believes that in our digital era, we should all have competencies in making prototypes using Arduino or unity, mainly because the competencies are shared among the teams of researchers.

Finally, about the concept of *the influence of the context on research activity*, he agrees that the context influences the research activity and, consequently the nature and the role of the prototype. At the end of the interview, we discussed the academization of the design discipline, and, in his opinion, prototyping is becoming part of the design discipline. Still, it is a bottom-up phenomenon rather than a top-down one. He doesn’t see academization. “Prototype is both a manifestation of an idea, so it is related to the practice and then to the education and a manifestation of a design research activity. He finally suggested an exciting definition for the prototype: “prototype as a provisional thing”, a contemporary sentence that embraces most of the concepts elaborated within the research project PARIDE.

5.2.1. 3 Case Study “Cohousing IoT”

Description Cohousing IoT was a Research Through Design project that prototyped social Internet of Things (IoT) devices for co-housing communities. It was developed in 2018 at the Georgia Institute of Technology under the supervision of Tom Jenkins, now an Associate Professor at ITU of Copenhagen (Jenkins 2018).

One of the main objectives of the research was to speculate on domestic IoT devices. By developing three tangible working prototypes, it wanted to imagine alternatives to existing arrangements of things and devices in the home. The prototypes were used to envision new roles for internet-connected things that supported and sustained a co-housing community’s social life. The development of the speculative prototypes went through a deep analysis made up of interviews, site tours, and attending everyday meals. Such activities provided different perspectives on co-housing, and thanks to them, it was possible to understand how shared life is lived and practised. Furthermore, the research project prototyped speculative technological systems to create new infrastructures and materials configurations. Three systems were prototyped to instantiate new social forces arrangements, not simply to have objects themselves. In detail, the researchers developed a community-based radio system, a platform for RSVPing to common events, and a device to help residents reflect on community participation.

The Cohousing Radio was built to connect residents in co-housing in a new, socio-material way; it imagined each residence with a small radio placed in the home. Residents can use this device to send audio files to other community members.

The Physical RSVP provided co-housing residents with a way to respond “materially” to invitations to events within the community. Every resident could register their intent to attend the event by placing a clay ball in a bowl; this way, the event’s organiser could plan for the correct number of people. These balls were equipped with an NFC read by an Arduino-based reader on the underside of the prototype. Thanks to the Arduino, a notification was sent to a shared community calendar to update the attendance.

The last Cohousing IoT prototype was a set of scales that helped a resident reflect on their participation in the community. In the Participation Scales prototype, the position of the scales’ arms represented an individual household’s level of involvement in the community (i.e. attendance at events, work hours, and so on). This prototype was envisioned to shift current ideas of domestic IoT to monitor the home’s condition to understand the needs of your participation in a community. The three speculative prototypes aimed to articulate current issues in co-housing while simultaneously proposing new opportunities for community collaboration via smart home technology.

Fig.5.5 Cohousing IoT
prototypes. Radio Prototype



Fig.5.6 Cohousing IoT
prototypes. RSVP Prototype



Fig.5.7 Cohousing IoT
prototypes. Scale Prototype



Case study: Cohousing IoT.

Data Collection and Analysis Tom Jenkins was very clear on the role of the prototype. He stated, “The whole project is about the prototype. The prototype is specifically used as a transition (from abstract to concrete) to make people understand”.

When it comes to terminology, there were no other used terms; the word “prototype” was the only recognized one.

Regarding the phase, the author declared that the three prototypes were used in the conceptualization and detailing phases while the fidelity was obviously high.

In the Cohousing IoT research, the prototypes had different aims, namely: to develop (finalise and create/design), to assess (evaluate and validate), to communicate (show, get feedback and convey), to represent (simulate and embody) to comprehend (share/negotiate and collect data), to research (produce knowledge) but most of all, to speculate and anticipate future scenarios. Indeed, as described, the main objective of the Research Through Design project was to use tangible prototypes to speculate new Internet of Things devices.

This Case Study is a very peculiar one since the research was based on interviews, site tours, and researchers attending everyday meals, just one class of prototypes was developed to reason on speculative scenarios.

While discussing with the principal investigator Tom Jenkins, it arose that the essence of research was highly speculative (it was marked as 5) while the nature of the prototypes was both physical and digital.

The aim of the prototypes though the overall research was in fact to be as tangible and interactive as possible to be used and tested by the residents and help the research groups to envision new scenario for the IoT devices.

The usage of the three prototypes in engaging in multiple ways offered advantages in terms of *thinking through co-housing* as a space for smart home technology design. Briefly, the essence of the research was to speculate about the role that computing technology can take on in that living together.

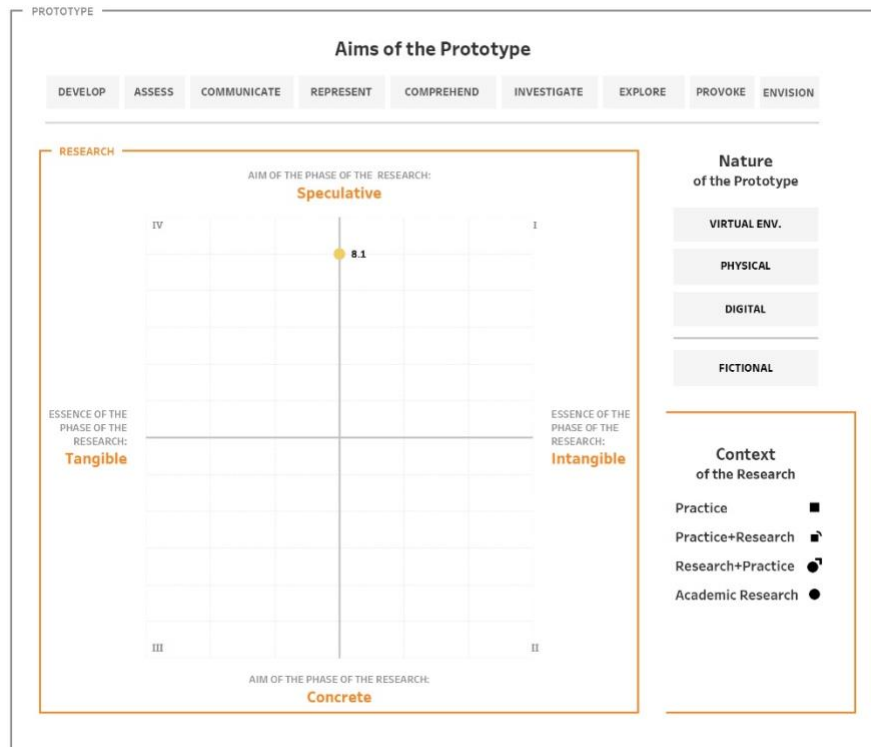


Fig.5.8 Case Study “Cohousing IoT” displayed in the interaction tool

4.5 Discussion

After sharing all interviews and Case studies, we – the research team of the study PARIDE created an interactive tool to display the Case Studies (Fig. 3.4). In such visualization, the three Cases presented in this chapter corresponded “SmartJ. for Baraka” to n°5; “Becoming the Body” to n°7 and “Cohousing IoT” to n°8. As the dots on the tool the represented group of prototypes made for the same step/aim of the research, we could see that most of the prototypes for these cases are tangible, with an exception for number 5.1 (in Fig.5.2) that was a speculative phase based on visual models.

“Becoming the Body” and “Cohousing IoT” fit into the speculative area of the tool while the other two groups of “SmartJ. for Baraka” belonged to the concrete area.

Selecting the objectives of the three Case Studies one by one, we found that most of the points on the interactive tool (Fig. 3.5) belonged to the first two objectives,

namely “develop” and “assess” (4 develop, 2 assess, 1 communicate, and 1 envision).

Even if the two academic research Case Studies (“Becoming the Body” and “CoHousing IoT”) were placed in a more speculative dimension, and “SmartJ. for Baraka” Case Study was oriented towards a context of concrete practice (precisely because it is based on collaboration with a company), there were phases that cross the graph and break these patterns. This is the case, for example, of the first group of “SmartJ. for Baraka” prototypes which was in the I Quadrant. This showed how speculative and fictitious approaches in design research can also be useful for practice-oriented (concrete) research. Or vice-versa, by exploring “SmartJ for Barakà”, “Becoming the Body” and “Cohousing IoT” research projects, we discovered that medium and or high-fidelity prototypes that apparently might be used for concrete (close to market) projects were actually developed for speculative and envisioning reasons.

When we observed the trends highlighted in Sect. 3.2.3 (Fig. 3.5), with regard to the objectives of the research phases, we noticed that two of the three Case Studies moved down towards concreteness and from right to left toward more tangibility, but then both come back up for reflection even though in different quadrants. This shows that the role of prototypes is to make the idea more concrete but also to tend and evaluate the research towards theoretical results. Indeed, as said, while one, “Becoming the Body”, is purely academic research, the other, “SmartJ. For Baraka”, is an academic study for an industrial partner. So, it was interesting to notice a similar path but in different areas of the tool that corresponded to the different context of the studies and, possibly, to the different research questions and, thus, role of the prototypes accordingly. While the Case Study “CoHousing IoT” remained mainly in the realm of speculation, meaning that all prototypes used here share the same main aim.

“Prototypes (Greek *protos* = first) are intended to test the function and performance of a new design before it goes into production. Traditionally, prototypes represent one of the last stages of the product development process before the product is industrially manufactured” (Erlhoff and Marshall, eds. 2008).

While this definition refers to a outdated idea of prototypes and the role they play in design research, nowadays prototypes can be intended as anything that takes an idea from our head and makes it visible to others. In this wider perspective the three Case Studies here described and analysed confirmed a more complex and refined meaning connected to the word “prototype” or, better, to the activity of prototyping.

We can prototype to communicate the idea to others or test with users, with the intention to improve that idea over time, discover new solutions, and envision and speculate future scenarios. The Case Studies analysed in this chapter concerned research from academia or from fields that combined research and practice and covered different facets of interaction design. They are united using mostly physical prototypes that are employed in research whose essence is mainly tangible.

They represented the evolution of design research that, on one hand, brought speculative steps into studies for companies, where prototypes supported the integration of design and technical aspects toward the concrete making of new smart jewellery. On the other hand, design research crossed boundaries connecting medical devices to artistic speculation into the making of provisional objects that would never be mass manufactured but sold as art pieces. Nonetheless design research investigated possible interactions among community of co-housing habitants through that making of working prototypes that could be experienced by the user but were meant to test hypothesis not to create new products. So, in the realm of interaction design, tangible prototypes support research for practice and speculation focusing in particular on the possibility to gather user reaction to new solutions and possibilities.

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