AN IDEATION METHOD IN DESIGN FOR IOT: CREATING OBJECT PERSONAS VIA SENSOR DATA

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ABSTRACT

AN IDEATION METHOD IN DESIGN FOR IOT: CREATING OBJECT PERSONAS VIA SENSOR DATA

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Internet of things (IoT) introduced some challenges as well as many opportunities for designers. Enhanced capabilities of the things transformed them from being passive assistants of humans to active agents that can collect and act on data. On the one hand, the emergence of new and more capable 'things' constitutes challenges for designers. Most of the studies are technology-driven, and the unprecedented experiences that designers cannot envision might result in disappointing experiences for users. On the other hand, the availability of data that is collected and used by the things provided a new source of information that designers might benefit in the early design process. The studies on the use of data collected from the things to develop new agents by designers are still emerging. This study aims at contributing to the design corpus by proposing a method for guiding designers in their design for the IoT process. This method proposes using sensor data collected from the connected things to create a design fiction prototype—an object persona from a thing-centred point of view. The method was developed through three workshops with designers. As a result of the iterative workshops, sensor data supported object persona creation was proposed for designers as an ideation method in the design for the IoT process. The effectiveness

of the method was then evaluated with experts. The method was found to be effective in the ideation process in design for IoT as it helps designers envisioning potential interactions of agents with users, with other agents, and with the environment.

Keywords: object persona, sensor data, thing-centred design, data enabled design

ÖZ

NESNELERİN INTERNETİ İÇİN TASARIMDA BİR FİKİR GELİŞTİRME YÖNTEMİ: SENSÖR VERİSİ İLE NESNE PERSONALARI YARATMAK

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Nesnelerin interneti, tasarımcılar için bazı zorlukların yanı sıra birçok fırsatı da beraberinde getirdi. Nesnelerin gelişmiş yetenekleri, onları insanın pasif yardımcıları olmaktan çıkarıp veri toplayabilen ve bunlara göre hareket edebilen aktif aktörlere dönüştürdü. Çalışmaların çoğu teknoloji odaklı olduğundan ve tasarımcıların hayal edemeyeceği benzeri görülmemiş deneyimler, kullanıcılar için hayal kırıklığı yaratan deneyimlerle sonuçlanabileceğinden, yeni ve daha yetenekli 'şeylerin' ortaya çıkışı tasarımcılar için zorluklar oluşturdu. Öte yandan, nesneler tarafından toplanan ve kullanılan verilerin erişilebilirliği, tasarımcıların erken tasarım sürecinde yararlanabileceği yeni bir bilgi kaynağı sağladı. Tasarımcıların yeni aktörler geliştirmek için nesnelerden elde edilen verileri kullanmasına ilişkin çalışmalar halen devam etmektedir. Bu nedenle, bu çalışma, tasarımcılara nesnelerin interneti sürecine yönelik tasarımlarında rehberlik edecek bir yöntem önererek tasarım külliyatına katkıda bulunmayı amaçlamaktadır. Bu yöntem, bağlantılı nesnelerden toplanan sensör verilerini kullanarak bir tasarım kurgu prototipi—nesne merkezli bakış açısından nesne persona-

ları—oluşturmak için önerildi. Yöntem, tasarımcılarla yapılan üç atölye aracılığıyla geliştirildi. Yinelemeli atölye çalışmaları sonucunda nesnelerin interneti için tasarım sürecinde bir fikir oluşturma yöntemi olarak sensör verisi destekli nesne persona yaratımı tasarımcılara önerildi. Yöntemin etkinliği uzmanlarla birlikte değerlendirildi ve yöntemin, tasarımcılara nesnelerin kullanıcılarla, diğer nesnelerle ve çevreleriyle olan potansiyel etkileşimini hayal etmede yardımcı olarak nesnelerin interneti için tasarımdaki fikir oluşturma süreçlerinde etkili olduğu görüldü.

Anahtar Kelimeler: nesne personası, sensor verisi, nesne merkezli tasarım, veri olanaklı tasarım

To my family

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CHAPTER 1

INTRODUCTION

Internet of Things (IoT), in its broadest sense, defines the internet connected devices that can talk to each other, collect data and act on the collected data. Ever since the introduction of this new concept, the internet connected objects—the things—have been replaced with ordinary objects that we have in our lives. Things are now active agents in our lives rather than passive assistants of activities. This change affected the interactions of people with objects as well. An interaction between a user and an object has become much more complicated than it used to be due to complex relations that interconnected objects bring into place. The expansion in the agents of an interaction should have a reflection in the design process.

The widely adopted user-centred design principles suggest that design starts with understanding the users' needs as the purpose of a design is mainly serving the user, the only agent. However, for the design for the IoT, users are no longer the only agents that should be served. It is mainly because the new product will not only be in interaction with its users but also be in interaction with other objects.

The present study is concerned with the new agents whose needs should also be addressed by the designers in the design for IoT. The new agents, the things, are the physical objects, materials, places, environments in a digitally connected world. The design for IoT points the design action of these new agents.

Knutsen (2014) advocates that connected products are still in infancy, and the studies on these products reveal that it is not well understood what these devices and services are. Therefore, the connected devices and their capabilities represent a demanding area of investigation in the design domain.

Existing studies for the exploration of emerging technologies are largely technology-driven, they do not provide any opportunity for designers to gain insight about the everyday needs of people. (Blomberg et al., 1993)

Although the expansion of IoT creates new design opportunities Cila et al. (2017), when it comes to the interaction, dealing with the increasing complexity of those devices is still challenging for designers. It is because literature for informing designers on how this growing adoption of technology should be embraced is inadequate.

Tuomi (2005) explains that designers used to deal with the interaction between an independent product and an individual person or other products that may be interfaced with. Interaction between objects and people transformed as connected products come into place. Designers now, have to think about the interactions in the complex system of social relations because people have to plug their new devices into the existing system to make them functional and significant. Thus, both object-centred views which put product characteristics in the centre and subject-centred views that take user characteristics in the centre remain lack in terms of developing designs that will operate in the era of IoT because the use forms the user as much as the user forms the use of a product. This stance is supported by Redström (2006) by asking the questions like what if designers quit searching for specific answers for the problems in practices and begin designing artefacts that are open to the answers from the users. Redström offers to turn back to the objects with a new perspective and leave these questions to the future users of the objects. Consequently, he points critical and experimental design to learn more about the use of its future users.

Dunne and Raby (2013) propose that the critique of the technologies can give an idea about the unquestioned use contexts of those technologies. Design fiction which is defined as a form of speculative design; uses fictional scenarios for speculating about the technology in human life in the future. The studies in design fiction are getting attention recently, but established methods to use design fiction for designing new things for IoT are still missing.

In this study, I aimed at using design fiction to understand the changing nature of things that can collect and act on data to contribute to the ideation process of designers in design for IoT.

1.1 Motivation

As a teaching assistant in an industrial design department, over the years, I witnessed the limitations that students face dealing with the design problems of the near future. In 2016–17 fall semester, final year students designed an autonomous campus shuttle for their industrial design course project. The project was carried out in teams. I conducted informal interviews with the design students about their design process. All the teams (Eight teams in a total of 36 students) reported that they interviewed with campus students to collect data to inform their design. However, the most recurring problems they found out were the ones related to drivers of the current campus shuttle. Thus, since they were designing driverless vehicles, then they assumed they would automatically correspond to the needs of the students. Then, they explained that they almost had nothing to refer to for envisioning the potential interactions since they could not have any design insights from their user studies.

This common frustration of all the teams guided me in the formulation of my research brief: find out if designers could have a more effective design process while designing for user experiences with the IoT technologies.

I started with a generic title: Design for IoT. In order to enhance my understanding on the subject of IoT, I got courses on ubiquitous computing, big data and data mining. As I developed an understanding on the data interpretation, I started seeing opportunities for designers. Then, I looked for ways to use data to inform designers on their design for the IoT process without turning the designers into data scientists. As I advanced in the study, I realised the change of the things and picked on this. Thus, my project has become more focused, and the title became: Creating Sensor Data Supported Object Personas as an Ideation Method in Design for IoT.

1.2 Goal

The goal of the proposed PhD study is the delivery of an idea generation technique for designing for the user experiences with IoT technologies.

The quantitative sensor data will be used for envisioning the objects' requirements

and support the creation of object personas which I define as the archetypes that communicate the observed practices of connected objects. Then, the designers will use these object personas for generating ideas.

In the era of the Internet of Things, the things will become the users as well. For that reason, the input for designers will be gathered both from the sensor data coming from the connected objects and users of those. As a result, the applicability of object personas to create design proposals by extracting meaning from the gathered sensor data from things will be tested.

1.3 Methodology and Research Questions

The study started with a general question: 'How can designers generate ideas during designing for the user experiences with IoT technologies?'

As the study was designed as an action research, this general question evolved in time. The evolution can be seen in Figure 1.1. There had been three iterations in the creation process of a novel idea generation technique for the design for IoT. The iterations were guided by workshops held with design students. Before the first workshop, a literature search was conducted to have an idea about the state of the art in design for IoT. As a result of the literature search in the domain of IoT, it was found out that there has been a drastic change in our perception towards the things. They have become agents just like humans. As a result of the literature search in the domain of design processes, it was found out that new approaches, methods and tools have been developing for the design of the things of IoT. These approaches, methods and tools require a critical perspective on user-centred design and reveal the potentials of data collected from the connected devices.This knowledge formed the first question: **'How can designers extract meaning from sensor data collected from connected devices?'** In search of an answer to this question, the first workshop was held with design students. As a result, I found out that the use of object personas may help designers to extract meaning from sensor data collected from the connected devices. Then, I dug deeper and aimed at finding out **'How does creating object personas with the help of sensor data affect ideation?'** To answer this question,

the second workshop was designed and held with design students. At the end of the workshop, the participants made it clear that the use of object persona boards helped their ideation by guiding them on the interactions of objects with users, other objects and their environments. At the third iteration, I would like to enhance the method and asked: **'How can I improve the object persona creation process to better support the idea generation?'** A data visualisation tool was created for the use of designers and presented to them together with the improved object persona boards in the third workshop. Since the proposed method was found promising another question was asked to prove the effectiveness of the method: **'What is the efficacy of using a new ideation method for the design for IoT?'** The evaluations of the workshop revealed that the use of object persona by using sensor data graphs increased the novelty of ideas in the design process.

1.4 Structure of the Thesis

First, a literature search will be covered in Chapter 2 and 3. Chapter 2 presents a concise background and visions of IoT to have a broad vision about the potential practices with IoT technologies. Chapter 3 discusses the design process for IoT, presents methods and tools from user-centred design and alternative and supportive approaches. Here, example studies that use alternative and supportive approaches to user-centred design to generate design insights in the design process will be presented and the concept of object persona will be introduced.

A series of workshops discovered the use of object persona. The strategies to conduct the workshops will be discussed in Chapter 4. Chapter 5 presents the three workshops. Section 5.1 and 5.2 cover Workshop 1 and 2 which were held to test the strategies. As a result of Workshop 1 and 2, an online tool was developed to inform the creation of object personas by allowing designers to interact with sensor data. Section 5.3 covers the test of the proposed tool via a design fiction outcome in Workshop 3.

Chapter 6 presents an answer to the last question and evaluates the efficacy of the proposed method identified in the light of literature search revealing possible data collection techniques from the agencies of IoT and the workshops iteratively pro-

gressing the discovery of sensor data supported object persona creation as an ideation method in design for IoT. Finally, Chapter 7 concludes the dissertation.

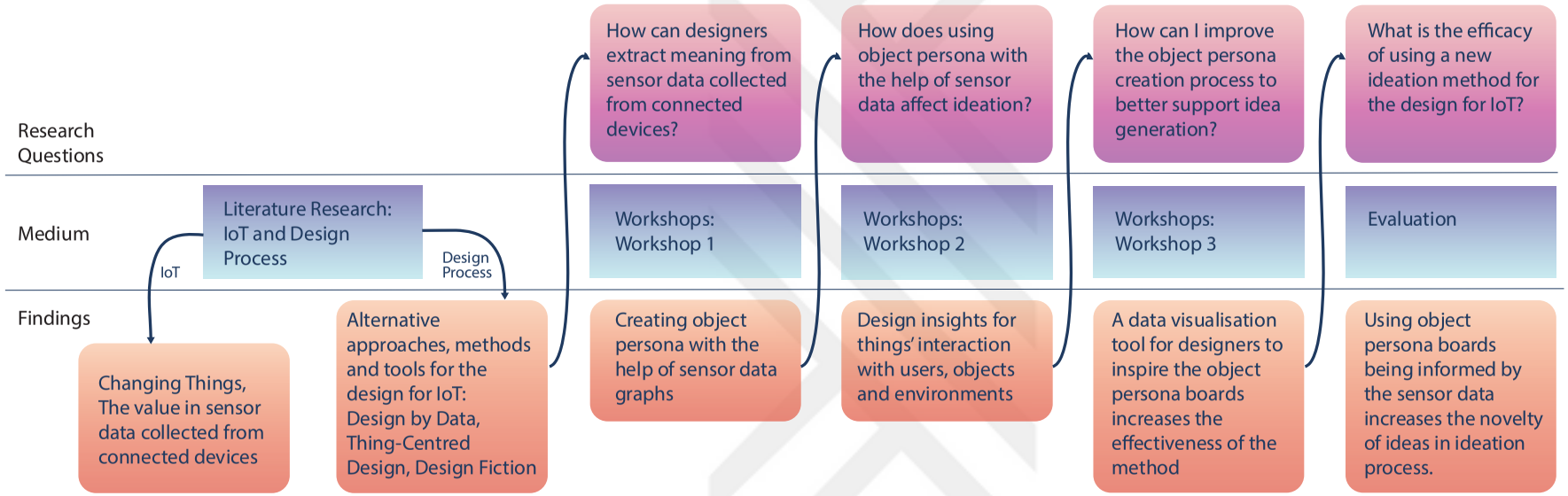


Figure 1.1: Research questions

CHAPTER 2

BACKGROUND AND VISIONS FOR IOT

This chapter aims to gain a broad perspective on the development and advancements in IoT. The search was focused on the advancements in technology that gave way to IoT, the different approaches adopted towards IoT and the projection of IoT in daily life. As a result, the advancements in technology helped to envision the future direction of IoT, different approaches helped to place the design practice in the scope and projection of IoT in daily life helped to have a better vision on the opportunities and challenges of IoT for the designers.

2.1 Background for IoT

Before the coinage of the term IoT, Mark Weiser envisioned the advances on the technologies of RFID, wireless sensor technologies, smart technologies, and nanotechnologies and put forward the term ubiquitous computing. In his paper The Computer for the 21st Century, published in Scientific American in 1991, he explained the technologies in the ubicomp era by saying 'The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it' (p. 94). From then on, various terms were used for describing the same concept. Mark Weiser also used embedded virtuality as an explanation to ubiquitous computing in the cartoon made by himself and provided by courtesy of PARC, the Palo Alto Research Center, Inc. (Figure 2.1).

The term pervasive computing is mostly evaluated as the synonym of ubiquitous computing. It is defined as the design of the computers which can become a part of the environment by integration into everyday objects and displays. The only tiny differ-

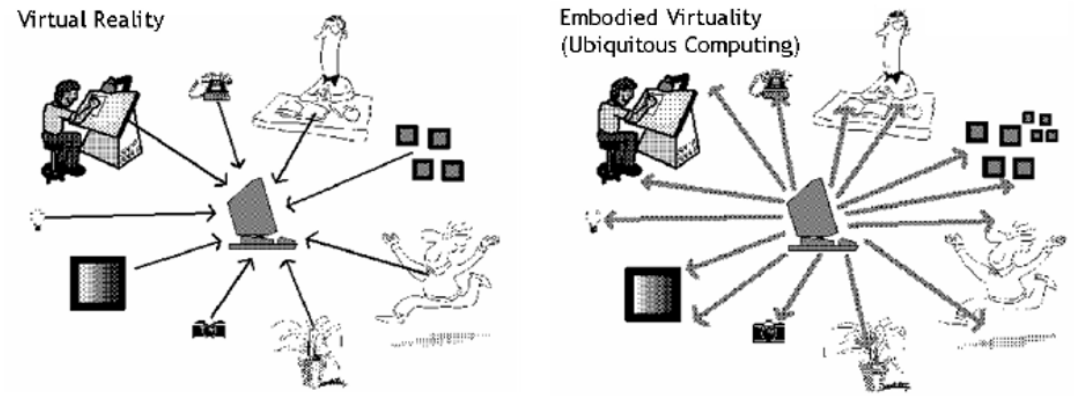


Figure 2.1: Mark Weiser's cartoons about UC vs. virtual reality (Mühlhäuser and Gurevych, 2008)

ence is explained by Mühlhäuser and Gurevych (2008) as while pervasive computing emphasises the process of penetration, ubiquitous computing focuses more on the final state. IBM Research Zurich presented one of the examples of pervasive computing systems in 1999. IBM and Swissair let passengers check-in by using their cell phones and assists them to the gate by providing them with departure information, boarding pass and gate seats in the airport.

One of the most used paradigms, ambient intelligence (AmI), said to be developed in the late '90s and explained as a consequence of the developments at the end of the last century (Aarts and Encarnação, 2006). It is defined as the everyday lives equipped with seamlessly integrated computational technology by Aarts and Marzano (2003).

The European Commission first drew attention to AmI research in 2001 (Ducatel et al., 2001). Afterwards, the studies gained pace. According to Maeda and Minami, AmI differs from ubiquitous computing as it takes advances in artificial intelligence so that AmI systems can be even more sensitive, responsive, adaptive, and ubiquitous (2006). However, according to Mühlhäuser and Gurevych (2008) and Aarts and Encarnação (2006), the main difference between ubiquitous computing and ambient intelligence are pointed as while the former is more technology-centred, the latter is more user and scenario-centred. In some of the studies, the term disappearing computer is directly linked to ubiquitous computing (Weiser, 1993), or pervasive computing (Krill, 2000). Some publications claim that ubiquitous computing, pervasive

computing, and ambient intelligence are referring to the same concept (Greenfield, 2006).

As can be seen in Figure 2.2, the terms were on the move in the same line changing their focus centre slightly like in the spiral shape by affecting each other like the colours in the figure.

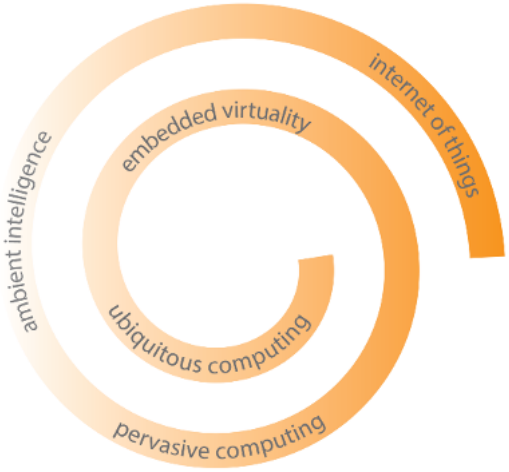


Figure 2.2: The relation between the terms

To sum up, despite the slight differences in concerns, all the terms seem to be the succession of each other and one of the most critical factors that affected the different terms' occurrence is the advances in technology beginning with tags.

In the literature, IoT is defined according to two different approaches. In this section, the different approaches in the literature are gathered to understand the edges and where the users could bring themselves into being between the Internet and the things. In this section, internet-oriented visions and things oriented visions are collected from the literature, and a table of definitions is presented.

The Internet of Things semantically means 'a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols' but there are a plethora of definitions in the literature (Bassi and Horn, 2008, p. 4).

According to Bandyopadhyay and Sen (2011), the reason for the variety among definitions is that IoT is syntactically composed of two words. While the term internet

focuses on network-oriented vision, the things pulls the term towards generic unconnected objects (Atzori et al., 2010). Therefore, the visions to IoT can be oriented around the Internet and things. RFID, wireless sensor tags, smart technologies, and nanotechnology can be listed under the Internet-oriented vision; things oriented vision includes everyday objects, prototypes, and according to some approaches, users (Nicenboim, 2015).

2.2 Internet Oriented Visions

Internet-oriented definitions put the Internet in the centre. They either imply that what is essential is the use of the Internet beyond traditional desktop realm for connecting the everyday physical objects as in Alsaadi and Tubaishat's definition (2015) or that what is going to make objects' presence pervasive and different is the Internet via RFID tags, sensors, actuators, mobile phones as in Giusto et al.'s definition (2010).

There are some necessities referred to in the Internet-oriented definitions of IoT. They are sensors to measure the environment, actuators to take action according to the measurements, processors to process the collected data, nodes to transmit the processed data and coordinators to handle all these components (Koreshoff et al., 2013b). Jenkins (2015) adds centralized servers, well defined APIs and electronics to this list. They also have to have some characteristics such as being able to perceive, communicate, remember and have policies (Jung et al., 2017). To have these necessities and characteristics, they become instrumented with computing technologies, sensors and network protocols so that they can connect to each other and exchange data (Nansen et al., 2014).

2.3 Things Oriented Visions

Things oriented definitions put things in the centre of IoT and define IoT from the perspective of connected non-human beings in the system. Having equipped with pervasive networks, miniaturization and mobilization capabilities, things start to cohabit and co-occupy the physical world with humans (Bleecker, 2006). As a result,

they can reveal new patterns and become actants that can perform in humans' lives by sensing, reacting, learning and evolving (Cila et al., 2017). In fact, the Internet-oriented visions also refer to the evolution of the meaning of things in time. However, the Internet-oriented visions take technological capabilities as the only limit for IoT. The things oriented vision refers to the change of the things in users' life. In order to grasp the evolution of the meaning of the things in time how things were used to be referred and how things of IoT are being referred to is presented with the references from the literature.

Even though they are pointed by different tags such as products, objects, artefacts; things have an essential role in human life for designers, social scientists and technology developers. Table 2.1 provides an overview of how things are referred to in the literature over time. For Appadurai, things have different values in specific social situations (1986). Their values differ at different times and spaces. According to Miller, things are situated in the centre of the social mundane (1998). As Turkle states, things also evoke memories, originate identities and incite ideas (2007). Their essentiality in social life is emphasised by Nevile et al. (2014). In parallel with all those, Nansen et al. take attention to things by stating their ability to carry histories, affordances, and relations (2014). Cila et al. (2015) advocate the importance of things by referring to them as witnesses, companions and accomplices in daily practices, a manifestation of values and experiences and thoughts and mergers of practices. In addition to the centrality of things in social practices, Cila et al. (2017) took attention to the deficiencies of things in a way that is approached until recently by emphasising their individuality, lack of intelligence and their narrow examination with a task-oriented approach.

After the introduction and fast proliferation of the Internet in our lives, things started to gain different meanings. The references to the things of the IoT in the literature are presented in Table 2.2. When things become able to connect to the Internet and set up a network in between, their abilities and place in human's life are interpreted in a bigger context. For example, Law points out that as the objects build up networks, they are going to adopt human characteristics such as communicating and collaborating (1991). One of the widely emphasised characteristics of the things of the IoT is gaining an identity as an agency. Bleecker thinks that things as agents carry information

Table 2.1: How things used to be referred

Appadurai (1986)	'Values that belong to certain temporal and spatial environment'
Miller (1998)	'Central to social mundane'
Turkle (2007)	'Evocative of memories, identity generators and idea provokers'
Nevile et al. (2014)	'Inseparable part of social life'
Nansen et al. (2014)	'Possessors of histories, affordances and relations'
Cila et al. (2015)	'Witnesses, companions and accomplices in everyday practices'
	'Manifestation of values, the way we experience the world and the way we think'
	'Mergers of different practices by connecting people with people and objects through time'
Cila et al. (2017)	'Individual and dumb socio-material assemblies undertaken with a narrow, task oriented approach'

for thinking and contribute to the social, cultural, political and personal substances (2006). Additionally, humans will not be the only ones who can upload, download, and stream data. In that way, things also become users of technology (Nansen et al., 2014). This view is also supported by Marenko and van Allen (2016). They write things like devices that can remember, recognize, adapt to and even counteract users' demands through hidden and pervasive digital mediums. Cila et al. (2017) think that as well as being political gatherings around shared matters of concern and hybrids of technological and cultural development, the things of the IoT are the agencies or smart things which establish relationships, influence the rhythms and routines of life to improve the quality of everyday experience. They also think that they are undertaken with a horizontal approach. In other words, it is not possible to approach the things as individuals, but they should be considered in a network, with others.

Table 2.2: Definitions of the things of IoT

Law (1991)	'Adopters of human characteristics via networks, such as communicating and collaborating'
Bleecker (2006)	'Agents circulating food for thought, bringing a Thing-y perspective on social, cultural, political and personal matters'
	'Occupants of world which upload, download, stream meaningful data'
Nansen et al. (2014)	'Users of technology'
Marenko and van Allen (2016)	'Devices that can remember, recognise, adapt to and even counteract users' demands through hidden and pervasive digital mediums'
Cila et al. (2017)	'Political gatherings around shared matters of concern affecting the world'
	'Hybrids of technological development and cultural articulation'
	'Smart things influencing the rhythms and routines of life to improve the quality of everyday experience undertaken with a horizontal approach'
	'Agencies which establish relationships'

In the light of these, it could be said that there is a transformation of things from being an integral part of the technology to being users of technology, from being individual objects to being networked entities, from being dumb to being smart, from being socio-material assemblies to being agents in life and from being assistant of daily practices to being a generator of practices (see Table 2.3).

Table 2.3: The transformation of the present things to the things of the IoT

Things in the past	$\Longrightarrow$	Things of IoT
integral part of technology	$\Longrightarrow$	users of technology
individual	$\Longrightarrow$	networked
dumb	$\Longrightarrow$	smart
socio-material assemblies	$\Longrightarrow$	agents in social life
assistant of daily practices	$\Longrightarrow$	generator of daily practices

This transformation eases the comprehension of the IoT. The IoT is referred as a concept where things can communicate (Berzowska, 2005), a new technical system of connected objects and materials (Ashton, 2009), a vision where everyday objects are managed thoroughly from the Internet (Santucci, 2009), a ubiquitous presence of objects aiming at a common goal though interaction in between (Giusto et al., 2010), scenarios of future in which objects can communicate through the Internet (Kopetz, 2011), a network of objects, places and environments (Koreshoff et al., 2013a), a set of methods and standards that enable tracking physical objects by digital tags (Nansen et al., 2014) or even a trend in which all the physical devices are connected and managed from the Internet (Jenkins, 2015) in the literature (see Table 2.4). To sum up, the Internet of Things covers the physical objects, materials, places, environments in a digitally connected world. In this thesis the IoT is used in reference to this cover; in other words, it points the connected future practices shaped by the things and their abilities. IoT data and sensor data are used interchangably since all the data collected from the things of IoT is through some kind of sensor and in the remaining of the thesis IoT data or sensor data is going to be used to refer to the data collected from the connected devices with the help of sensors. In this study, the data was not gathered from the connected devices in isolation but it was always affected by the

environment where the sensor integrated objects are in and by the users that interact with the objects.

Table 2.4: The definitions of IoT

Berzowska (2005)	'A concept of an environment where things can communicate to each other'
Ashton (2009)	'A new technical system of internet connected objects and materials'
Santucci (2009)	'A vision where everyday objects are manageable thoroughly from the Internet'
Giusto et al. (2010)	'A ubiquitous presence of objects which aim at achieving a common goal by interacting with each other'
Kopetz (2011)	'Scenarios of immediate future describing objects that communicate through the Internet'
Koreshoff et al. (2013a)	'A network of interconnected objects, places and environments'
Nansen et al. (2014)	'A set of methods and standards that enable tracking physical objects by digitally tagging them'
Jenkins (2015)	'A trend in which all the physical devices are connected and managed from the Internet'

2.4 Challenges of IoT

All the attempts to integrate the IoT to current practices bring critiques and challenges together. Some of the applications were not accepted by the users or failed despite huge investments and hard works. The pointed challenges include technological inadequacies and human refusal. The advances in technology promise that in the near future, the shortcomings will disappear and human-related challenges will decrease. However, it has commonly been assumed that the integration of IoT in life will continue to be a point of discussion by changing its focus slightly.

In the cornerstone article 'The Computer for the 21st Century' (1991), Weiser expressed his concerns about the expensive data transmission rates and transparent

linking of wired and wireless networks comprising the issues with communication protocols and the number of channels for connecting every device. He envisioned that the expensive data transmission would become progressively cheaper. As he claimed, both the data transmission and the mediums for that such as sensors and tags are becoming more affordable every day. In 2016, Google announced that it would provide limitless storage. However, the other issue about linking the devices that Weiser pointed is still up for grabs. According to Santucci (2009), interoperability will be the most important challenge for IoT because of private, public and mixed-use networks. Still, network foundation in terms of the limits of current architecture's mobility, availability, manageability and scalability, security and managing heterogeneity of the applications, environments, and devices are the problems that need attention (Bandyopadhyay and Sen, 2011). However, several studies are focusing on these problems right now, and almost every day, a solution to a problem is developed. For example, in 2014, Mayer et al. presented a paper discussing the composition of heterogeneous services in smart homes and provided a demo in which it is possible to control the ambient temperature, alarm and media playback by using a single interface easily by the users.

On the other hand, since the very first usage of the Internet for sharing data, the privacy of the users has been debated. Based on the idea of collecting personal data from users, the IoT has been discussed whether it is ethical, reliable, secure or safe. In 1998, Brin claimed that most of the information that was considered to be private back then, such as data about health, relationships and habits would become too quotidian to worry about. Greenfield supported this idea by saying that privacy would become too hard to attain and turn into a phenomenon that nobody worries about (2006). However, the issues about the autonomy of the IoT devices is still an ongoing issue. Santucci (2009) claims that automated decisions will mostly result in the feeling of loss of control for both the data subject and the data controller and there is a need for new information concepts in which the subjects are aware of this data journey. The creation of complex identity management systems based on interoperability, identification, authentication, and authorization could be a solution for other problems.

Despite the developed solutions for the technical problems, several products failed

even though they are technically adequate but developed in isolation from the context of use. In other words, enhancing products with sensory capabilities or processing powers may not create meaningful experiences for users as long as they react inappropriately in particular contexts or requires unbalanced trade-offs. For example; when the smart fridges were first introduced, the companies were able to combine two technologies successfully, but they miss the meanings that it was going to provide for user experience. In 1999, Electrolux introduced Screenfridge, which seems like a standard refrigerator but equipped with an internet connected computer on the door (see Figure 2.3). It was basically a combination of a computer and a fridge. It fulfils the necessities of both devices. However, because of lack of functional focus, different life cycles of the combined technologies and the high price when compared to the value, the successful application of technology resulted in unsuccessful experiences and the products were not welcomed by the users (Kuniavsky, 2010).



Figure 2.3: Electrolux Screenfridge, 1999 (Electrolux Group, 1999)

The sneakers that were produced by the collaboration of Google and Adidas are another example of the successful application of technologies but unsuccessful user experience. Talking Shoe is a pair of sports shoes that have a microprocessor translating the sensor information into audio instructions (see Figure 2.4). The built-in pressure sensor and accelerometer takes measures of the activity of the wearer and the shoes give audio feedback and information about the activity of the user. When this product is evaluated in different scenarios, it could be seen that it might be both fun and em-

barrassing for the user to wear this shoe in different contexts. That is why it is pointed as a gadget rather than a product that users bond with by Cila et al. (2017).



Figure 2.4: Talking Shoe Spencer (2013)

These examples point to a gap in the approaches for the development of the things of IoT. For instance, as Jenkins (2015) points out, developing an IoT system may enforce an algorithmic lifestyle on users. In the case of Talking Shoe, it is hard to decide which parts of the experience are to be assigned to the device so that people do not act like exercising even if they do not, for making their shoes proud. Additionally, as pointed by Markussen and Knutz (2013), the virtuality of IoT devices can obscure the physicality of the products like in the case of Screenfridge. The designers of the Screenfridge missed the actual complexities of physical products while dealing with the complexities of the technologies.

Koreshoff et al. (2013b), point to the gap by saying that IoT products offer new means for communication. Still, the consequences of the extension of this communication between other devices and people are not discussed. People are present in the IoT systems as data providers, and it results in overlooking the problems that can be faced when they become a part of the system. These approaches may be a result of the technologically driven evolution of the IoT. The background of the term provides a vision for the future of the IoT.

Overall, in this chapter, the points below were discussed:

- The background research of IoT presented that IoT will proliferate in the near future with the accessibility of the technology.
- Thing-centred approaches in IoT presented that the roles of things in our lives

have been changing and things are becoming active agents in our lives.

- Applications of IoT showed that research on the IoT is dominantly technology-driven and results prove that users' roles in IoT are overlooked while dealing with the two aspects of IoT: the Internet and things.

CHAPTER 3

DESIGN FOR IOT

As pointed previously in Chapter 2, the IoT literature is predominated by technology-focused studies. That is why, while searching for the design for IoT, I decided to use snowballing (Wohlin, 2014) as the literature search strategy to be able to spot the experience-focused studies. Both forward and backward snowballing procedures were followed. As Wohlin describes, backwards snowballing uses a paper's reference list to discover new papers and forward snowballing is searching for papers citing the paper being examined.

As the procedure suggests, I began with a tentative set of papers to start the snowballing. I used Google Scholar, ACM Digital Library and Elsevier eLibrary to come up with the first papers. My keywords were 'design for IoT', 'IoT in design', 'novel technologies', 'design research', 'agent', and 'agency.' After I learned about the new method 'thing-centred approach', then I had a second round to start the snowballing. In the second round, I used the keywords 'thing-centred design', 'non-anthropocentric approaches', 'critical design and IoT', 'speculative design and IoT', and 'design fiction and IoT.' Since this is a rapidly developing area, for the first set of papers, I selected the ones published in the last 20 years. Then, by reading the abstracts, I eliminated a big bunch.

In the first round, I started with the design process in user-centred design and scrutinised research and ideation phases for the design for IoT. In the second round, I encountered different uses of data collected from non-human agents in design for IoT. First, I will summarise the different methods and tools used in user-centred design (UCD) in search of the design opportunity. Then, I will present relatively alternative tools and methods that might be used in the design for IoT. The alternatives will be

discussed with examples to rationalise and justify the study design.

3.1 Search for the Design Opportunity in UCD

Ambrose and Harris define seven phases in the design process (Ambrose and Harris, 2009):

- *Problem definition* phase where designers define the design problem
- *Data collection* phase where designers research to collect information to feed the ideation
- *Ideation* phase where designers generate ideas as potential solutions to the identified problems
- *Prototyping* where designers prototype the ideas to test the proposed solutions
- *Selecting* where designers select amongst the most viable proposition
- *Implementation* where designers implement the selected proposal for production
- *Learning* where designers learn for prospective projects

Martin and Hanington (2012) make a similar categorisation for the steps taken in the design process. They named five steps:

- *Planning, scoping and definition* where designers define the problem
- *Exploration, synthesis and design implications* where designers research to inform the design
- *Concept generation and early prototype iteration* where designers engage with the idea generation
- *Evaluation, refinement and production* where designers iteratively test their ideas

- *Launch and monitor* where designers continue reviewing and analysing the final design

In a later study, Sanders and Stappers (2014) lay those steps in a timeline and collect these steps under four main phases along the course of the duration of the design process (Figure 3.1):

- *Pre-design* phase covers the research of designers to inform the generative phase
- *Generative* phase leads the opportunity area for design
- *Evaluative* phase points the evaluation of the results of the design development
- *Post-design* phase indicates the research of designers to understand how people actually experience the design

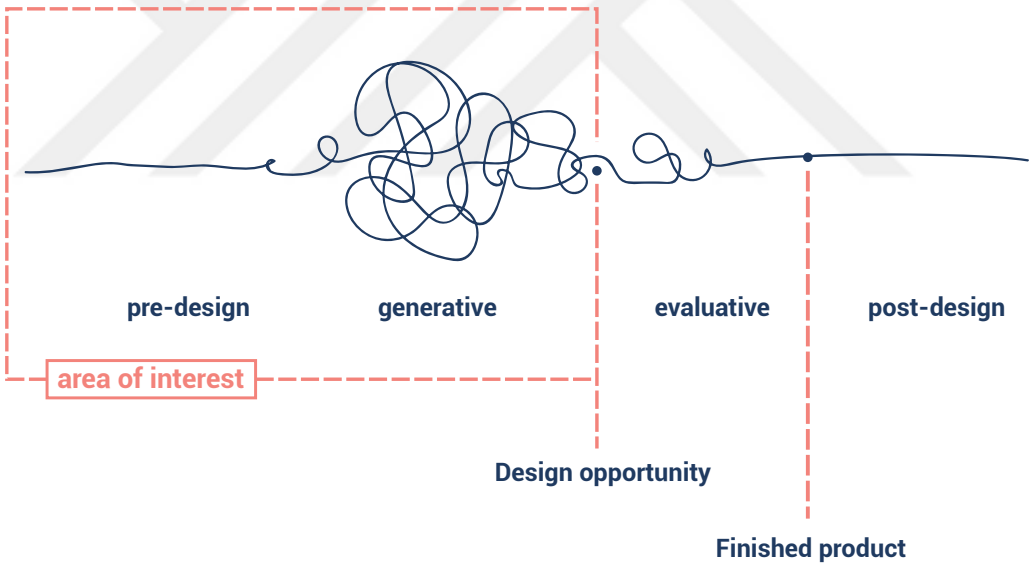


Figure 3.1: Area of interest in the design process—adapted from phases along the timeline of a design process (Sanders and Stappers, 2014)

According to this timeline, the design opportunity occurs somewhere between the generative phase and evaluative phase. The focus of this study is on the design opportunities for IoT. That is why evaluative and post-design phases are not in the scope of this thesis and will not be covered in the following sections.

Whilst names and stages have small differences in the design process in the literature, the point that takes the designers to the design opportunity includes a research and ideation phase.

Fischer and Giaccardi (2006) further minimise the steps and say that all design processes go through two phases: design time and use time. In traditional methods, designers design a complete system for users with or without them in design time and the users use the complete systems even though their needs, objectives and situational context change (Fischer and Giaccardi, 2006). At design time, the designers can only anticipate users' requirements. Then, at use time, the tasks may not match with the anticipated ones. In order to decrease the gap between design time and use time, the user-centred design emerged in the 1980s.

The User-Centred Design (UCD) as a term became widely used after the book User Centered System Design (Norman and Draper, 1986). As also pointed out by Gulliksen et al. (2003) since UCD was applicable to design in general but not just system design, so the word system in User Centered System Design dropped in time. As the name suggests, this approach puts users in the centre, giving them active roles in the design process. Norman suggested some principles to help designers in the user-centred design process in his seminal book The Psychology of Everyday Things (POET) (Norman, 1988). A few years later, Nielsen published heuristics for usability engineering adopting Norman's principles (Nielsen, 1993). Building on the same concept, the idea of putting the users at the centre, understanding the needs of the users and aiming for an empathetic design have been popularised in the HCI literature.

In industrial design, studies in ergonomics and human factors in the human body could be interpreted as the first attempts to understand users better. Ritter et al. (2014) summarise the advancements in ergonomics under four categories: classical ergonomics, error ergonomics, systems ergonomics and cognitive ergonomics. They explain that in classical ergonomics, the aim is not only finding out the optimum measures for a tool but also to find the optimum physical work environment. In error ergonomics, the aim is to understand the reasons behind the human errors in a system and to minimise the frequency and effects of them. The systems ergonomics, the

more holistic one amongst the three, aims at understanding how users and systems interact focusing on the tasks and activities. This is still different from the user-centred approach because system ergonomics do not aim at understanding the users' needs.

The understanding of characteristics of the human body gained by these ergonomic studies was limited in guiding the design to fit for the increasingly complex needs of users. The development of computer systems changed the roles of humans to controllers of machinery, resultantly changing the focus of ergonomics 'from doing to thinking' (Ritter et al., 2014, p. 39). Thus, cognitive ergonomics studies came into play. As Ritter et al. emphasised this field had a lot in common with the UCD since it also addresses understanding the users' perception, processing, attending to, and use of information to accomplish their goals. Overall, in industrial design, ergonomics paved the way of UCD since the method proved to be successful in many studies.

Kelly and Matthews (2014) explain the well-deserved value of user-centred design in two categories. First, after the introduction of the idea of the user, the stereotypic people that designers have in their mind were replaced by theoretical or conceptual models of actual people. Second, this change led to a more holistic perception of design problems by designers. As a result, the focus of design went beyond form and function. Moreover, as technology disperses from work settings to domestic environments, the idea of use has changed. That is because, unlike the user figure, which has been used as a tool in the design process, the use practices intended by the designers started demonstrating a mismatch with the real practices. Despite user-centred methods being adopted for more accurate anticipation of the context of use, they found not to be adequate in answering the changing needs and contexts of the users (Henderson and Kyng, 1991). That is why designers turned their attention to other agents that might have an effect on the use practices to better meet the requirements of users. The introduction of IoT made understanding the other agents or 'things' easier with the accessibility of data collected from and used by them. In the remaining of this chapter, after mentioning the tools, methods and approaches that have been used in the user-centred design in search for the design opportunity, I will focus on the alternatives that utilise the opportunities that IoT introduced in terms of the agency of things and availability of their data.

3.1.1 Research Phase in UCD

In the research stage, designers can use qualitative or quantitative methods. In the user-centred approach, interviews or observations, better yet interviews with observations are pointed out as the most effective way of gaining knowledge to inform the design process (Goodwin, 2009). The research stage provides designers with tentative user groups. Before the ideation stage, designers identify the target group and can conduct further research for a deeper understanding of their target user group.

In the case of design for the IoT, users are not the only agents that designers need to gather data from and understand. Moreover, designers may not reach users with previous experience, thus, qualitative user input. As a result, use practices intended by designers may not match with future practices. For that reason, it becomes difficult to follow a typical design process for the design for the IoT.

Interviews and focus groups (Halaweh, 2015) or task-centric approaches (Abowd and Mynatt, 2000) are not adequate for investigating emerging technologies. Similarly, as design thinking takes the interaction with existing objects as a basis, it will limit the new design possibilities (Brereton and McGarry, 2000) with new technologies, so it is not the most ideal approach to adopt for the design for IoT.

Another widespread method amongst designers, design ethnography, aims at understanding users' behaviour and practices by the use of ethnographic methods. Salvador et al. (1999) define design ethnography as 'focuses on the broad patterns of everyday life that are important and relevant specifically for the conception, design and development of new products and services' (p. 36). Similar to the other methods, it also is not very sufficient in the inquiry during the design for IoT. Lindley et al. (2014) think that design ethnography might not be beneficial for studying emerging technologies because design ethnography puts forward the existing state of things by focusing on the present and the requirements of people changes rapidly with the effect of evolving technologies (Rosson and Carroll, 2002). Conversely, design research should focus on how the world could be in the future instead of privileging the status quo (Grand and Wiedmer, 2010).

Although the expansion of IoT creates new design opportunities for designers (Cila

et al., 2017), user-centred design approaches for research phase are devoid of a way for dealing with the increasing complexity of those devices.

3.1.2 Ideation Phase in UCD

Idea generation is used in different disciplines to support generating solutions to various problems (Schröer et al., 2010). Osborn divides the ideation process into three 1953:

- *Fact-finding* includes the research phase that I explained in detail in the previous section. It includes problem definition and data gathering.
- *Idea finding* is the stage where designers come up with the initial ideas and select or combine them.
- *Solution finding* is the stage to evaluate the ideas created in the previous stage and implementing the selected set.

In the previous section, I covered fact-finding or research and data gathering in design process. After this process, according to Osborn, idea finding was used to be left to chance (1953) except for a couple of methods that can be devised. They are listed as the Gordon method, attribute listing, forced relationships and morphological analysis by Osborn in (1953). Very similarly, Jones listed a few methods of searching for ideas as synectics and morphological charts, and he added brainstorming and removing mental blocks in 1970. Even though there are countless methods used by designers in the ideation process nowadays, these methods are the oldest ones and could be referred to as the inspirations for the successors.

- The Gordon method was introduced by Gordon (1961). It is also known as Synectics. In this method, after the problem definition, a group of designers follow a loosely structured procedure to find a solution to the problem. First the defined problem is analysed by an expert. Then, each member rewrites the problem by breaking down the problem. The team, then, decides on a problem set, creates analogies, gives examples and repeats these steps to distil the ideas.

According to Osborn (1953), exploring different aspects of a problem can bring extraordinary approaches which could not be discovered otherwise.

- Morphological analysis was developed by a Swiss astrophysicist and aerospace scientist Zwicky (1948). He used this method to structure and classify the astrophysical objects. The root of the word morphology is from classical Greek (morphe) and means the study of shape or form. He extended this word beyond the shapes of 'geometrical, geological, biological, and material structures, to study the more abstract structural interrelations among phenomena, concepts, and ideas, whatever their character might be' (Zwicky, 1969, p. 34). Once the structure is analysed, it was advised to find associations between the ideas so that designers could easily come up with different ideas. I think the 6-3-5 method (method 635) which has been used more recently in design and also marketing could be defined as a form of morphological analysis. Rohrbach introduced this method in 1969 as a specific form of brainwriting. A group of designers write down their initial ideas and pass their ideas to the next person in a predefined and limited time. The next step is taking the others' ideas and developing new ones inspired by the predecessors, modifications of ideas or new ideas generated in each phase. The same process is repeated until each designer gets their original ideas. As a result, immature first ideas are improved in each phase and evolved into better versions.

- Attribute listing was developed by Crawford (1954). Designers should list all the attributes of an object or an idea and deal with each attribute. Engaging with all the attributes would ensure covering all the aspects of an idea and encourage revealing different and better variations. One of the methods that has been used recently; concept mapping, could be identified as a different version of attribute listing. Ausubel is pointed out as the founder of concept mapping (Martin and Hanington, 2012). While he was trying to understand how children learn new concepts, he realised that when new information is built upon the concepts that children already know, it is more meaningful. To further improve the idea, he offers a visual map to represent the known concepts so that designers can study the existing connections and expand on the previously known to find new connections leading new ideas.

- Forced relationships was explained by Whiting (1958). As the name implies, designers force the limits to find relationships between what seem to be unrelated at first sight. Then, they use the newly explored associations as a starting point and generate new ideas.

- The term brainstorming can be identified relying on Osborn's book on creativity titled Applied Imagination, published in 1953. From that time onwards the technique developed considerably. Still, in essence, it can be described as a systematic way of eliminating a list of ideas generated by a group to solve a particular problem. According to Taylor et al. (1958), brainstorming is not only about producing many different ideas by stimulating a group of people, but it also increases the chance of finding good ideas as the probability is higher to find a better idea in a large sample (Osborn, 1953).

- While explaining removing mental blocks, Jones gives the examples of morphological charts, attribute listing and forced relationships. He additionally mentions Roget's Thesaurus (1852). It can be summarised as an overarching method name for the ones that are used when the apparent solutions to a problem were not satisfactory or acceptable (Jones, 1970). Affinity diagramming could be an example of this method's widely and recently used version. It was introduced with the KJ technique by Kawakita (1982). It can be defined as a bottom-up exercise. The researchers begin by grouping small details and try to find overarching themes for each group.

All these methods to find new ideas are seen as a part of a problem solving strategy. Lawson's study (1979) on design behaviour and problem-solving strategies of designers could be useful to discuss the data use in solving a design problem. According to Lawson's findings, the designers' approach to problem solving is different from other scientists'. He explains that while scientists adopt problem focused strategies, designers adopt solution focused strategies. Cross (1982) explains the difference with the 'central feature of a design activity' (p.224), which is a quickly generated satisfactory solution. Instead of making a detailed analysis of the problem, designers focus on the satisfaction aspect of the solution without worrying too much about the optimisation of the solution (Simon, 1969). Another reason in the designers' approach to problem

solution could be that they generally deal with ill-defined problems (Cross, 1982). To be able to generate solutions to ill-defined problems, designers learn 'to define, redefine and change the problem-as-given in the light of the solution that emerges from his mind and hand' (p.224).

According to Kolko (2011), the goal of design research is to inspire the design. He says, after the research phase, designers reaching wisdom from data start extracting meaning from data, continue with experience frameworking and end with empathy and insight. During these processes, affinity diagramming, flow diagramming, concept mapping, forced semantic zoom, forced temporal zoom, reframing and insight combination are listed as the methods that can be used by designers.

Other than these, there is a significant number of methods to support designers in their creative idea generation process. Martin and Hanington (2012), list a hundred methods that can be used in the design process in their book.

Shah et al. (2003) gather studies on ideation processes under two different approaches: logical ideation and intuitive ideation.

Logical ideation relies on the systematic analysis of the problem. This type of idea generation is used mostly by scientists and engineers by using the previously defined procedures. They decompose the problem at hand, analyse the problem in a very detailed manner, create a lot of solutions to find the most feasible or optimised solution to the problem. Logical methods are examined either as history-based methods such as Pahl and Beitz (1996) and TRIZ (Altshuller, 1984) or analytical methods such as SIT (Horowitz and Maimon, 1997).

Intuitive ideation focuses on thinking out of the box. Instead of detailed analysis, intuitive ideation uses synthesis to create satisfactory solutions. In line with Lawson's study and Cross's explanations on designerly ways of knowing, designers' idea generation process can be categorised under intuitive ideation. That is also why this study's scope is limited with intuitive ideation.

Intuitive ideation is further categorised in five branches: germinal, transformational, progressive, organizational and hybrid ideation (Shah et al., 2003).

- Germinal ideation techniques promote generating ideas from scratch such as brainstorming.
- Transformational ideation techniques offer ways to create new ideas by transforming existing ones such as attribute listing.
- Progressive ideation techniques focus on creating many ideas by repeating the same steps, such as morphological analysis.
- Organisational ideation techniques use grouping of similar ideas to distinguish the recurring themes or differentiating the insightful ones such as affinity diagramming.
- Hybrid ideation refers to different ideation techniques in different phases of the ideation, such as synectics described above. It is an example of a hybrid ideation because it involves germinal and progressive techniques. The team members generate their solutions as per germinal ideation and through repetitive steps, they improve an idea as per progressive ideation.

While designing for the IoT, intutive ideation would still be designers' way of problem solving but I believe the ideation techniques covered in this section followed by the traditional research in design process covered in Section 3.1.1 could be improved in order to deal with the mentioned complexity of things of IoT. The next section will discuss some of the alternative and supportive approaches to UCD to be inspired for the development of the problem solving process of designers in design for IoT.

3.2 Search for the Design Opportunity for IoT

As it was explained at the end of Section 3.1.1, there are relatively alternative methods, tools and approaches that have been used in design that use emerging technologies. Amongst the countless ways that can be defined as relative alternatives of user-centred design, I believe non-anthropocentric approaches, data-enabled design and critical design had interlacing examples (see Figure 3.2). Below, I will discuss each with some examples and introduce my proposal; object persona which I believe is located in the interconnection of these three approaches.

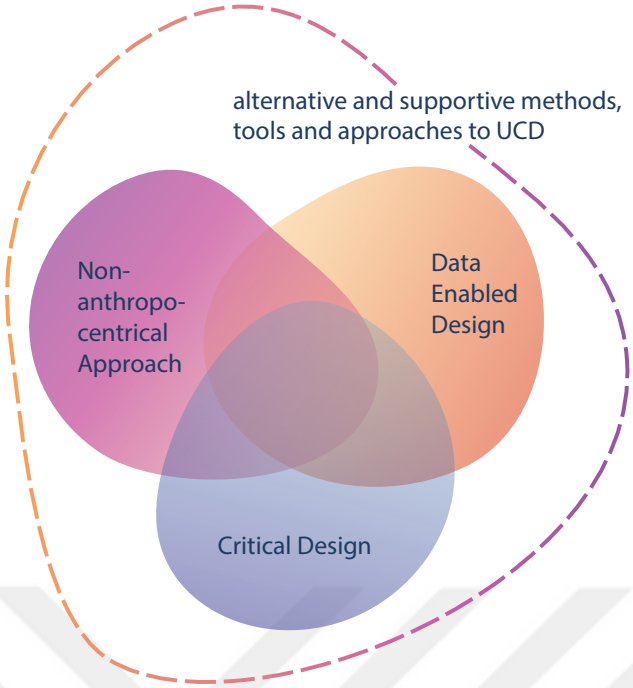


Figure 3.2: Focus in alternative and supportive methods, tools and approaches to UCD

3.2.1 Non-anthropocentric Approaches for Design for IoT

The experiences that change and progress in time may not only belong to the users but also to the products themselves as they evolve in function, behaviour and personality with their users' changing needs (Keyson, 2008). To be able to comprehend these experiences, the two agents in this interaction should be assessed beyond the conventional conflict of people and machines. As Callon explained, the dissent between ends (1984) and means or in other words, the humans and non-humans can be understood by moving away from the human-centred approaches to a non-anthropocentric or an anthro-de-centrifying (Jönsson and Lenskjold, 2014) approach.

There are different approaches and methods for understanding the effect of things on experience in humanities (DeLanda, 2006), social sciences (Latour, 1992) and design literature (DiSalvo and Lukens, 2011; Nansen et al., 2014) and they all can be categorized as non-anthropocentric perspective. This perspective aims at figuring out in which conditions, agents' capabilities and limitations collaborate or counter to

establish, delegate and reconfigure actions (DiSalvo and Lukens, 2011).

Cila et al. (2017) argue that if designers engage with objects as they usually do with the users in the design process, they can obtain unique insights about their roles in social practices by a thing-centred approach. Thing-centred approach can be defined as a form of non-anthropocentric design approach. Thing-centred approaches seem to oppose human-centred approaches, but they create new opportunities for designing experiences of things in a scenario by better understanding, critiquing, and intervening (DiSalvo and Lukens, 2011). The users in the thing-centred approach are not overruled by things, but as opposed to being put in the centre, they become another party that needs to be paid attention. The theoretical roots of this approach can be found in different disciplines.

Nansen et al. (2014) take the Object-Oriented Ontology (Harman, 2009) as the theoretical background for their method Object-Oriented Ethnography. Object-Oriented Ontology is a term referencing to the object-oriented programming to emphasise that interaction cannot be hierarchically ordered according to the composition of objects. Nansen et al. take this term with a focus on ethnographic enquiry to investigate the object's social life because they think that interaction is not unique to humans. Object-Oriented Ethnography is offered a way to discover, understand and conceptualise objects to support digital augmentation. It is claimed that with the adoption of this perspective, it could be possible to discover the roles of everyday objects in social and material interactions and support these objects with technology to empower these roles.

DiSalvo and Lukens point non-human expressivities (DeLanda, 2002b) together with Actor Network Theory (Latour, 2005) as the theoretical background of their study on the experience of decentring: seeing the city and sensing the city (2011).

In this study, ANT forms the background as it comes from science and technology studies, but the others are either coming from humanities or computer science.

Actor Network Theory (ANT) is a conceptual toolkit from sociology designed for the development of science and technology (Latour, 2005). It proposes that treating humans and devices equally would provide insights about future products and services.

It also argues that non-humans have a fundamental role in any action and experience (Callon, 1984). Here, non-humans have a crucial role in the formation of any kind of experience.

According to DiSalvo and Lukens (2011), ANT supports the idea of agency as the quality of not only humans but also non-humans. According to Bradshaw (1997), the non-human agency has capabilities that involve reactivity, autonomy, collaborative behaviour, inferential capability, temporal continuity, personality, adaptivity, and mobility.

According to DeLanda (2002a), the non-humans can provide information about the actants in the solution space as well as they inform the solution space so that they can unveil design solutions they are unnoticed in the human-centred design approach. The studies below exemplify how this perspective informed the designers and shed light on their way in ideation.

Blendie could be one of the earliest examples for a non-anthropocentric approach. According to Dobson (2004b), machines can have expressive, engaging behaviours as well as dominant characteristic features, egos, and desires. Blendie (see Figure 3.3) is a blender enhanced with custom made hardware and software for sound analysis and motor control. In order to engage with the blender, the user has to speak in the language of the machine. Even though everyone can communicate with Blendie, it has its own moods, desires, and preferences. For example, higher-pitched voices cause the machine to work faster. Dobson thinks that this behaviour can help users understand and build a strong connection with the machine. As a result, a more meaningful relationship is established between the user and the machine.



Figure 3.3: Blendie (Dobson, 2004a)

Living interfaces project, including *thrifty faucet*, *impatient toaster* and *intimite door lock* can be given as another example to non-anthropometric approach.

Thrifty Faucet uses a faucet enhanced with servo motors to be able to see if a faucet with a life-like appearance can help people articulate in their water consumption (see Figure 3.4). Togler et al. (2009) tested their prototype in 9 houses and saw that the organic movement that enables kinetic interactions and tangible communications help in the communication between the object and the users. They concluded that the kinetic interfaces like they presented could increase the awareness of users on water consumption with specific postures.



Figure 3.4: Thrifty Faucet (Togler et al., 2009)

Impatient Toaster is another project included in the series of experiments of Living Interfaces project. Burneleit et al. (2009) created a toaster with an Arduino microcontroller board and two servo motors which moves nervously if the user does not use it for a while (see Figure 3.5). They tested that the impatient toaster with six users if an object with a character of its own can be excepted. They reported that human-like attitudes of the toaster have positively affected the emotional engagement between the object and the user.

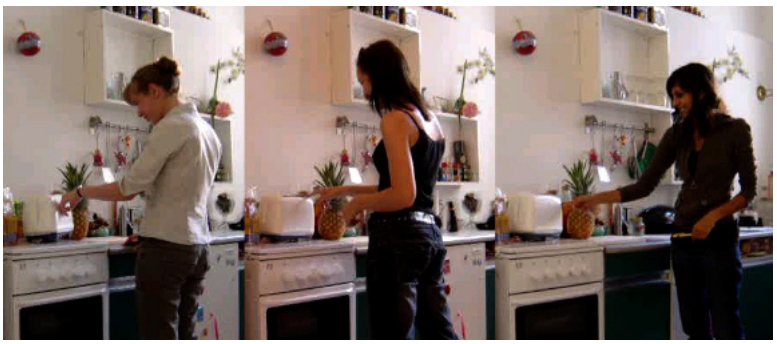


Figure 3.5: Impatient Toaster (Burneleit et al., 2009)

Intimate Door Lock, another project in Living interfaces project uses a camera augmented mirror enhanced with the Arduino microcontroller board to test if the human-like behaviour of an object can increase the intimacy between the users and objects and create powerful interactions (see Figure 3.6). In the project, to be able to open the door, the user has to kiss the mirror. Roy et al. (2009) tested their prototype in five houses and saw that the interaction with the door lock had positively affected users' mood as all the users left the flat with a smiley face.



Figure 3.6: Intimate Door Lock (Roy et al., 2009)

City as Learning Lab (Call) was introduced as an example for non-anhtropocentrical approach. DiSalvo and Lukens investigated the use of sensors in a design project both as a subject and as a medium (2011). In City as Learning Lab (Call) project, they employed speculative design to pursue technological fluency. The project consists of two workshops, namely Seeing the City and Sensing the City. In the former one, Seeing the City, the researchers made a team of youth to make them aware of the capabilities and limitations of robot use for the infrastructure of a city. The aim was recording a list of elements from the perspective of a robot. A robot, a remote-controlled truck was controlled by one of the team members and a laptop saving the recording was carried by the other team member. They discovered that, as the perspective of team members and camera is different even if they were able to spot the elements on the given list such as traffic lights, the items were not on the footage. In the latter one, Sensing the City, the researchers gave a task to participants who are engaged with information technology very often to note the highest and lowest measures of sensors detecting CO, CO_2 and sound and pleasant/unpleasant, noisy/quiet

and relaxing/stressful places.

The participants went to their favourite and beastly places. However, the sensors did not understand the unpleasantness of participants in the public toilet. Similarly, the sound they define as annoying such as traffic noise has the same level of loudness with the noises described as pleasant such as children playing in the garden for the sound sensor. Therefore, the participants understood that sensors do not sense their affective environment and experiences, and they can only operate in the material environment. As a result of this project, researchers claim that the outcomes can enlighten some design problems for the future community engagements. This study proves that a non-anthropocentric approach can be insightful for the design problems that include non-human interactors.

Never Hungry Caterpillar can also be pointed out as an example for the non-anthropocentric design approach. In the case of IoT, technologies are used with the aim of solving a specific problem of users. Eventually, the products or systems come to an end that they have full automation as a result of this aim. However, as Laschke et al. (2011) stated, designers could try to anticipate the novel experiences by not fixating on that technology is a solution to existing problems but by acknowledging technologies as an opportunity to novel and meaningful social and emotional experiences through thinking beyond the pure functional benefits. They propose that the engagement between things and users could only be achieved by creating friction between them. This friction will create a dialogue between the thing and its user. In their study, Laschke et al. introduce 'transformational products.'

The Never Hungry Caterpillar is one of the examples which created mentioned friction resulted in more meaningful experiences (see Figure 3.7). It focuses on energy waste by a performing caterpillar. It is an extension cable which fidgets awkwardly as if it suffers in cases of excessive use of electricity. In the study, they found out that a suffering action created a tendency to help in participants. Reducing electricity consumption or coming into action on the electronics that are forgotten in stand-by were observed as a result of this tendency. The participants stated that they did not want to watch a suffering being even though it was an abstract representation. Therefore, if the things they were using were in standby mode, for example, they turned

the device off to save the caterpillar. As a matter of fact, it is technically possible that the caterpillar can autonomously turn off the devices that are not in use or on standby for a long time. However, the autonomous device would not provide the dialogue that participants needed for a meaningful experience.



Figure 3.7: Never Hungry Caterpillar (Laschke et al., 2011)

Million Story Building is another example study of non-anthropocentric design approach from 2011. Having asked the questions like what a building would say if it could talk, how it would feel about its visitors, what would affect their moods and desires, or what kind of relationship it would have if it could communicate with its visitors (McVeigh-Schultz et al., 2012a); Stein and Fisher (2011) made an application called Million Story Building to be used in a faculty. By integrating Twitter, Flickr, QR Codes, movie tagger, sensor information, videos, displays and so on to an interface, they created an engaging building. As the inhabitants choose to have a more active relationship with the building, the building learns more about the specific users and starts offering personalized, context-specific information to the users.

Story Object can also be defined as an example to non-anthropocentric approach in design. Having been inspired by the study PUCK of Stein (2011) (discussed later in Section 3.2.2.2); McVeigh-Schultz et al. (2012a) wanted to give voice to everyday objects and designed a table called story object allowing objects to share their stories and histories via displaying photos. When a person using the Million Story Building app approaches a story object, the object detects the person via Bluetooth and displays the stories around the building via images, video, and text.

Vehicular Lifelogging was inspired by Story Object and can be another good example for non-anthropocentric design approach. McVeigh-Schultz et al. (2012b) built a vehicular lifelogging prototype for MINI Countryman. By using in-car sensors and GPS trackers, they tried to track the important experiences both for the driver and for the car during driving. Then, they used these data for triggering notifications in a relevant context. For example, rain sensors were used as a reminder of a car wash instead of triggering automatic windshield wipers and as a way of showing the gratitude of the driver to the car.

Addicted Products is an example of non-anthropocentric approach together with design fiction application. Addicted Products (see Figure 3.8) propose a scenario in which the products can change their owners without the active consent of their users (Rebaudengo, 2012a). The connected products are described as an agency, and they are addicted to being used by their users. According to the scenario, a concept was developed: if the toasters decide that they are underused by comparing themselves with their peers, i.e. other toasters, first they try to draw attention and then if it does not work, they change their users. During the research phase of the project, the designer could try to understand what addiction means to a person and what drives the addicted person's behaviours. By conducting a survey with 80 people, the designer came up with a model of addiction.



Figure 3.8: Brad the Toaster (Rebaudengo, 2012b)

According to this model, a future scenario was presented. In the scenario, manufacturers make use of the network of their products to compare product usage. As a result, the products would continuously compare themselves with other products in the network in terms of usage frequencies to increase their usage. They use social media, i.e. Tweets, to show their demand for attention. When they decide they are

not used at their bests by comparing the usage frequencies of others in the network, they find themselves a new user. As a result, a concept proposing a web interface of the service is produced to demonstrate the average use of the toasters, users and possible new users. Lastly, the prototypes of the concept were tested in different places of New York, to assess the project and develop it.

Anithings is also an example for non-anthropocentric approach with design fiction video. Anithings are a set of digital objects that have personality and inner life (van Allen et al., 2013) (Figure 3.9). They act autonomously to contribute to creative activities. Instead of presenting the best option, they provide information to support the decision making process of their users. An Anithing curates the relevant information according to its personality, presents it to the user and other anithings and interacts with its user and with each other. They are offered as a paradigm to the interfaces stuck in the digital spaces and automated recommender systems.

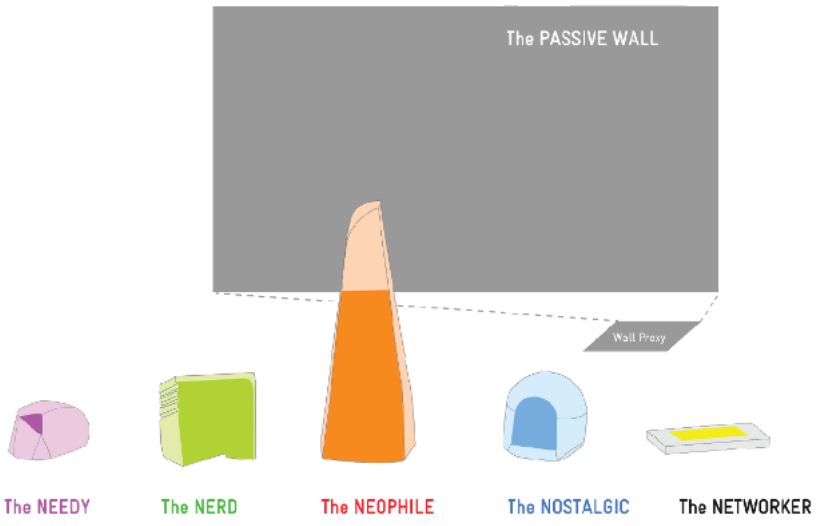


Figure 3.9: Anithings (van Allen et al., 2013)

Anithings are described as an experiment that uses research through design and explores the new types of interactions in the complex world of internet of things by interactive prototypes in design fiction videos. In this project, researchers aimed at raising questions about alternative futures of smart devices instead of following a design brief to solve a problem. Pursuing this aim, they built prototypes to explore the ideas about animistic design in contexts. Before the implementation, they studied

some proof of concept prototypes and instead of user testing, they tested final scenarios through a design fiction film. In the film, Anithings help a designer in the ideation phase of a design project. In the process, things help the designer in search of a concept and sharing her ideas with a colleague (Figure 3.10). Anithings propose design insights as well as providing strategies and design patterns for current interaction systems.

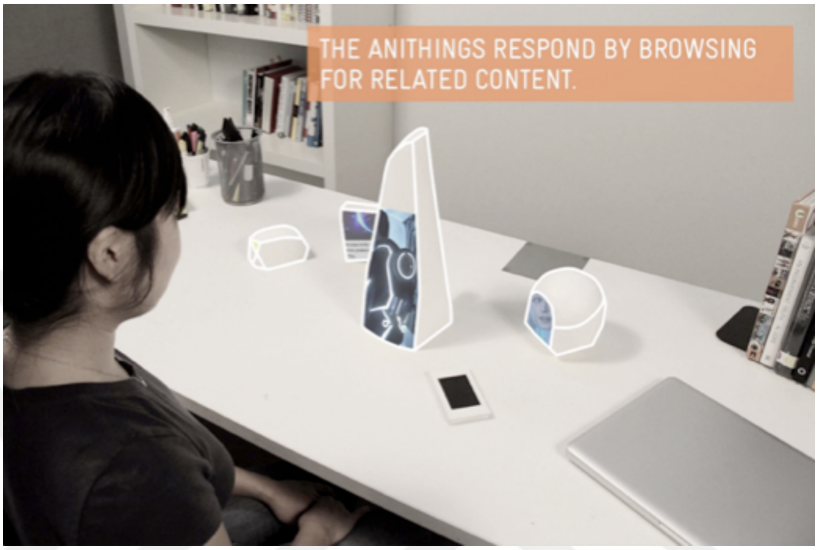


Figure 3.10: Design Fiction for Anithings (van Allen et al., 2013)

Listening to Everyday Kettle is described as an example for thing-centred design. A ThingTank project (Giaccardi et al., 2016), 'Listening to Everyday Kettle' aimed at understanding what objects can tell about their use so that new models of use can be explored. In the study, a fridge, a cup, and a kettle were equipped with cameras with sensors. Every time the user is engaged with one of the products, the cameras took photos (see Figure 3.11). Moreover, human ethnographers studied on the practices that users of those objects undertook. Therefore, it was possible to catch data that was not possible to be seen by human researchers but can be identified by objects. Through the analysis of gathered photos, researchers using machine learning technologies aspired to find outliers in data sets to inspire innovative design solutions. At the end of the project, they proposed that algorithms may reveal data to design things that human researchers may miss out. Ethnographers in the project think that it was possible to create unique insights by using temporality, movements and relationship of the objects.



Figure 3.11: Photo taken from the perspective of a kettle and data streams read from the sensors on it (Giaccardi et al., 2016; Speed and Oberlander, 2016)

Interview with Things is the most recent example of non-anthropocentric approach. Chang et al. (2017) use a different approach to using data in the design process of connected things. They combine thing ethnography, an approach used for gaining information for the socio-material networks of things, and animistic research, an approach used for making sense of collected data. They see things as co-ethnographers and co-designers and make use of data collected from things' perspectives by interviewing the things. They collect data from the thing perspective with the use of attached cameras and sensors to scooters used in Taiwan and processed data is presented to the professional actors to speak for the things. In this way, they aim to help designers by developing empathy with things so that they make use of data in creative ideation. Time-lapse cameras and smartphones with GPS tracking app are attached to the scooters to collect data from the things' perspective for data collection (see Figure 3.12). Then, researchers prepare the photos in a way that they present the daily routines and object portfolios for data organization. Finally, they present what they prepared for professional actors and conduct interviews with actors speaking on behalf of the scooters. In the end, they reveal several conflicts between what designers expect from users to do and what users intend to do. For example, while modifications in the scooters made by the users were not expected by the designers and might be interpreted as a misuse, it is a method for users to reflect their identities and attitudes. Creating appropriations creates new relationships and expectations. There-

fore, they concluded that, if designers facilitate the appropriations, more meaningful experiences can occur between the thing and the user.



Figure 3.12: Equipped motorcycle, view from the action camera and interview with actors (Chang et al., 2017)

3.2.2 Data Enabled Approaches for Design for IoT

For the IoT, designers may not have a clear identification of potential problems with the help of IoT users, but designers have a huge amount of data collected by the connected devices at hand before a clear problem definition.

On the one hand, the accessibility of the data offers opportunities for designers for extending, enriching and shifting the experiences of people (Koreshoff et al., 2013b). On the other hand, the scale of data creates challenges for designers to make use of the data in the human-centred design process (Wolff et al., 2016).

According to Wolff et al., data can be used in the design process to create a concept for, to identify and develop the connected products and services and reveal the people's habits so that design choices can be validated. They also emphasised that it is hard to materialise the data to integrate it into the final design and combination of methods from human-centred design, sensor networking, data science, visualisation and simulation is needed. Otherwise, the design of a new connected product would mean embedding a chip in something, as Cila et al. (2017) emphasised. Knutsen (2014) advocates this claim by saying that even though things of IoT are a fusion of technology and cultural articulation, design-based inquiries are needed to handle the novel realities, relationships and conditions of objects.

van Boeijen et al. (2013) explain the input that designers take from data in two categories, namely data for exploration and data for validation. While data for exploration

is often qualitative, data for validation is quantitative. Data for validation is mostly used for the optimisation of the proposed design instead of the generation of a proposal (Bogers et al., 2016).

As Kun et al. (2018) summarized, using digital data in the design process has been taken attention recently. They think that various techniques, methods, and tools can be used by designers to extract meaning from data. These techniques, methods, and tools can be categorized as either the ones that require teaching non-experts the necessary programs (Baumer, 2015) for working with data or the ones that require exploring data using visualisations (Grammel et al., 2010). In the former way, non-experts will be educated to use data science workflow. Kun et al. (2018) list the agreed steps in the literature for the data science workflow. The flow starts with a question, continues with data collection to answer the question, interpretation of data with visualisation or modelling and ends with presenting the results. The usual data workflow is staged to formulate the question, to collect data for answering this question, to analyse the data and to communicate the findings. Hill et al. (2017) offer organizing workshops for teaching novices the basic programming in their study 'democratizing data science.' D'Ignazio and Bhargava (2016) offer using a set of learning tools in their work Data Basic. However, it is always competitive to overcome the high learning curve in teaching non-experts the analytical work and the necessity should be questioned further. In the latter way, exploring data with visualisation, tools that enable non-experts easily collect, store and visualise data can be used. This way, novice users or non-experts like designers can use the data workflow in-line with their research process such as supporting qualitative techniques with data analysis as Kun et al. exemplified.

According to Speed and Oberlander (2016) how designers design around data could be categorised either as design from, design with or design by data.

In their paper, Speed and Oberlander (2016) report that while design from data is seen as the 'established methods' for designers, design with data is pointed out as the potential area of research for addressing human data interactions and design by data is reported as the emerging area of research. Inspired by their outcomes, I would like to focus on design by data in this study. I also thought that, in design for IoT, since the designer's data gathered from users should be supported with the data coming from

other agents, in this study, design with and by data should be in focus. Below are the explanation of design from data and explanations and examples of design with and by data.

3.2.2.1 Design from Data

Design from data is the type where designers get inspired by the quantifiable attributes of the agents. Designers design from data via various methods from established ethnographic methods that are widely used in user-centred design such as 'user observations (Abrams, 2000; Stempfle and Badke-Schaub, 2002; Kawulich, 2005) and interviews (Bernard, 2000; Byrne, 2001; Rubin and Rubin, 2005); to cultural probes (Gaver et al., 1999), technology probes (Hutchinson et al., 2003) and Contextmapping (Visser et al., 2005)' (Speed and Oberlander, 2016, p. 5).

3.2.2.2 Design with Data

They explain that design with data as the type where designers get to reach the data flows to create a link with the users to better empathize with the artefacts' effect on users. Online research methods such as virtual ethnography (Hine, 2000), netnography (Kozinets, 2006), cyber-ethnography (Keeley-Browne, 2011) and online ethnography (Wilson and Peterson, 2002) are given as the examples of collecting this kind of data to design with data. PUCK, connected toilet roll holders and connected baby bottle projects can be listed amongst the examples of design with data. Below, details can be found for each project.

PUCK (Place-based Ubiquitous Connected and Kinetic) is a project by Stein (2011) and can be defined as an interactive architecture. In the project, a transparent data infrastructure was built by embedding sensors within walls, floors, and ceilings. Then, the collected data was presented to visitors through touch interfaces and a mobile application. Having seen the energy and water consumption, changes in temperature and carbon dioxide levels, and wireless network activity inside the building, the visitors get to learn their individual and collective impact in the building. As a result of the study, it was seen that visitors become more engaged with the building.

Connected Toilet Roll Holders can be another example for design with data . Speed and Oberlander (2016) reported a project where five connected toilet roll holders measure the mass and length of the remaining toilet paper and present to the users (see Figure 3.13). In the project, instead of giving the collected IoT data to third parties, the device streams the data to a personal data store. It was explored that it was possible to identify the amount of toilet paper used in particular toilet practices. Moreover, detailed analysis revealed that less likely events were possible to be identified, such as guests in the house or a user with a runny nose. At the end of the project, it was seen that the users started interpreting data and built relations with domestic practices such as running out of toilet paper or even spotting a stranger in the house while the users were away for a holiday.

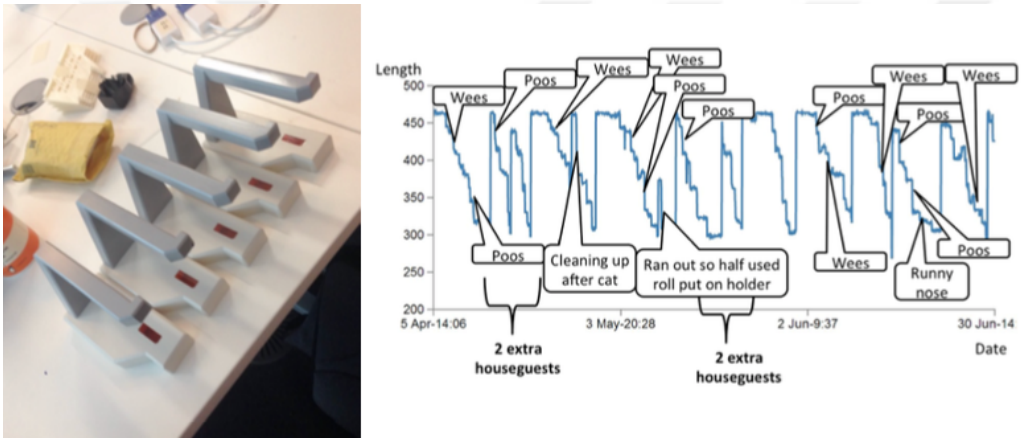


Figure 3.13: Connected toilet roll holders and data graphs illustrated for the users (Speed and Oberlander, 2016)

Connected Baby Bottle can also be an example of design with data. Bogers et al. (2016) used sensor data in a simpler product. They presented a case study named 'Connected Baby Bottle.' They used sensor data coming from a baby bottle collected before, during and after feeding in order to explore opportunities for behaviour change (see Figure 3.14). They explored the influences of collecting different means of data on the design of smart products for behaviour change. In the project, they used a baby bottle which they enhance with some electronics such as microcontroller with accelerator and temperature sensor, SD card and battery. They used sensor data for detailing behavioural patterns and interviews for relating these patterns with the corresponding experiences. They carried out the research in two parts, namely contextual and

informed step. In the first step, after they collected bottle-feeding parameters through the baby bottle from families, they presented the data to the participants during interviews. In the second step, they used what they have learned from the first step to update the sensors in the prototype. According to the data they collected from the baby bottle and interviews conducted during the study, they presented participants insight cards through an app and saved their reactions. At the end of the process, again, they interviewed the participants. Their findings showed that despite the limited time of the study, the parents realized some problems in their feeding and have already started to change them.

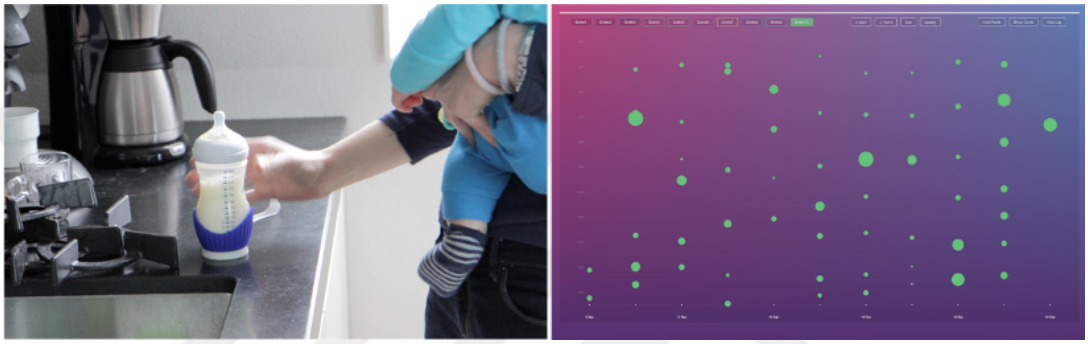


Figure 3.14: Connected baby bottle and data canvas created with the data coming from sensors on the bottle (Bogers et al., 2016)

3.2.2.3 Design by Data

Lastly, they explain that design by data as the type where systems have a significant effect on the design of other products or services by the analysis of data of the agents in an interaction. They further elaborated this vision with the exponential increase in the data coming from the three-fold interactions of humans and machines: the data would help with the discovery of novel design opportunities.

Personal Data Legibility in Network Sensing Systems could be an example for design by data. Tolmie et al. (2016) placed a multi-sensor package in bedrooms, kitchens, living areas and bathrooms in three homes to track the energy consumption of the families. Before deployment of the packages, short interviews with family members were conducted. After three to four weeks of the deployment of the packages, an ethnog-

rapher revisited the houses with the visualisation tool. The main purpose of the study was to capture the gap between what was read by the sensors and what was socially meaningful. During the interviews, it was seen that the families tend to reason their behaviours around places, time, people, practices, events, routines, and exceptions by looking at their sensor data. As a result, the researchers found out that the sensor data made the mostly unsaid order of domestic life observable and reportable. When the networked sensors are considered only, the human action remains lack and it may result in the misrepresentation of data. Therefore, by including the end-user in the picture, they thought that they might eliminate the risk and help in the design process.

Working with IoT Data in the Home can be listed as another example for design by data. This project is a part of CharIoT project. The IoT was used to support the work of energy advisors by collecting environmental data from sensor kits and interactive systems together with provisioning advice.

In another study, Fischer et al. (2016) built a prototype with temperature, humidity and light sensors to provide professional energy advisors with users' definitive patterns and their causes in their home. They organized their study in three phases: anticipating data work with pre-visits to homes to be informed about the context, rehearsing data work for extracting meaning from data and performing data work with in-home visits for identifying patterns and their possible causes and generating solutions. As a result, they supported Yang and Newman's study on interactive and intelligent experience with Nest—a thermostat which can generate personalized heating and cooling schedule learning from the users' preferences over time (2013) and reported that as long as things are unable to understand the context, situations, and intent, irrespective from the intelligence level of the things, third parties can only make speculations with the reading no matter how informed they are. They further discussed that, in order to appropriate data for augmenting life, the data should be mapped with the context. They explained that their proposed system was to help people in understanding their data and formulating responses rather than to create automatic sense-making.

Data Enabled Design Canvas can be introduced as one of the most recent examples for design by data. In CHI 2018, as a continuum of *Connected Baby Bottle* project,

van Kollenburg et al. presented ‘Data Enabled Design Explorations’ with another case study where parents tracked data from their babies (see Figure 3.15). In that paper, they explain that they aim to use data as a creativity tool for enhancing the design. They create their prototypes in a way that can evolve with the explorations they made in the process. They consider the data as a medium that helps to collect insights without being there but in real-time. They create physical data loggers, a tool kit that involves push buttons saving data when pushed, knobs saving data when rotated, text module saving text messages and video module saving short videos. The loggers keep track of the data, and a canvas visualises related data interactively. Parents can get to decide what kind of data is valuable for them and worth to be tracked so that the canvas is updated accordingly. The researchers assign labels to the data collected and together with parents, they make changes in the canvas and iterate their contextual prototype to materialised concepts.



Figure 3.15: Family tool kit with text module, video module, rotating knob, push button (in hand) in parent dashboard (van Kollenburg et al., 2018)

Researchers have been looking for ways to appropriate data collected from sensors in the design. The data collected from buildings, vehicles, and objects were used for understanding the human, enhancing the experience or used as a source for designers, researchers or ethnographers.

3.2.3 Critical Design

Bardzell explains the critical theory as 'an umbrella term that offers sophisticated theoretical resources for the study of cultural artefacts and their use in the communities that create them' (2007, p. 13). Critical theory can inspire designers with the alternative perspectives to explore hidden symbolic systems, ideological structures, relations between objects and users, interactions between the agents and socio-cultural contexts (Bardzell et al., 2012). Dunne and Raby mention critical theory as a starting point in their approach to critical design.

According to Dunne and Raby (2013) critical design which means design about ideas opens up a space for envisioning the future as it deals with unreality by definition. In the book, Speculative Everything, Dunne and Raby wrote that all good design is critical so critical thinking is what they are interested in. Therefore, they coined the term critical design to stand against prejudices about mundane products (Dunne and Raby, 2013).

The critical point in critical thinking is the change possible at the end, which is positive and idealistic. It is differentiated from other design approaches by the use of different forms of design in fictional or imaginary worlds that opens up a space that does not have boundaries of commercial products (Auger, 2012). For example, fictitious objects can be used for an inquiry to open up discussions with broad audiences (Mollon and Gentes, 2014). According to Sanders and Stappers (2014), they can be used in the early phases of the design process for generating insights about the future usages, by 'exploring, expressing and testing hypotheses about future ways of living' (p. 7). Kerridge points that fictitious objects make users view themselves in the created scenarios (2009) so that the impact of technological development can be discussed not only bounded to the object but also to the scenario that the users are in. It means that it is possible to explore ideas before they become real by discussing potential ethical, cultural, social and political meanings (Dunne and Raby, 2013). According to Wright (2010) in order to understand what is possible depends on showing people the possible alternatives. Dunne and Raby (2013) say that even non-feasible alternatives that are created for users are important because they can open up a pathway to building up the user's own alternatives. It might be because as Dourish and

Bell (2014) reasoned, the possible futures of the people depended on their present perceptions including their understandings, expectations, and frustrations. Therefore, showing them that other cases can exist can be eye-opening.

To be able to conduct design inquiries for IoT, the concept of the future has to be examined thoroughly. Dunne and Raby assess futures on a scale beginning from now and reaching to the fantasy in their book Speculative Everything (2013). They explain their interest as designers as the possible futures that are used as a tool for the desired future by understanding the present. The possible futures here refer to the scenarios raising questions. In order to describe the area of interest, they illustrated a cone starting from present reaching to the far future. The cone encapsulates several smaller cones representing the possible, plausible and probable futures. The smallest cone represents the probable futures. Even though it is the most explored area in terms of design methods, processes, tools and practice, most designers work in this area for sketching the most likely futures which exclude the extreme upheavals. The bigger cone refers to the plausible futures. It aims at envisioning alternative futures as well as it encapsulates what probable is interested in. Scenarios are built in this space for exploring futures. The biggest cone refers to the possible futures. It aims at envisioning what can be possible, which is impossible in today's world. The invisible cone which encapsulates all refers to the fantasy, and it has no connection with the current. There is an intersection between probable and plausible. It is called preferable, and Dunne and Raby (2013) point that area that is open to designers to operate in, assign design roles, explore contexts and methods.

Design Fiction is referred to as a form of critical thinking. According to Auger, they both aim at the questioning of existing and future objects about the way they are and the way that could be (2013). They also both are free from the commercial restrictions and want to draw attention to social, cultural, technological, environmental or economic issues (Sarmiento et al., 2016).

The term design fiction is firstly used by a science fiction writer Bruce Sterling. He defined design fiction in his book Shaping Things in 2005 as 'the deliberate use of diegetic prototypes to suspend disbelief about change' (Sterling, 2005, p. 30). Lindley (2015) explains that diegesis, the root of diegetic refers to 'the world of the story'

so a diegetic prototype means a prototype presented in a world of story. Kirby (2010) emphasises that using diegetic prototypes in narratives places the emerging technologies within a social context. Subsequently, placing a new technology within a narrative raises the questions about 'ethics, values, social perspectives, causality, politics, psychology and emotions' (Kirby, 2010, p. 11), causing not only understanding technological outcomes but also social, political and personal ones (Tanenbaum, 2014). It is because design fiction addresses broad audiences and bases upon the acts of collective imagination (Dourish and Bell, 2014). Below, there is a selection of examples to discuss design fiction with previous projects. *Spime*, *Uninvited Guest* and *Curious Rituals* could be given as an example of critical design.

Spime is a thing that is designed to fit into the vision of the internet of things (Figure 3.16). According to this theory, a spime is an image of an object on the Internet. This image does not exist until someone requests it. The object comes into being with an order which requires credit card information to guarantee the request. Therefore, it is a virtual object in the beginning, and it becomes an actual object afterwards. All the spimes are tagged with a link after being ordered. The tags provide manufacturing and delivery details of the required object. The links can be updated for available services. When a spime reaches the end of its life, its link is deactivated and recycled. In other words, a spime is born and dies as data (Sterling, 2005).

Spime is defined as a speculative, imaginary concept, part of which has already become real. In this theoretical concept, the order should be named, coded, identified, and historicized. The identity that matters the most here because the physical object is described as to be so insignificant in the space-time setting that only limited interaction between it and people can occur.

In the process, concepts and design specs should be tagged with a unique identity to be fabricated, tracked, searched and recycled. At the end of the process, all the information will turn into metadata to be used in future spimes.

Uninvited Guests was created within Thing Tank project created by design agency Superflux (2015). The project researches the scenarios in a smart home environment where things do not only communicate with each other but also respond to the needs of humans in the environment. Focusing on the elderly monitoring in a connected en-

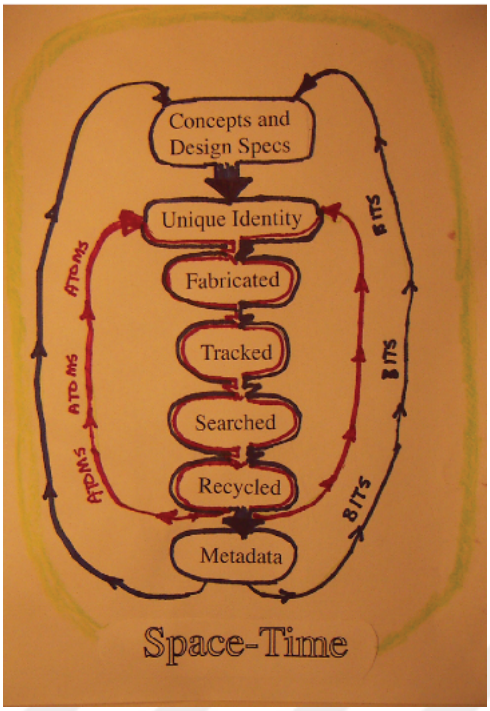


Figure 3.16: Spimes (Sterling, 2006)

vironment, the project raises questions about the situations where human behaviours and device's responses to the behaviours collide. The research outcome is presented as a video with some smart objects. In the video, an elderly person receives connected devices such as a cane, fork, and pill container from his children as a gift. After some experiences with the devices, the man finds his way to keep up with the rules that are imposed by the devices. In the end, he continues his life as the way it was by deceiving the devices (Figure 3.17).

The project employs design fiction to foresee future things for elderly care. The research phase of the project started with some questions focusing on;

- the relationships that humans develop with the objects which become smarter and more autonomous in the connected home
- the role that human will play in the world of objects as agencies
- the reflection of the effect that humans have in objects' life and objects have in humans' life on our cultures, beliefs, and preferences

In search of the answers, the team focused on three thematic areas; Neural Network, Objects with Attitude and Defiant Behaviours. For each thematic area, narratives and scenarios were developed. In the scenarios, symbolic bright green coloured smart objects were used to provoke questions about the colliding moments of human and object agency. They can be named as the diegetic prototypes of the design fiction scenarios.



Figure 3.17: Uninvited Guest (Superflux, 2015)

Curious Rituals is a project developed by members of the Near Future Laboratory; Nova et al. (2013). The project investigates the gestures, postures and digital habits adopted by people by the advances in a digital environment for envisioning the future. The design fiction video raises questions about the domestication of technology, construing and then recycling it. In the video, a woman unlocks and starts her car using biometric features along with specific gestures and she communicates with her friend through fictional interfaces (Figure 3.18).



Figure 3.18: Curious Rituals (Near Future Laboratory, 2014)

The project presented a design fiction scenario to speculate about the evolution of digital gestures with the growing integration of technological objects. It was a two-phased project. The first phase started with field observation (Figure 3.19) and interviews with people who develop new gestures to interact with the networked objects. It was realized that the physical interactions were unanticipated results of the design process and technological development.

The result of the observation shows how people normalize the 'futuristic technologies', which, in the beginning, seem to be complicated. For the second phase of the project, they categorize the gestures and behaviours of people under seven clusters: classic gestures, nervous movements, fixing strategies, holding devices, vocabulary set by designers, personal tactics to make use of technologies and new social interactions.



Figure 3.19: Observation for the project Curious Rituals (Near Future Laboratory, 2014)

As a result, possible alternative scenarios were produced describing how future technologies could be adopted, misused and re-appropriated. As a result, a design fiction scenario in the form of a film was produced by focusing on the situations and the motivations that could appear while interacting with the upcoming technologies. The film also speculates about the emerging gestures in the digital environment. As the film explores alternative uses, it refers to the annoying moments that users could face with the digital interfaces and awkward situations that occur as a result of the interaction that we cannot encounter with the corporate videos envisioning the future.

The outcomes are presented in a way that can be used as an input for the design process of the digital interfaces by illuminating the transformation of the current gestures and rituals.

3.2.4 Discussion on the Approaches for Design for IoT

To be able to grasp the design opportunities in IoT, there are various methods, techniques and tools that can be used by designers in the design process. In IoT, the things, as well as users, are active participants in the practices. Thus, it would be

better for designers not to overlook the input that can be gathered from the things in the early phases of the design process. For this reason, user-centred methods could be supported by the non-anthropocentric approaches to include the things in the research phase. Data could be incorporated into the design process as an inspirational factor (design from data), enablers for the understanding of different interactions (design with data) or collaborators in the design process (design by data). As the things in IoT can gather and analyse data from the agents of an interaction, in design for IoT, design by data come to the fore as a promising act. After the research phase, designers engage with the idea generation activities. In this phase, it could be better for designers to adopt a critical perspective towards existing methods in design for IoT, bringing the things to the centre.

This study inspired from the studies on thing-centred design, design by data and design fiction to create an ideation method using data collected from sensors of the objects to create design fiction prototypes (see Figure 3.20).

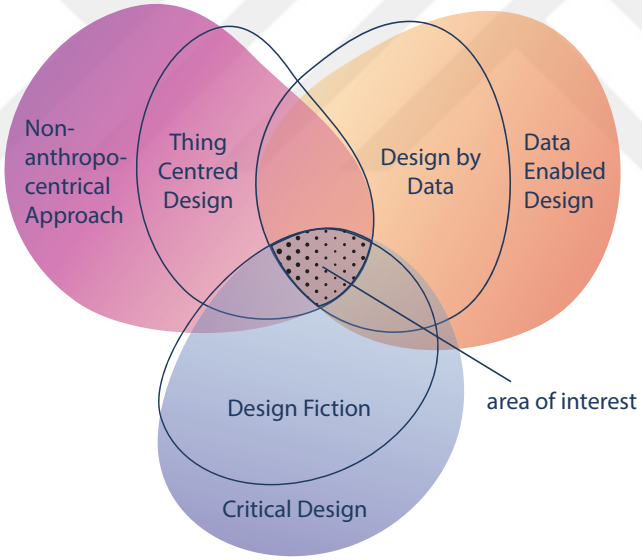


Figure 3.20: Area of interest

There are various studies in the literature that use sensors to emphasise object interactions or use sensor data to understand human behaviour. With the increased availability of sensors, design researchers started using sensors to enhance the objects and exploring ways to use sensors for better interactions. In a way, they used sensors for articulating the objects' reactions to human interactions. After a decade, it was

seen that through the sensors that were placed in objects, we collect a considerable amount of data. Then inquiries about extracting meaning from data started. Design researchers study the sensor data for understanding human behaviours to design for better interactions with objects.

The examples show that data was used in design studies for two reasons: using sensor data for understanding people to enhance their experiences or using sensors to assign humanly characteristics to the objects and create more meaningful interactions between users and objects. In the former way, researchers concluded that when coupled with user insight and context information, the sensor data could become a powerful source to be used in the design process. In the latter way, the researchers proved that attributing humane characteristics to non-living things could improve the engagement between users and objects.

In his book Emotional Design, Norman (2004) questions the attributes of intelligent objects. He says that an everyday object, for example, a toaster, cannot get better in serving its users if it does not have emotions such as pride. It is because, in humans, it is the positive emotions that make living valuable, reward success in life and lead to development. That is why people strive for better. Therefore, a similar incentive should be present in the objects as well. Moreover, the connected things should communicate with their users. They have to understand the emotional state of their users to clarify the ambiguities, and they have to show their state to be recognised by their users. Reflection of pleasure and displeasure, energy or exhaustion, confidence or anxiety might increase the interaction between the users and the objects. The media equation theory by Reeves and Nass (1996) had also claimed that when people faced with any medium that showed sufficient cognitive friction would get human treatment. Therefore, the interaction between humans and this kind of mediums becomes similar to the interaction between humans with any other conscious human being.

Informed with these findings, I tried to find a way to assign characteristics to the non-human agents to enhance the experiences in IoT. In the next section, I will make an introduction to the idea of object persona which I think a projection of the highlighted area of interest by covering user persona development and its effects on the development of object persona.

3.3 Persona Use in Design Process

The root of the term persona comes from the Latin word ‘dramatis personae’ or in other words, characters in a play.

Cooper (1999) is accepted as the first researcher to use the term persona. He developed a method called ‘goal-directed design’ (p. 123). According to this method, the end goals of the user and the persona define each other. Although he mentions four different types of goals named as personal, corporate, practical and false goals, he emphasises on personal and practical ones. That is because he sees interactions that help users achieve their practical goals without breaching their personal goals as a significant feature of good interaction design. Thus, understanding the practical goals is a very important step in persona creation. To be able to spot the practical goals, they have to be differentiated from tasks. Tasks are the intermediaries that are used to achieve the goal. Cooper uses technology for differentiating goals from tasks because he says tasks change with the developments in technology, but the goals remain the same (1999).

Personas are introduced as a tool devised in this method. Cooper defines personas as ‘pretend users’, ‘hypothetical archetypes of actual users’ and ‘byproducts of the investigation’ (p. 124). Keeping the goals in mind, all the personas should be created in a very detailed and accurate way. Although a persona is not a real person, the personas should be based on previous user research. Even though names and personal details could be made-up, the personas rely on the collected data.

Cooper creates and gives detailed and case-specific examples on the personas in 1999, but he does not offer a guide for creating them as a design tool. Starting from this definition, in her book, Designing for the Digital Age, Goodwin emphasises the role of personas as the devices for storytelling and defines personas as ‘archetypes’ used for goals and behaviour patterns of observed potential users (2009). Similarly, Adlin and Pruitt define a persona as a fictitious but credible representation of a target user group (2010). In a user-centred perspective, the use of personas and their contribution to the design process have achieved a consensus in the literature. After collecting data from users, personas help designers making sense of data, communicate the

information to the team effectively, improve the design decisions by contextualizing the social and emotional aspects and achieve consensus between team members for the design direction by helping in the visualisation of the best product behaviour (Goodwin, 2009). These benefits were proved by the experiments comparing how uniquely our brain engages with people other than computers (Gallagher and Frith, 2003) and animals (Mason et al., 2004).

User research is offered as the primary raw material of personas (Adlin and Pruitt, 2010; Goodwin, 2009). While Adlin and Pruitt refer persona planning for explaining the importance of extracting information from data for the persona; Goodwin proposes ways for assigning roles to interviewees and identifying behavioural and demographic variables for each role in making use of the data gathered from the real users. According to her, personas should always have skills, attitudes and behaviours, mental models and goals and may have demographics.

Goodwin (2009) offers nine steps in the persona creation process. Even though it was stated that persona creation is not a linear process, a relative order can be defined. It starts with dividing interviewees by role, and as a second step, behavioural and demographic variables should be determined for each role. Then, interviewers have to be mapped to variables. In the next step, potential patterns should be identified and explained. This step is followed by capturing the patterns and defining goals. Once these steps are fulfilled, the distinctions should be clarified and detailed. The last three steps are about filling in the other persona types, grouping and ordering them and lastly developing communication tools for them.

Another perspective for persona creation by Adlin and Pruitt (2010) defines five main steps in a persona lifecycle. The first one is named 'Family Planning', and it refers to figuring out the problems and data sources within reach for a solution. The second step is called 'conception and gestation', and it is defined as the process of turning data into information. The third step 'birth and maturation' is about introducing the persona to the team. The following two steps in the proposed persona lifecycle are about making use of created persona in design and measuring the success of it, which are named 'adulthood and lifetime achievement and retirement.' The persona creation process of the two perspectives can be seen in Figure 3.21.

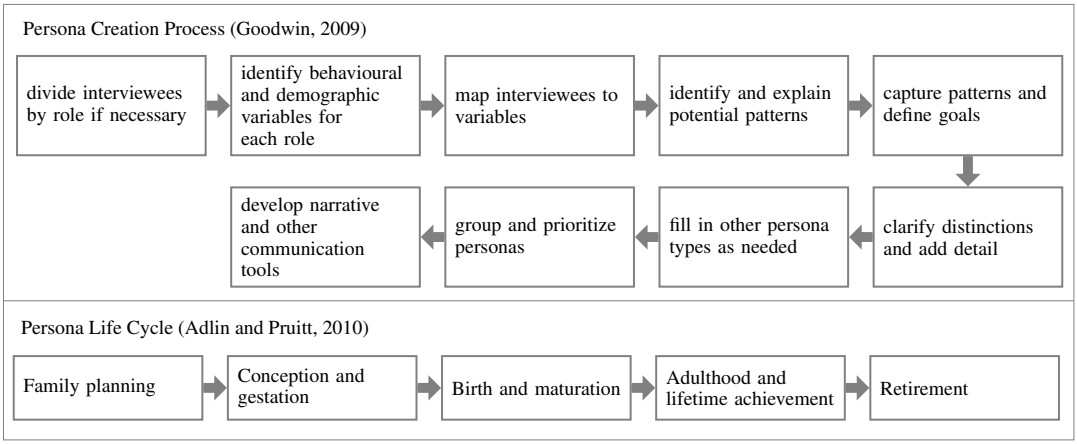


Figure 3.21: Persona creation process by Goodwin (2009) and persona life cycle by Adlin and Pruitt (2010)

The first perspective emphasises perceiving the aims of the created person by elaborating on identifying behavioural patterns suggested by Cooper et al. (2007, p. 99). The latter perspective is more about collecting and organizing large amounts of data and creating relationships between them, such as creating detailed affinity diagrams (Courage and Baxter, 2005, p. 47). In either perspective, the main task is turning raw data into a format that the team will be able to imagine a person whom they can empathize with. However, like it was criticized by Nielsen (2002), Adlin and Pruitt's method can be lacking in depth and insights as it embarks on the character-based approach. According to her, to be able to create more sound personas, physiology, sociology, and psychology should be taken into account together like in Goodwin's method.

Recently, it is being discussed if the use of object personas can make a similar contribution in a thing-centred design process. Cila et al. (2015) propose that the use of object personas is a way for looking deep into the social context of an object for designers so that designers can understand the object and its use practices better with them. They added that, if designers equip the objects with personality, history, interests, needs, and moods, they can elaborate better on the use context of an object and this may turn into design insights.

Thinking about the personality of objects does not comply with the situated design methods, understanding this perspective requires a critical point of view. Iivari and

Kuutti explain that critical theory helps us broaden our vision from the oppressions of our prior experiences (2017). For these reasons, in this study, it was aimed at using an object persona created with a critical point of view, employing a design fiction perspective to suspend disbelief. The things' personas will place a new technology within a narrative, informed by the things themselves through sensor data. They will raise questions on the experiences of users with these things. Design fiction will help anticipation of the context via creating an object persona that designers would easily adopt in their process. The details of the object persona will be discussed in Chapter 4.

CHAPTER 4

METHODOLOGY

As it was briefly mentioned on Section 1.3, this study was organised and held as action research. This chapter will succinctly cover action research, and why and how it was used in this study.

4.1 Action Research

Kurt Lewin coined the term action research in 1946 (Lewin, 1946). He used action research to learn about organizations through changing them. After his studies, action research started to be used in various domains. The definition of action research of Rapoport (1970) is the widely quoted one: 'Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework' (p. 499). Action research requires collaboration between the researcher and the researched practice. This feature of action research is well suited in flexible design research (Robson and McCartan, 2016). That is why action research can be identified as an appropriate method in design studies.

The research activity of this study can be defined as an action research. This study presents a systematic investigation of a potential design method through workshops to test the new procedure and produce knowledge. It was thought that the best way to investigate a new design method could be through the potential practitioners of this method.

According to Robson (2002), action research is about taking action in the real world

and then, explain to others what and why the researcher did so. As the name implies, action research is about action and research or in other words, practice and theory.

The relationship between action and theory in action research has been discussed extensively (Cassell and Johnson, 2006; Whitehead and McNiff, 2006). Since theory and action feed each other, action research is defined as a cyclical process by a lot of researchers. For example, Susman and Evered (1978) list five phases in the cycle: 'diagnosing, action planning, action taking, evaluating, and specifying learning' (p. 588). Kemmis and McTaggart (1988) defined a cycle with: 'plan, act and observe, reflect' (p. 11). Stringer (2007) has a simpler cycle for action research process: 'look, think, act' (p. 8). In the study, I looked at the findings, think about ways to improve the previous act, and act on the decision.

Susman and Evered (1978) list six characteristics of action research. These characteristics also support the suitability of adopting action research for this study. They are explained below:

Action research is future oriented

Action research deals with practical solutions for more desirable futures (Susman and Evered, 1978). In this study, I would like to have a useful and efficient solution to the difficulties of designers while designing for the futures.

Action research is collaborative

Interdependence between the researcher and served party defined as an essential feature of action research. In social science, usually, the observers should set aside their own values to analyse and criticise what has been observed. However, in action research, both research and the served party collaborate on the actions, so the plan and action serve the values of both parties. In this study, three workshops were conducted. The findings of each study guided the plan of the other. In other words, the theory as the served party and the researcher collaborated on the plan for another theory.

Action research implies system development

The outcome of the action research contributes to both the solution of the problem at hand and the corpus of problem scope. The first workshop conducted in quest of

an answer to the research question has become the first ring of a chain. The findings of each workshop both become an answer to a question and stood as a ring itself and trigger another question. The findings of the three workshops formed a chain to present a worthwhile contribution.

Action research generates theory grounded in action

Action research uses theory as a guide to diagnosing the problems and generates potential actions to deal with the diagnosis. In this study, I embedded grounded theory within action research just like some authors did or recommended so (Henfridsson and Lindgren, 2005; Kock, 2004; Baskerville and Pries-Heje, 1999; Yoong and Pauleen, 2004). The gathering and analysis of data that we collected via workshops guided the possible actions.

Action research is agnostic

In action research, the process generates the research goals, questions and the method. Moreover, it is not possible to foresee the results of the selected actions before the implementation. Since I was dealing with a relatively new problem in design—designing for the IoT—I could not plan the next step until I gathered the knowledge from the current step. That is why I planned the whole process in which an action creates a reaction.

Action research is situational

Current situations of the actors involved in the action research affect the related action, and thus, they can change as the situations change.

As Archer (1999) points out, action research could produce extremely valuable findings that might not be obtained otherwise. However, it is situation specific; thus, the results are difficult to be generalised. This is the most prominent disadvantage of carrying out action research. For those reasons, he advises that the researchers who carry out action research should always be mindful about this drawback.

In this study, I was looking for communicable results for the cases where designers cannot easily reach users with experiences with the IoT technologies. In other words, the scope of the study was very specific. Moreover, I adopted a critical approach

both in study design and analysis of the results. Therefore, I was always aware of the limited extent to which I can generalise our results. Forasmuch as the outcome of the hypothesis was tested to verify the potential validity of the results. Measuring the effectiveness of the method will be discussed later.

According to Raelin and Coghlan (2006), informed action is the aim of action theory. However, how the action could be informed if not by theory, is the critical question that action researchers should need to answer.

Grounded theory, the theory building method from data gathered from social research is the answer of several action researchers (Glaser and Strauss, 1967), to guide their theory development. Dick et al. (2009) list the examples in information systems literature. The list includes the study of Henfridsson and Lindgren (2005) which embeds grounded theory within action research, the study of Baskerville and Pries-Heje (1999) which uses the term 'grounded action research' since the studies naturally combine grounded theory with action research and the study of Yoong and Pauleen (2004) which used another term 'grounded action learning' for a similar process.

Action research can be differentiated from the grounded theory with the gradual evolution of theory as the study progresses.

In this project, as discussed in Section 1.3, there were sub-questions to find an answer to the main question. The answer to each question has gradually developed a theory of 'sensor data supported object personas as an ideation method in design for IoT can be effective.'

Figure 4.1 illustrates how the research on practices with IoT started a chain reaction. As a result of the research on the current practices of IoT presented the vision of seeing the objects as agents and sensor data came out as the way to collect data to inform the design process. Presentation of sensor data in the form of data graphs created the question of how designers can extract meaning from data graphs. The current designers' tools for visualising data led the way of using object personas to extract meaning from sensor data graphs. Presentation of object personas as a diegetic prototype of design fiction resulted as a promising method to design for the experiences with IoT.

According to Frayling (1993), there are three types of research in design, namely;

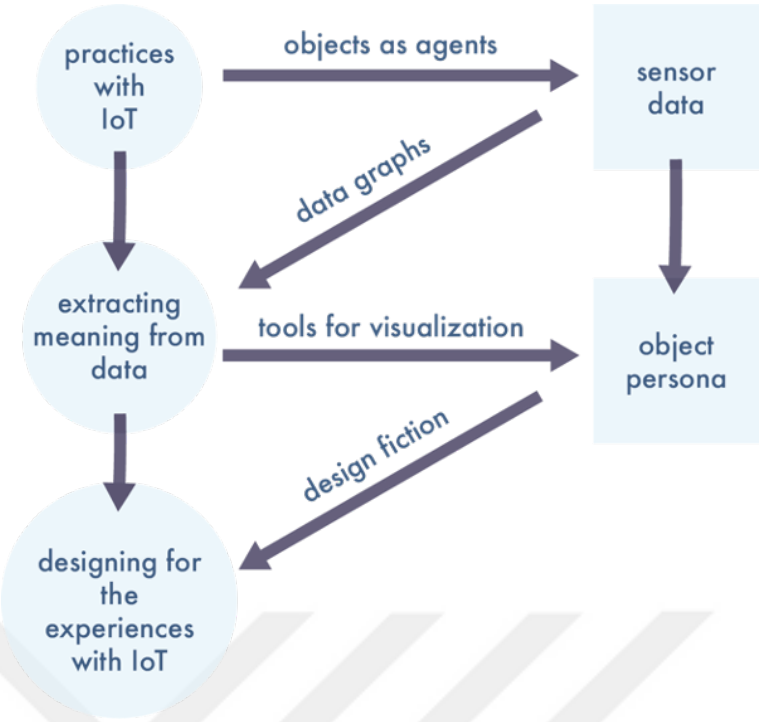


Figure 4.1: The relationship between the actions and findings of the study

research into design, research through design and research for design. Research into design deals with historical research, aesthetic and perceptual research, research into theoretical perspectives on art and design. Research through design is more into materials research, development, work and action research such as altering a technology to innovate and contextualizing it. Research for design focuses on the end product as the artefact aiming at knowledge in the sense of communication tools.

To understand possible technological futures, hypothetical or fictional products can be used and the use of products as a source of knowledge for both their designers and users is a part of the practice of research through design (Vaihinger, 1924). Design for IoT requires the designer's point of view. Thus, research through design could be the best way following Vaihinger's definition and Frayling categorization.

In this study, three workshops were organized to find out how designers can make use of sensor data using object persona in the earlier phases of the design process. Although there were differences among the workshops, some tools were used for collecting data, visualising the data and, making data usable for designers with object personas.

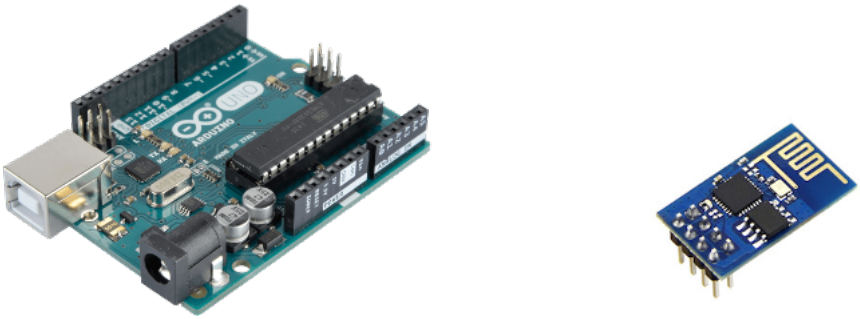
Home is one of the prominent places for the experiments of IoT as it is possible to make objects from utensils to furniture, to process information and to act accordingly (Venkatesh, 2008). Even though home is not the only potential field for investigating the object sociality, it is open for people to create meaning, improvise and entangle in (Nansen et al., 2014). The kitchen space is one of the most efficient or utilitarian places at home in terms of the outcomes in technology design (Bell et al., 2003). Moreover, there are also studies in the kitchen to enhance social interactions of people (Nansen et al., 2014). For that reason, in this study, the kitchen environment has been chosen as a starting point for the observation of connected objects.

In the following sections, the used tools in the workshops are explained and discussed why they were chosen to be used over similar ones. The next chapter will discuss the workshops in detail.

4.2 Used Tools: Sense Box

To be able to transform objects into connected ones with the cheapest and most accessible electronics, an easy to build extension was aimed. Taking the ease of programming of Arduino into account, an Arduino Uno board was used to make things 'smart' (see Figure 4.2(a)). For securing the Internet connection, given the affordability and broader community, the ESP8266-01 module was added to the board (see Figure 4.2(b)). A simple coffee machine was employed to test the extension. Cheap sensors such as a thermistor, photo-resistor, distance and pressure sensor were added to the board (see Figure 4.3). As a result, a simple extension for things that transforms an ordinary object to an internet connected device that is able to speak for itself through the sensing capabilities was created. (See Figure 4.4)

According to Buchenau and Suri (2000), there are three categories for the prototypes. They are either for understanding current user experiences, exploring or evaluating new design ideas and help to explain the design ideas. The first category is for producing high fidelity prototypes for understanding the factors that might affect the design of an existing system which is hard to reach or hard to experiment on. The second category aims at the exploration of physical components that affect the user



(a) Ardiuno Uno board

(b) ESP8266 wi-fi module

Figure 4.2: Board and wi-fi module

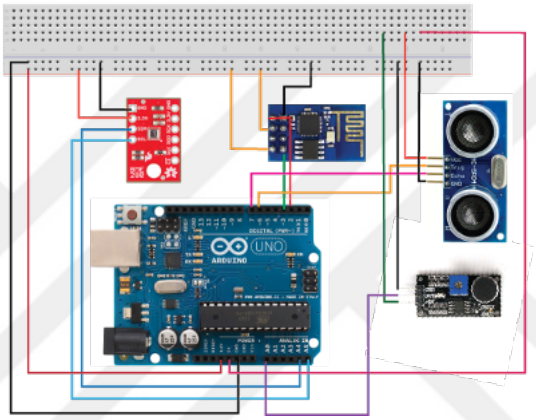


Figure 4.3: Connections of the sensors to the Arduino Board

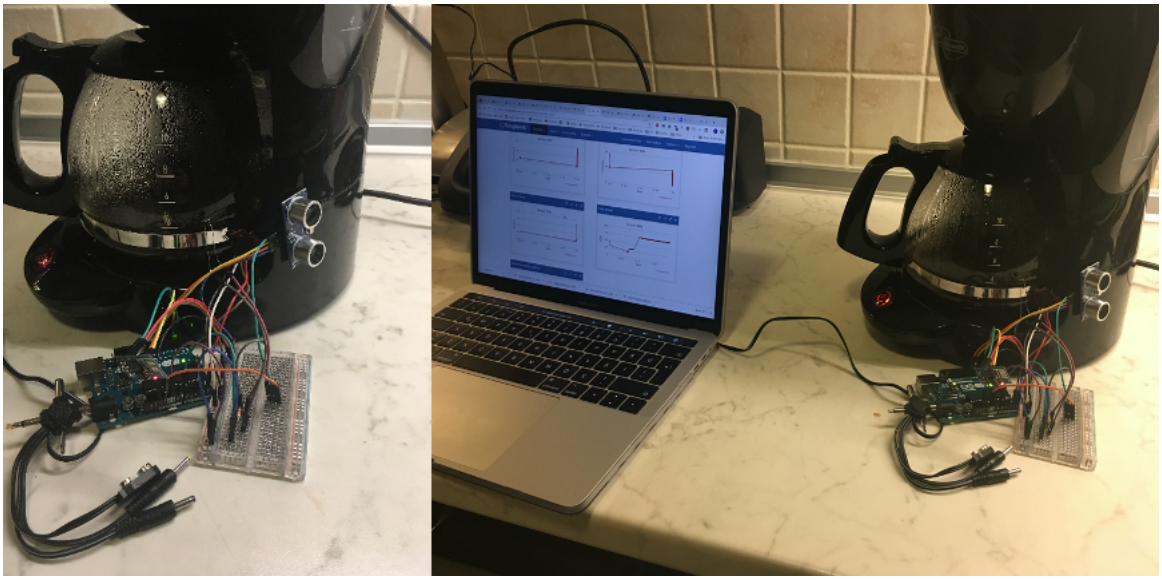


Figure 4.4: Quick and dirty connected coffee machine prototype

experience through gaining more information about the possible experiences of users. The last category aims at explaining a design solution to an audience through experience by interacting with the prototypes. The quick and dirty prototype made in this study is more in the second category than the others. It was aimed to be used for gaining an understanding of possible future experiences of users in the prospective studies.

4.3 Used Tools: Thingspeak

Mashupping is described as a way of gathering existing content to create new applications which are 'connected, integrated, contextual and personalized' (Boulakbech et al., 2017). This term is offered by taking the different use cases and preferences of people into consideration because conveniently creating new services form the existing ones will help people in various areas such as health care, home automation, and smart cities by providing connected sensors, data management and personalization in services (Dar et al., 2011).

In order to deal with flexible and timely data coming from IoT devices, mash-up tools are introduced. The term mash-up can be defined as a platform for developers to combine dams and present data through Web or mobile apps (Rümpel and Meißner, 2012).

There are numerous advantages to using mash-up tools in IoT big data. According to Mahapatra et al. (2016), the analysis of big data generated from IoT devices can create important insights to enhance user experiences. For example, learning about traffic patterns can decrease traffic congestion, structural health monitoring can avoid damages in the buildings and floods can be better provisioned, and precautions can be taken. Moreover, the offered interface presenting the journey of data between sensors, actuators, and services could help end-users in making sense of the place they have in the era of the Internet and things.

Although there are multiple IoT systems such as ThingWorx, Air Vantage, Axeda supporting the management of things and data; they do not enable quick mash-ups of connected things (Blackstock and Lea, 2012).

Some of the most prominent examples of IoT mash-up tools can be listed as Xively, Open Sen.se, Paraimpu, WoTKit, ClickScript, NodeRed, and ThingSpeak.

Xively is an IoT system mainly for organizations to connect their products and track them. The service provides businesses with data processing, integration, and visualisation capabilities to ease the management of big data the things produce.

Open Sen.se provides a platform in which users can connect their devices and visualise and process data. It is considered to be an IoE (Internet of Everything) platform rather than an IoT one because it aims at a world where all the things can communicate and interact (Kleinfeld et al., 2014). However, it is not possible to share devices with others.

Paraimpu is a web platform for the design of modern API based architectures, software development, creating prototypes and new product bootstrap. It provides processing capabilities and allows sharing, but it does not offer any visualisation to users. Besides, it is highly commercialized.

WoTKit is a toolkit that supports the management of sensors and actuators in collection, aggregation, storing and processing sensor data. It is very capable of handling IoT big data, but it aims at organizations such as IoT hardware manufactures, industrial IoT or building management and does not support individual users for free.

ClickScript is a platform that supports collecting data from IoT devices. As it is written in JavaScript, it cannot use resources from web services.

NodeRed is another IoT mash-up tool that is getting more popular among IoT studies every day (Kleinfeld et al., 2014). It also uses building blocks to connect IoT devices. Therefore, it is easy to use for non-programmers. It allows users to reach software platforms and web services. Moreover, it uses JSON (JavaScript Object Notation) so that the flows can be shared. It has various nodes, including one for reaching Twitter data and one for understanding sentiments of written comments. Therefore, it might have great potential in the analysis of online comments. However, it does not offer a built-in graphic analysis for online sensor data.

ThingSpeak is a tool for IoT analytics. It allows users to collect, analyse and trigger a reaction based on collected data.

It offers to create channels for your connected devices and provides the opportunity of accessing other public channels. It means that, by creating a public channel for my coffee machine, I would be able to see the visualisations of collected sensor data. Thingspeak offers eight different fields for gathering data from various sensors. It gives an API so that it is possible to send data to the website and through a public key and it is possible to reach the visualised data. Additionally, by keeping the collected data in the cloud, it secures the data and eliminates the need for paid space. That is why, Thingspeak was used for IoT analytics in the study.

The tool also allows making changes in the visualisations of data through MATLAB. I tried to add predefined time intervals for the data log. After I update the MATLAB code, I saw data logs every once in ten seconds, and it becomes easier to grasp the whole use pattern (see Figures 4.5 and 4.6).

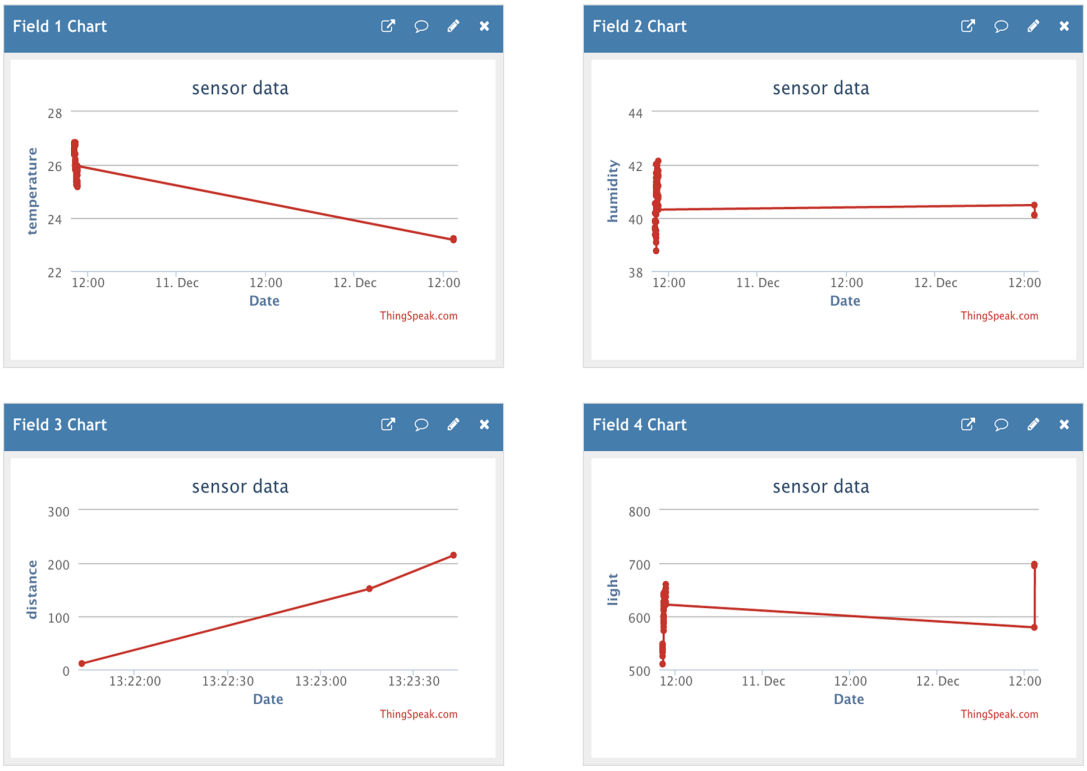


Figure 4.5: First data graphs visualised by Thingspeak



Figure 4.6: Revised graphs of Thingspeak



Figure 4.7: Data graphs for example interpretation

For example, by looking at Figure 4.7, I can say that the user approaches the coffee machine around 23:20 starts it and gets away from the machine for a while and after about 20 minutes the user comes back and takes her coffee. As the humidity decreases, it can be said that the coffee is ready in about five minutes, but as the temperature continues to increase, the user does not turn off the coffee machine even after she takes her coffee. By looking at the light in the coffee pot, the user probably consumed all the coffee she made but forgot to turn off the machine.

After each workshop, the presentation of data to the designers was updated according to the comments of the participants. The final version of the data visualisation can be seen in Section 5.3.1.

4.4 Used Tools: Object Persona Template

Despite the difference in the mentioned persona creation steps in Section 3.3, they are based on Cooper's definition. He emphasises on demographic and behavioural variables to create a user persona. To detail behavioural variables, designers should define the frequency and duration of key tasks, mental models, motivations and goals, attitude towards goals. To be able to clarify the goals; behaviours, frustrations, feelings, aspirations, and interactions with others are pointed as auxiliary elements. Thus, I decided on the headings of the object persona templates based on Cooper's work.

In the first workshop, I presented an object persona template to the participants. It had five main areas to cover all the mentioned demographic and behavioural variables. First row, the first main area in the template, was for the demographics and daily routine of the thing. For the demographic variables, the first cell in the row was dedicated to draw or describe the thing in question. Since the behavioural variables could be generated with the help of key tasks, a daily routine and timeline of the thing were asked to be filled out. The second and third row in the template were divided into two, constituting the remaining main areas. Based on the key tasks identified in the first row, the other titles were presented to complete the auxiliary elements of the behavioural variables. All the titles had an explanatory sentence to give more idea what the title is about.

After each workshop, according to the participants' comments on the template, the areas, titles and explanations were revised in the template. The final version of the persona template can be reached in Section 5.3.

CHAPTER 5

WORKSHOPS

To be able to draw a pathway for designers in the design for IoT, I would like to see what designers can do with sensor data. The main aim here was to shift the designers' attention from users to objects. Therefore, I decided to use object personas. Then, I tested how designers can be engaged with data and how they can use this data in the design process. For the tests, three exploratory workshops were organized to answer the research questions:

- Workshop 1: Secret Life of Objects to see how designers can extract meaning from IoT data.
- Workshop 2: Connected Practices to see the impacts of object persona creation in ideation.
- Workshop 3: Talking Things to see how we can improve the object persona creation to better support the idea generation.

Workshop announcement posters can be seen in Figure 5.1. In each workshop, I iterated the data sets and apparatus in our study design. A similar procedure was followed in each workshop. The procedure can roughly be divided into three: before the workshop, during the workshop, and after the workshop.

Before the workshops, I set up the sensor kit, made a pre-interview with users, took photos of the objects, collected and stored sensor data on the cloud.

Then I prepared environment cards in which there are photos of the connected objects, a summary of the pre-interviews. These cards will inform the designers about where the objects are located, what kind of object we are talking about, and the environmental factors that may affect the sensor data and inform the speculation.



Figure 5.1: Workshop Announcements

During the workshops, I made a presentation about the object personas. Even though the designers were familiar with the persona concept, the object persona was new to them. In the presentation, the widespread methods of persona creation were reviewed, and the distinct characteristics of object personas are pointed. Participants were presented with object persona templates to guide them through the new concept.

Then, sensor data graphs were presented to the participants together with environment cards and object persona templates, and they were asked to fill in the templates by making use of the data graphs. Upon completion of the templates, participants presented their object persona.

The procedure changes after this step in each workshop. In Workshop 1, participants designed a launching page for their persona in a created world. In Workshop 2, participants carried on with their ongoing process and designed a product that can transform to serve different cooking practices. In the last workshop, the participants interviewed the user of the objects and created a diegetic prototype for the future of a connected kitchen.

I sent an online survey to the participants after each workshop. Additionally, after the second workshop, I interviewed the participants. A summary of all the workshops can be seen in Figure 5.2.

		WS 1 Secret Life of Objects	WS 2 Connected Practices	WS 3 Talking Things
Research Questions		How can designers extract meaning from IoT data?	What is the impact of object persona creation in ideation?	How can we improve the object persona creation to better support the idea generation?
Data Sets		Three coffee machines in different homes with temperature, humidity, light, noise level, proximity and water level sensors	Two coffee machines, two tea makers, a fondue maker in different homes with temperature, humidity, noise level and proximity sensors	A coffee machine, a kettle, a toaster in the same home with temperature, humidity, noise level and proximity sensors
Participants		14 participants who completed the first two years in industrial design education	24 participants who took the 3rd year studio course	6 participants who are master students in industrial design
Duration		Half-day workshop independent from course content	Half-day workshop as a class activity	Full-day workshop independent from course content
Apparatus	**Before:**	Sensor kit with coffee machines in different kitchens, Thingspeak, Pre-Interview	Sense box with different machines in different kitchens, Thingspeak, Pre-Interview	Sense box with different machines in same kitchen, Thingspeak,interactive data tool, Pre-Interview
	During:	Printed data graphs, Environment Cards, Object Persona Template	Data graphs in transparent sheets, Environment Cards (detailed), Object Persona Template	Interactive data tool, Environment Cards (detailed), Persona Template
Process		Persona Presentation, Introduction of Object Persona Template, Data Graphs and Environment Cards, Filling the object persona template with the help of sensor data graphs Presentation of Object Personas Survey about participants' thoughts on sensor types, visualization, object personas, designer insights	Persona Presentation, Videos showing how sensors work, Introduction of Object Persona Template, Data Graphs and Environment Cards, Filling the object persona template with the help of sensor data graphs Presentation of Object Personas Survey about participants' thought on sensor types, data visualization, duration of data collection Interviews about the effects of data on object personas and object personas on final products	Persona Presentation, Videos showing how sensors work, Reference values for sensor measures, Introduction of Object Persona Template, Interactive Data Tool and Environment Cards, Filling the object persona template with the help of sensor data graphs Presentation of Object Personas Preparation for the interview with user Interview with the user of the objects Generation of a diegetic prototype for the future connected kitchen Presentation of the prototypes Survey about interactive data tool, object personas, designer insights
Analysis		Content analysis of object persona boards, survey and observations	Content analysis of object persona boards, survey and observations Thematic analysis of interviews	Content analysis of object persona boards, presentations, survey and observations
Results		Use of object personas based on sensor data graphs may help designers in extracting meaning from IoT data.	Object personas positively impact design insights by encouraging designers to think about interactions of objects with users, other objects and environments	Data tools for interacting with sensor data, detailed environment cards and user interviews can enhance the use of object persona in the design process.

Figure 5.2: Summary of the workshops

5.1 Workshop 1: Secret Life of Objects

A workshop was organized with a colleague Emre Çağlar who is interested in design for story worlds to both see what designers can do with sensor data and if they can create an object persona in lights of the presented sensor data. 'Design Fiction Workshop' took place on 6th February 2019 at a design studio in the METU Department of Industrial Design. It was a full day workshop, but the object persona creation part lasted for the half day.

5.1.1 Before Workshop 1

Data Sets Used in Workshop 1

Three data sets were created in Thingspeak to be presented to the participants. I used a quick and dirty prototype to enhance the coffee machines (Figure 5.3). A similar set up was applied to three different coffee machines in different houses to collect data.



Figure 5.3: One of the first trials of sensor connected machines

The data sets were created from the sensor data collected from three different coffee machines based on three different flats shared by at least two people. All the coffee machines were equipped with sensors measuring four different variables. To be able to see if there is a difference in usage of one type of sensor data over others, each

coffee machine had at least one different sensor. The common sensors that all the devices had were the sensors measuring temperature and proximity. In addition to these; Data Set 1 had sensors measuring humidity and the light in the carafe, Data Set 2 had sensors measuring water level and noise level, and Data Set 3 had humidity and noise level (see Appendix A). All the sensor data from three coffee machines were collected for four days as of two weekdays and two weekends and visualised in three Thingspeak channels. Each data set was assigned to two teams to be able to see the similarities and differences in interpretation. It should also be stated that the teams were able to see the other teams' data sets as well. The teams were engaged with data sets and complete the object persona template for two hours.

Environment Cards Used in Workshop 1

After a coffee machine was enhanced with sensors, photos were taken to illustrate the immediate environment of the device. The images were used to form a card where a photograph showing the machine equipped with sensors to show where sensors were planted on the device, a photograph showing where the machine is located and a photograph showing when the machine is in use. The cards (see Figure 5.4) also give very brief information about the users of the machine such as how many users were using the machine, the occupations of the users and since when the users were using the machine to spark a discussion between the team members. Detailed information was intentionally avoided not to limit the design fiction prototypes or in other words, the persona of the machine created by participants.



Figure 5.4: Enviroment cards used in Workshop 1

Object Persona Template in Workshop 1

As it was covered in Section 4.4, the persona template used in the first workshop had five main areas (see Figure 5.5). It was foreseen that in the first part, designers would use the data sets actively to create a routine for the machines. In the other areas, designers would use the timelines that they created in the first part to create a profile for their object and dig deeper in terms of behavioural variables.

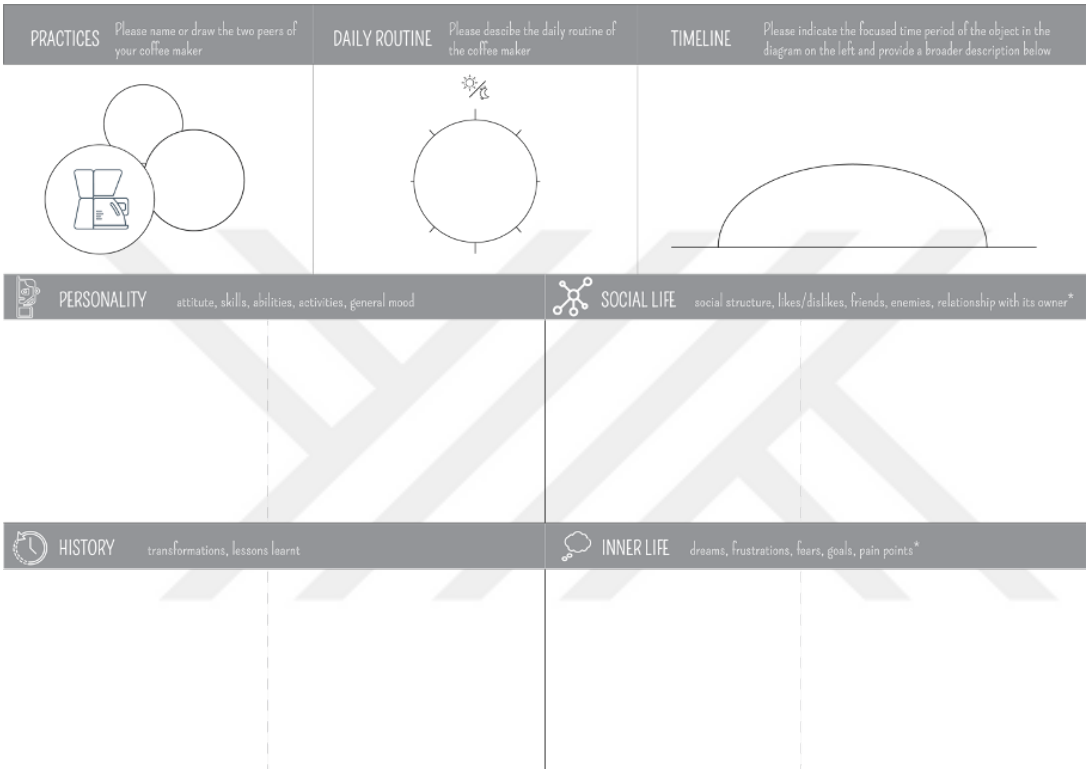


Figure 5.5: Object Persona Template used in Workshop 1

Participant Recruitment

Call for workshop posters were hanged in the METU Architecture Building walls and researchers announced the workshop via personal social media accounts.

In consideration of the design curriculum, we called for participants who at least completed their first term in third-year. In addition to this, there was a questionnaire to recruit participants asking if the applicant has experience with persona creation and familiarity with the concept of design fiction. 36 participants applied from different

universities. A total of 14 participants were recruited from third-year students (4 students; 3 from METU, 1 from Gazi University), graduates (6 designers graduated from METU), masters (3 students; 1 from Eskişehir Technical University, 2 from METU) and PhD graduates (1 from Liverpool University). We formed six groups with at least one post-graduate student in each group. Even though only three of the participants were familiar with the concept of design fiction, all of the participants were familiar with building design scenarios. Two of the groups had three people, and the other six groups had two people.

5.1.2 During Workshop 1

The object persona creation part of the workshop was started with an object persona presentation to inform the participants about the new concept. In the presentation, some of the persona creation methods were referenced, and object persona concepts were exemplified. Then, a template for object persona, all the data sets in digital format and the environment card of the machine from which data is collected were provided to the participants. The participants were asked to create their object personas based on only one data set, but other data sets were also within their reach to see whether they would like to compare their object with other connected machines. At the end of two hours, all groups presented their object persona boards, which can be seen in Appendix B.

After the lunch break, the second part, world-building started. In the completion of the second part, we wanted participants to think about a world where all the objects have personalities similar to what they created in the first part. This property was assured by a chip called a personality core (PC). As a result, they were required to create diegetic prototypes in the form of a product launching page for the new version of their coffee machine. In the second part of the workshop participants were triggered with some world-building exercises. At the end of the second part, the participants had a world where all objects have PCs. At the end of the workshop, all the groups had a launching page for the new versions of the coffee machines, which reflects their objects' personas.

5.1.3 After Workshop 1

At the end of the session, each group presented their personas and explained their notes on the boards. At the end of the workshop, the researchers sent an online survey. The questions included;

- which sensor data they used most while creating an object persona,
- what kind of sensor data they would like to see for creating a better object persona,
- what they think about the visualisation of the sensor data,
- what do they think about the duration of the data graphs,
- what they think about the environment cards and to what extent they made use of it while they are creating their object persona boards,
- if they believe that creating object personas can help them in the design process.

13 participants (out of 14) completed the survey. The results of the survey are presented below.

5.1.4 Results of Workshop 1

The results of the context analysis of the object persona boards and the overview of each group's design fiction prototypes according to the related reflections from object persona will be covered under Section 5.1.4.1. The results of the survey will be presented under Section 5.1.4.2. This section will end with a summary of the workshop results and taken measures for the second workshop.

5.1.4.1 Persona Boards

The persona boards are examined under each heading with the help of their comments from the presentation. Timeline and daily routine were combined by all the groups

either for explaining an action or an emotion (see Figure 5.6). That is why they were combined for analysis as well.

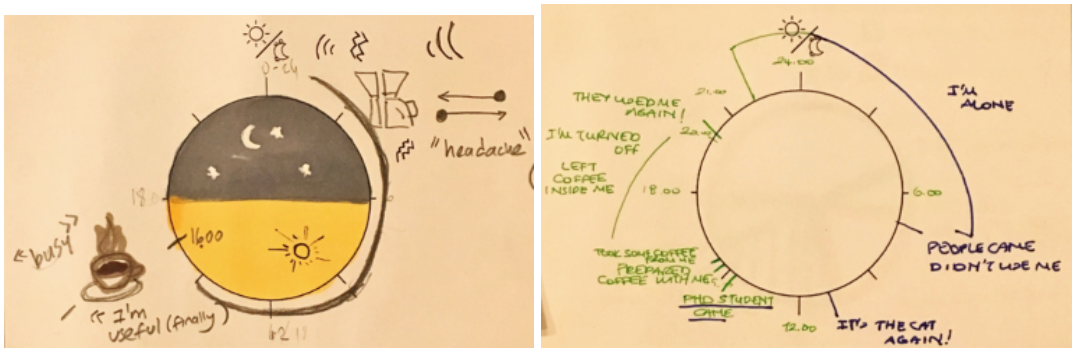


Figure 5.6: Daily routine examples from the object persona boards

To compare the interpretations about daily life, timelines created by the participants were digitalized and brought together. While participants were filling in the timelines and daily life in the object persona template, they were identified as the key tasks of their persona. As can be seen in Figure 5.7, there were lots of common points about usage and practices such as cleaning, resting socializing or staying alone.

During the presentations, all the groups mentioned that they had some difficulties when they started engaging with the data graphs. However, they stated that they were impressed by their persona boards and how they turned 'scary' sensor data graphs into a design material.

All the presentations were transcribed. During the presentations, all the teams revisit all the headings in the object persona template, but they all have a different emphasis on their coffee machine. There were sub-headings under the main headings of personality, social life, history, and inner life. Even though all the subheadings were not mentioned in the final object persona boards of the groups, there were prominent ones common in all groups. The details will be discussed below.

Group 1

The prominent attribute of the coffee machine of Group 1 is about being a bit old. Even though he is old, he has younger friends (users), and he is holding onto life as

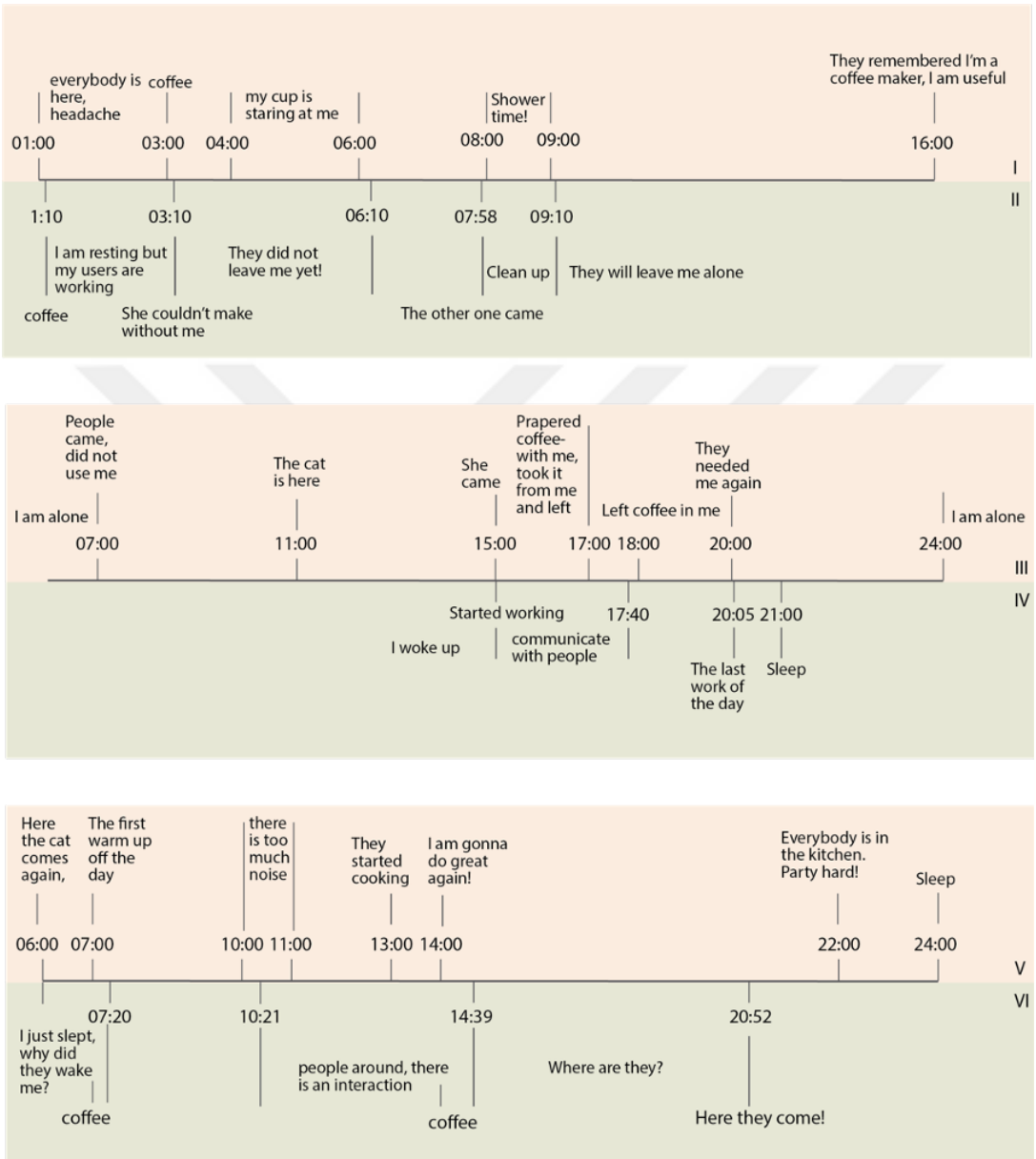


Figure 5.7: Timelines created by participants of Workshop 1

it is indispensable in the house. He also does not like noise around, especially in the night time because it is when the environment gets vivid but loves listening to gossips. It has a big fear of becoming obsolete and wants to reserve its place.



Figure 5.8: An excerpt from the final product of Group 1

In the final prototype (see Figure 5.8), it was observed that this group reflects the personality, its relationship with its user and motivation from the object persona with some design insights on the thing's interaction with users and environment. They turned to be old into something preferable by associating oldness with wisdom. As it is wise, the user can get advice from it. Having younger friends reflects itself by being welcoming. As it is open to new experiences, its parts are interchangeable so that it can adapt to new users. Loving gossips resulted in being aware of what is going on at home, and it reduces the risk of being obsolete because the user will need it as it knows all the details about its environment.

Group 2

The same coffee machine was described as a grouchy old lady by Group 2. It is very ill-tempered, but it loves its users because they still value it. Even though it is aware that it cannot perform as good as it used to, it knows that it is experienced enough does not want to tire herself for performing better. It is afraid of being replaced by the kettle and hates the newer devices. She wants to be displayed in the living room when not in use.

In the final prototype (see Figure 5.9), the group change the targeted user group based on the motivations, abilities and relationship with its owners in the object persona. As their machine does not perform well, and its prominent characteristic is being a



Figure 5.9: An excerpt from the inal product of Group 2

grouchy old lady, they advertise this for the ones who do not like their coffee hot. They reflect oldness with being experienced, so they emphasised its emotional value in their launching page by focusing on its possible experiences of users and environements.

Group 3

The coffee machine is described as a lazy one by Group 3. According to Group 3, the lazy coffee machine wants to spend more time with its best friend coffee cup and very afraid of electricity cuts because it loses communication with the outside world. Instead of its users, it has stronger relationships with the objects around. When it is alone, it prefers not to be interrupted.



Figure 5.10: An excerpt from the final product of Group 3

In the final prototype (see Figure 5.10), the group reflects the friends, personality and its relationship with users from their object persona. The focused on its relationship with its best friend, coffee cup, and made the coffee cup a part of the machine. They

also present a clear interaction with its environment as it has a distant relationship with its owners. We never see the object user relationship in the launching page but a clean kitchen environment where it was placed on the kitchen counter.

Group 4

Group 4 interpreted their machine as a loner. According to Group 4, the coffee machine is lonely because its enemy, the kettle, takes all the attention. Therefore, it is terrified of malfunctioning and wants to stay clean all the time in case of its users needed it. To be able to compete with its enemy, it takes its job very seriously.



Figure 5.11: An excerpt from the final product of Group 4

The group reflects the enemies and motivations from the object persona in their final prototype (see Figure 5.11). They focused on its relationship with the other objects and environment. The machine sits in an elegant kitchen and does its job seriously and very professionally. To be able to increase its interaction with its users, it makes small talks to motivate its users, and it has a relationship with its peers.

Group 5

According to Group 5, their coffee machine is a hardworking and friendly one. It aims to spend more time with its users. It thinks that if it were able to make better coffee, it could be loved more by its users. It likes to have a coffee grinder as well to make better coffee.

Group 5 reflects personality, motivation and relationship with its owners from ob-



Figure 5.12: An excerpt from the final product of Group 5

ject persona in their final product (see Figure 5.12). They focused on the interaction with the coffee machine with users and emphasised their coffee machine's friendliness. The coffee maker has a very close relationship with its users. There is also an emphasis on the quality of the coffee it produces in the final prototype.

Group 6

Group 6 defined their coffee machine as an egoist. They explained that they compared the values and used the frequency of other devices and saw that their machine performs better and used more often than others. Therefore, now, it knows it all but its biggest fear is to be plugged out because of another new or better performing machine. Its biggest dream is to stay clean all the time, break the kettle and to work more effectively.

In the final prototype (see Figure 5.13), Group 6 reflected fears and motivations of their object persona. They focused on its interaction with the user and the other objects. As a result of the distinct characteristics of the coffee machine, they reflected an intimate relationship with the user. By referring to its biggest fear, they show that the user can only get rid of the device by taking it off from the electricity.

As it can be seen in the Table 5.1, not all the parts of the object persona had a reflection on the final outcome. Motivations and relationship with the user were highly referred by the team in the generation of final design ideas. Roughly, there are three prominent reflections of object persona in the final outcomes: interactions with users,



Figure 5.13: An excerpt from the final product of Group 6

Table 5.1: Reflection of object persona on final outcomes

Groups	Object persona	Final outcome
Group 1	friends, motivations, personality, relationship with user	interactions with user and environment
Group 2	motivations, abilities, relationship with user	interactions with user and environment
Group 3	friends, personality, relationship with user	interactions with objects and environment
Group 4	enemies, motivations	interactions with user and objects
Group 5	personality, motivation, relationship with user	interactions with user
Group 6	fear, motivations	interactions with user and objects

other objects and environments. In the next workshop, measures taken for increasing the sections that could be helpful in the ideation and traits for all the interactions in the final outcomes.

For informing the second workshop, the participants were asked to fill in a survey about their experiences in Workshop 1. Both during the presentations and under some of the questions in the survey, participants emphasised that it took time for them to understand how to read and interpret the data graphs.

5.1.4.2 Survey

The survey results and discussions will be presented after each question asked in the survey.

1. *Which sensor data did you use most while creating an object persona?*

   According to the responses, temperature and proximity were the most effective ones. They are followed by water level, noise level, and humidity as can be seen in Figure 5.14. As some of the participants mentioned in their presentations, the type of the sensor data was helpful for them as long as they help them speculate on the uses of the machines or the behaviours of the users.

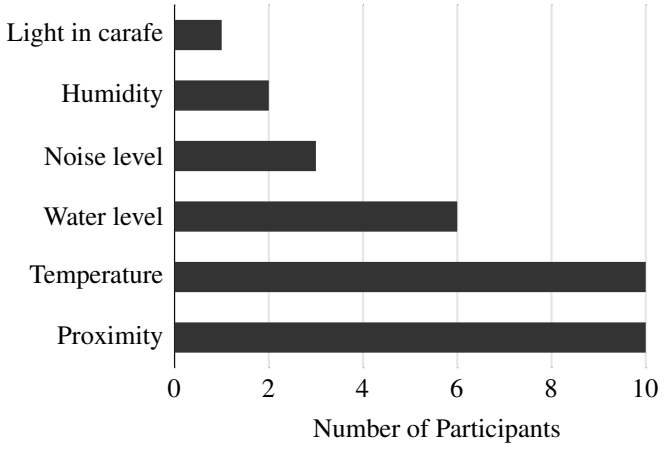


Figure 5.14: Answers to the question 'Which sensor data did you use most while creating an object persona?'

2. *What kind of sensor data would you like to see for creating a better object persona?*

   When this question was asked, the participants were encouraged to think outside the technical constraints.

   Participants wanted to add an energy sensor (3 out of 13), a touch sensor (4 out of 13), a sensor that takes photographs (2 out of 13) and placement sensor, which shows the location of the device at home (2 out of 13). The remaining two participants found the provided sensor data adequate. They explained that they needed to see energy to be certain about the usage, touch data in addition to proximity because they cannot be sure if the user only approximates the object or interacting with it, photos were taken in certain intervals to see the conditions of the object, and placement sensor to see if the object is moving.

   It can be said that the participants wanted to have more data to be sure about either the use or the environmental conditions of the objects. Since I do not have access to the sensors that will meet the criteria of the participants, I took measures to provide more information hinting the use and environment of the connected objects by providing more detailed photos and more detailed data graphs with extended duration.

3. *What do you think about the visualisation of the sensor data?*

   Five of the participants indicated that they would like to have brief information on how the sensor work and a brief explanation of how they are reflected in data graphs. Seven of the participants found data graphs condensed, which make it harder to understand and build relationships between them. They explained that the graphs could be more organized. When they get the data graphs side by side or one below another, a reference point has to be seen to make them more readable. One of the participants thought that the graphs were fine, and it was easy to read.

   To overcome the problems faced with the data graphs in the second workshop the data graphs were printed in transparent A4 sheets. All the data that belongs to different day is printed on a separate sheet. Moreover, the intervals between data readings were the same for reference.

4. *What do you think about the duration of the data graphs?*

   While 8 of the participants thought that the amount of data was not enough and for a better routine analysis it should have been increased, two groups indicated that the data amount was sufficient for them and more data could have complicated their analysis. The comments of the groups about the visualisation of the data graphs and the amount of data they were presented in graphs are covered in Table 5.2.

Table 5.2: Comments of participants on data visualisation and the amount of data presented

Groups	Visualisation	Amount of data
Group 1	'It would be better if we could bring different sensor data under each other and see relations faster.'	'For creating a daily routine, the data was inadequate.'
Group 2	'It was hard to read the graphs because small changes were hardly observed.'	'It was enough to meet the expectations, and more data could be harder to handle.'
Group 3	'The intervals between data were closely spaced, and more detail in the graphs can make it easier to understand the small changes.'	'More data could be more helpful.'
Group 4	'It would be nice to be informed about the parameters or how sensors work.'	'For persona creation, more data would be more helpful to make our interpretations more plausible.'
Group 5	'It was really difficult to understand the small changes in data graphs. More detail and close up visualisation were needed.'	'It was enough because the data was getting clearer as we made more comparisons between one data type and others.'
Group 6	'To be able to see data under each other could help us comparing the data.'	'Observing the machines more than four days could be more useful.'

5. *What do you think about the environment cards and to what extent did you make use of it while you are creating your object persona boards?*

   The responses show that the environment cards helped all the participants in the creation of object persona boards. The comments of the groups made during the presentations are covered in Table 5.3.

6. *Do you think that creating object personas can help you in the design process?*

   Most of the participants (12 out of 13) responded to this question positively. All of them agreed that creating object personas provided them with a different

Table 5.3: Comments of the participants about the environment cards

Groups	Comments on environment cards
Group 1	'It helped us to rationalize our interpretations from data.'
Group 2	'The use of real photos from the machine's environment helped us in characterisation.'
Group 3	'It helped us in creating a more meaningful scenario.'
Group 4	'We interpreted data with the environment cards, without them, our persona would be shallower.'
Group 5	'Seeing other objects in our machine's environment helped us relating our machine with them.'
Group 6	'It helped us in the creation of scenarios that could occur in that specific environment.'

perspective. One of the participants was a bit sceptical about creating object personas based on sensor data. The participant questioned if there might be other ways to be in the shoes of the objects. One of the participants emphasised that using object personas helped in thinking about the environment and the object's relationship with other objects. Another participant questioned what could an object do when not in interaction with the user and one of the participants thought that by collecting sensor data from the objects and creating object personas based on the collected data might provide the insights that might not be collected from the users.

In addition to these comments, during the workshop, it was noticed that the participants examine the graphs by changing the colours of line, changing the opacity of the graphs and putting them on top of each other and turning them upside down by using tools like Photoshop and Illustrator (see Figure 5.15).

As a wrap-up, even though the groups chose different paths for evolving the characteristics of their coffee machine; their starting point, sensor data, was the same. Therefore, they have similarities for the use frequency. During the persona creation, designers mentioned some fears or dreams that can lead to design insights.

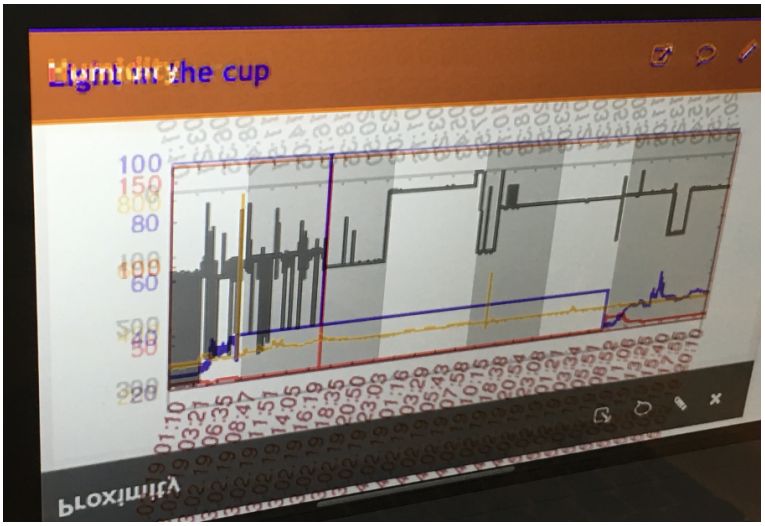


Figure 5.15: Examination of data graphs of Group 1 in Workshop 1

As Workshop 1 revealed promising results for the proposed method, a follow-up workshop was organized by considering the feedbacks of the participants from Workshop 1. The summary of the feedback and taken measures for the second study is explained in Table 5.4.

Table 5.4: Feedbacks of Workshop 1 and taken measures for Workshop 2

Feedback	Enhancements
Environment cards were helpful	Photos from wider angle were added
It was hard to observe the small changes in data graphs	Data was presented in a bigger space
A briefing about the parameters in the data presentation could have been helpful	An explanation about how sensors work is made by videos before the workshop
Different data types one under another could be helpful for comparison and understanding of data	Acetate papers were used to present data graphs
Four days of data may not be sufficient	A week of data was presented
Data graphs that belong to other machines did not help create the persona of our machine	Other machines' graphs were eliminated

Other than the discussed feedbacks of participants, it was noticed that, during the data collection phase of the study, it was not safe to expose the cables of the electronics. Therefore, the prototype was iterated. For the data collection phase of the second workshop, the owners of the machines offered with a prototype that can be seen as a kit that everyone takes and adds to their device safely and easily.

5.2 Workshop 2: Connected Practices

A workshop was conducted by 25 design students as a half-day exercise of the third-year industrial design course to see if sensor data collected from IoT devices can be used in the design process. In the study, eight teams composed of either three or four design students were presented with five different data sets; one was generated from a fondue maker, two were generated from two tea makers and two were generated from two different coffee machines.

5.2.1 Before Workshop 2

Before Workshop 2, Sense Boxes designed to offer to the users of the machines that were going to be used for this workshop. This way, if the designers needed to collect data themselves, they could use these boxes to plant the houses that they would like to observe and collect data.

Sense Boxes were made from corrugated cardboard, and sensors were placed inside (see Figure 5.16). When the kits are placed next to the machines, the sensors work as in the previous workshop (see Figure 5.17).

Each data type was placed under one another in a sheet, and data that belong to one day were presented in different sheets of acetate papers. Therefore, each group had seven sheets of data graphs (see Appendix C). Environment cards are designed with pictures that were taken with a wider angle (see Figure 5.18).

Object persona templates (see Figure 5.19) were revised so that the exercise could be compatible with the ongoing project in the third-year design studio. The project was about designing a flexible, adaptable cooking platform for, particularly shared kitchen

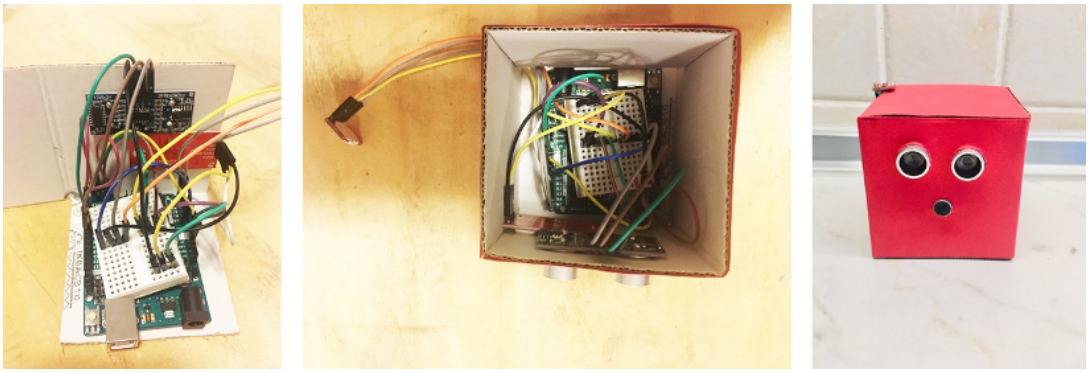


Figure 5.16: Sense box

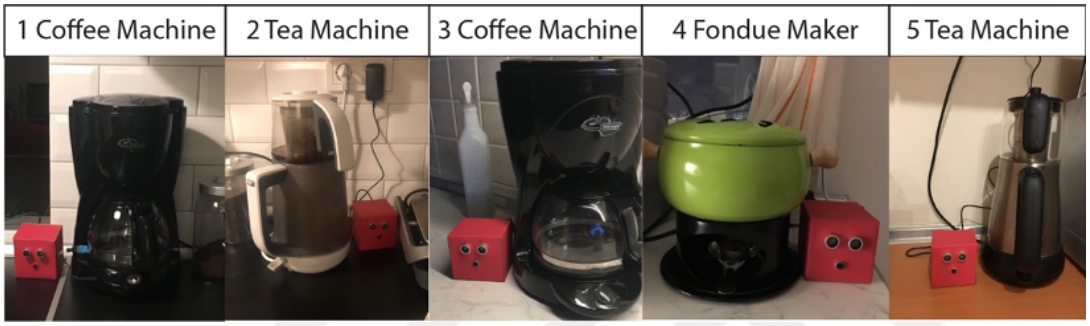


Figure 5.17: Machines connected to the sense boxes



Figure 5.18: Environment cards used in Workshop 2

environments. There were three categories for the practices, and students should have focused on at least one device from each category. The devices in the first category, which include tea maker, coffee machine and fondue maker were enhanced with the boxes to ensure to provide each team with one data set.

Moreover, after each part, an insight heading was added so that it would be easier to see the effect of each part of object persona on the design outcome.

5.2.2 During Workshop 2

A presentation was made to the participants before the workshop. Each sensor used in the study was introduced with videos. In the videos, the values that sensors read with the changes in the variables were shown and explained.

After the presentation, the students were asked to examine the data graphs and fill in their persona board templates in three hours. In completion of the workshop, all the teams presented their boards (see Figure 5.20).

Data Set 1 (Appendix C.1)

The week can be summarized as follows. The temperature in the environment revolves around 23 degrees. Especially early in the morning, an increase followed by a decrease is observed. The increase takes the temperature up to the values of about 45 and this getting warm and cooling down period takes about two hours. This change happens four times in a week. When there is a change in temperature, there is definitely a change in humidity as well, but vice versa is not always correct. When the temperature starts increasing, the humidity makes a peak first and subsides. After that, it increases to a certain point and decreases again. It can be said that most of the time (3 out of 4 days) the variety in proximity increases when there is a change in temperature and humidity.

Team 4 used this data set to create their object persona. They marked five uses in a week for the coffee machine in their persona board. They stated that temperature data helped them the most in spotting the usage. In the persona board, they indicated that

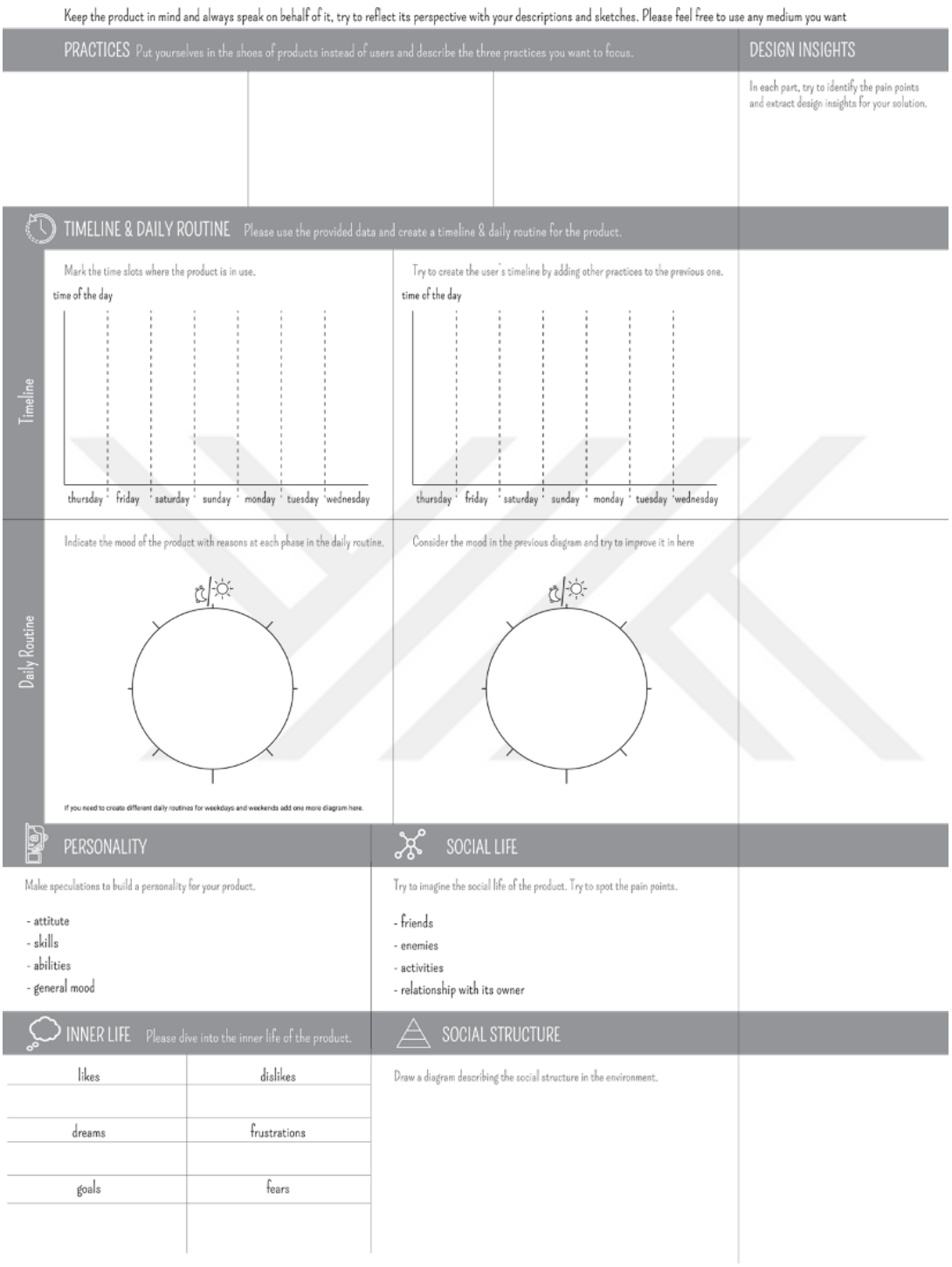


Figure 5.19: Object persona board used in Workshop 2



Figure 5.20: Pictures from Workshop 2

on Thursday after 13:00, they were in the kitchen, but they did not use the machine. On Friday, they thought that they were not in the kitchen and maybe not at home at all and the product was not used. On Saturday, they indicated that the product was used at 6:11 and after that, users were only in the kitchen for a short time in the afternoon. On Sunday, the product was used in 6:04 and made their breakfast at 7:01, and after that time, the kitchen was not used. On Monday, they commented that the product, again, was used for the morning coffee. On Tuesday, they marked a usage for a morning coffee at 5:14. On Wednesday, they thought that the routine of the users was broken and it might be their off day. Therefore, they made a long breakfast with their friends, but they did not use the coffee machine. They stated that, for these assessments, they first examine the temperature data. If they found a considerable change in temperature, then they evaluate the relation with other data types. The design insight that they extracted was about the relationship of the design with its environment. According to them, the workshop inspired them to think about what happens when the product was not in use because they felt that their product was happy only when in use. They created a scenario by looking at the routine they found out from data, and according to that scenario, the coffee component was used heavily during the mornings. They built the scenario for the use of the other components of their design accordingly.

Data Set 2 (Appendix C.2)

The week can be summarized as follows. There is at least one increase in temperature higher than 10 degrees difference everyday. Whenever this happens, there is a change in humidity and proximity as well. The increases in temperature happen almost always (except Sunday) during the same time in the morning. The changes with relatively high differences in temperature and humidity are followed by an increase in the frequency of the changes in proximity data.

Team 1 used this data set to create their object persona boards. They indicated that they started evaluation from the changes in proximity. They put data sheets on top of each other. According to their persona board, they spotted a usage on Thursday around 13:00. They indicated two usages on Friday at after 6:00 and 11:00 for roughly an hour. On Saturday, there is a usage around 14:00 for a relatively shorter time. On Sunday at about 6:00 and 13:00 and Monday at about 6:00 and 15:00, there are two uses of the machine. On Tuesday, one use started around 5:30 in the morning. Another use started at 14:00, but they marked the usage for a longer time than the other ones during the week. On Wednesday, there are also two usages in similar times as on Tuesday but, the marks indicate a shorter time for the duration of the usage.

According to their comments, when they spotted an increase in temperature and humidity together in the datasheets, they marked that as a usage. However, they cleared out that if there was an increase in the temperature but no change in humidity, they thought that their device was affected by the toaster in use.

Data Set 3 (Appendix C.3)

To summarize, it can be said that, there is a correlation between temperature and humidity and mostly (5 days a week) the temperature rises from about 20 degrees up to 60 degrees. This change happens mostly early in the morning (4 days a week). Humidity and proximity being close to 0 are also highly related. Whenever there is an observable change in the values, the proximity approaches to 0.

Team 2 stated that they made assessments by comparing all the data types. According to their persona board, the machine was used on Friday between 09:00-11:00. On Saturday and Sunday, there is a misuse. On Saturday the device was used between 11:00 and 12:17 and Sunday, it was used between 06:11-06:21. On Monday, Tuesday and Wednesday, the machine was used around 5:00 in the morning. They explained that when the user presses the on/off button without water in it, the device creates a 'puff' sound like it exhales because it tries to use the water inside, but there is not any. Moreover, they thought that if there is an increase in the humidity without any change in temperature, the users are using the kettle in the kitchen. That is why the humidity does not go as high as when it works. They also specified that even though the misuses upset the machine, it enjoys being in use and be happy in those times whereas it gets unhappy in the times when it is not used at all. During the misuses, the mood is neutral. The design insight of this analysis is an app that informs the users about the usage of the machine. The use, misuse or overuse can be seen through the app. The app will also notify the user about the state of their device.

Data Set 4 (Appendix C.4)

The week can be summarized as follows. On Friday, Saturday and Sunday, there are changes in every kind of data. The changes are not similar to each other in terms of occurrence time or duration, or values. However, the impact of one data on another is similar. When there is an increase in temperature, the humidity increases for a short amount of time and then decreases and the variance in proximity increases. Besides these days, on Tuesday, there is an observable change in humidity that can be related to the changes in proximity but not any other data.

This data set was used by Team 5, Team 7 and Team 8. All the teams have marked three usages on their persona board with different comments.

Team 5 said that they paid attention to temperature data the most. They cleared out that the uses were spotted by evaluating humidity and temperature together. They also added that they considered the noise level to be able to understand when the users are in the kitchen. They also stated that they put data sheets on top of each other to make comments on them. According to their persona board, the machine was used

on Friday between 18:00 and 21:00, on Saturday it was used between 12:00 and 13:00 and lastly, on Sunday, the device was used between 16:00 and 18:00. While creating a persona for their object, they indicated that they treated their object as a person and especially, trying to spot the enemies helped them a lot in their design. The design insight they extracted at the end of this exercise, they said, trying to protect the product from its enemies. They realized that water is an enemy for their product because it can destroy the electronics. Therefore, they decided to eliminate the water leak by conserving the product in a sealed shell. They also added that the heat that their object produces is an enemy for the user and the countertop. Therefore, they tried to higher the product from the bottom and thought about heat resistant handles.

Team 7 indicated that they also follow the temperature first because the machine works with heat. They added that they used proximity data to think about what was around and the noise for when the users were around. According to the notes in their persona board, the machine was placed near to a noisy fridge. On Thursday, there was few movements around and no usage. Friday was indicated as one of the liveliest days of the house. The machine was used between 18:00-20:00, and just before the usage, it was cleaned. On Saturday, the cat in the house was a bit hectic, and the machine was used for a small amount of time at noon. On Sunday, there were guests at home; the device was cleaned in the morning and used between 16:00-20:00. On Monday, Tuesday and Wednesday they indicated no usage. However, there is a note that kettle was being used on Tuesday. In order to make these comments, they stated that they looked at the temperature data and if there is a change above a certain point than they checked the proximity. They also emphasized that they animated the object while filling the personality. They indicated that this exercise made them aware of the 'socio-cultural environment' of the objects. They realized that if the product they design was to be placed next to a kettle, then their product will be affected by that. Thus, the design insight was about the placement and the relationship of their design with other objects. They pointed out that, they realized that their design would not be the rendered clean object in the white background as they assumed before.

As well as the other teams that studied the fondue machine, Team 8 also indicated that they started from the temperature data. They said that their approach for reading data was based on finding an apparent change in temperature and looking at the projection

of that change in other data types. They also listed the data types they used most as noise level and proximity after temperature. In the persona board, like Team 5 and 7, they marked three usages: on Friday in the evening, on Saturday in the evening and on Sunday in the afternoon. They did not specify a time for the usage. They also inspected the data sheets by putting them on top of each other and thought that the machine gets happy when in use and socializing people. They emphasized that during the personality creation, they thought about the competitors a lot, and it inspired them for their design insight. They explained that they did not think about the main functionality of a fondue maker and find out what we have in the kitchen environment that can fulfil this functionality already. They said that they try to melt the chocolate with the fondue maker, but they can also do that in a microwave. Therefore, their first design insight was creating something that eliminates the things that have the same function and serving the needs of different activities that those things refer to. While speculating about the friends, they have decided that the sticks of the fondue maker are the best friends of the machine. It loves to be stick with them all the time. Therefore, they tried to hold all the parts of the machine together and eliminate a loss.

Data Set 5 (Appendix C.5)

There is a correlation between humidity change and the increase in the variance of proximity data in the whole week. There are days like Thursday and Friday, where temperature and humidity changes show similarity. In those days, the humidity shows a similar reaction to the increase in temperature as a peak and decrease. In addition to these, the humidity increases considerably (20 to 60 g/m3) in the environment at least once a day in most of the days (6 days in a week).

Team 3 and 6 used data set 5 to create their persona boards. Team 3 spotted three usages of the machine during the week. They stated that they mostly relied on temperature data to indicate the use and counted entirely on neither the proximity nor the noise level. On Thursday, from 9:00 to 11:00, on Friday between 14:00 and 16:00 and on Sunday, almost all day, i.e. from 9 am to 9 pm. The team agreed that they marked a use when there was an increase in temperature and humidity together. If the temperature were increasing only then, they thought that the toaster was in use.

They also indicated that they considered the duration of the uses. They decided on the interaction type between the machine and the users by looking at the increase in noise or decrease in proximity. When the duration is short, they thought that the users added water or gave a fresh refill to the machine. Moreover, if the increase in the temperature was high, then they thought it might indicate a usage, but if the increase was not steep, they decided that the machine was affected by the environment. Considering all the assessments they made, the design insight that they used in their project was the interaction between the design and other objects in the environment. Thinking about what happens when the object is not in use encouraged them designing the product placement and storage scenarios as well.

The other team that examined this data set was Team 6. Unlike Team 3, they marked four usages in their persona board. On Thursday between 8:00 and 10:00 and on Friday, Saturday and Sunday between 14:00-15:00, they thought the tea machine was used. They also specified that the device was very happy while in use. They indicated that they determined these usages from temperature data. Even though they took temperature data as a starting point, they emphasized that all data was very important to them. The team pointed out that they took a lot from this exercise for their design. While creating the persona for the machine, the team stated that while thinking about the fears, they realized that as the machine was in love with being used and cared for its users, it was afraid of harming the user. Therefore, the most important design insight of them was creating protection from heat in their design. They also pointed out that it was nice to see the real usage information because they generally have only 'googled information.' For that reason, even though they had an idea about the ideal time it took to make tea, they only assumed how much time it took for users to make tea on a regular day. They also thought that it would be more useful to make this exercise even before the user observations in the process.

5.2.3 After Workshop 2

Online surveys were sent to the participants of the workshop to understand to what extent the data types, presentation and duration affected the persona creation exercise. The questions were:

1. Which data did you find most useful for creating the object persona?
2. What kind of data would you like to add to the presented graphs? / What kind of data would you like to see other than the ones presented? (There does not need to have a sensor readily available) Please explain briefly.
3. What sampling rate that data is presented could make more sense for you in the process?
4. What kind of graphs would be more useful/easier in making sense of data?

All the participants filled in the survey. The results are presented in Section 5.2.4.2.

Interviews were conducted with each team two weeks after the workshop, when they were about to finish their studio project. In the interview, the teams explained how they used the data sets they were presented in generating their persona board and how they used this exercise in their design project. Each interview lasted about 15 minutes. Each data set and the comments of the teams that used those data sets are presented below.

5.2.4 Results of Workshop 2

The results of the context analysis of the object persona boards with the explanations from interviews will be covered under Section 5.2.4.1. Details of the object persona boards created in Workshop 2 can be found in Appendix D. The results of the survey will be presented under Section 5.2.4.2. This section will end with a summary of the workshop results and taken measures for the second workshop.

5.2.4.1 Persona Boards and Interviews

When the object persona boards are analysed, I saw that I could gather similar themes for explaining what the participants created during the workshop.

I observed that while the demographic variables for the objects mostly rely on the environment cards and pre-interviews conducted with the users of the objects, the

behavioural variables rely on the sensor data. First, designers identify the key tasks for the objects then; they extract the duration and frequency of these tasks. With this information at hand, they speculate about the motivations and goals of the machines.

During the interviews, participants assessed their overall process in the workshop as a team. I asked the teams to explain their object persona boards briefly, how they created their board, their design insights and if they used their insights in their final design. When it comes to the design insights that affected the final design according to the comments of the teams, all the groups agreed that they all reflected their design insights from the exercise to their final designs.

After the thematic analysis of the interviews, I validated my interpretations from workshop 1 and identified three main themes to explain how designers interpret data. Design students interpreted the data graphs to create an object persona relating data with objects interactions with its users, other agents, environments.

Here are some examples of how the teams interpreted data relating the data to interactions with users, other objects and environments.

- **Data interpretations related to interactions with users:**

  Team 1 explained that when they did not see a correlation between the changes in data types, for example when there was an increase in humidity but no change in temperature, then they assumed that the user put something in the machine and left it like that.

  Team 2 explained that by looking at the proximity and noise level, they realized that the kitchen was used until very late hours, three days in a row. Therefore, they thought that the user was in the final week, so for three days, she worked until late at night in the kitchen, drinking coffee. Their comments explained that the sudden changes in the temperature points represented the product in use. The momentary increase in the humidity just before the decrease is an outcome of a misuse.

  Team 3 said that there were long durations where the machine maintained the high temperature. They thought that 4 hours was a long time to make tea, so they assumed that even though the users were drinking their tea intermittently,

they never turned the machine off. They could not understand where the interaction started and ended. Then, by taking proximity data into account, they tried to spot the interaction of the user with the machine during the prolonged tea drinking activity. They also thought that longer the working time lower the machine's mode. They took precautions for making the device resistant to high temperatures so even though it worked for longer durations, it would still stay comfortable.

Team 5 explained that they considered the noise level to be able to understand when the users were in the kitchen. They always assumed the usage happened with friends. They created a scenario where the user woke up, made their breakfast and met with friends to make fondue.

Team 6 said that in a day they realized a dramatic increase in noise level late at night. After they discussed a lot, they decided that there was a problem with the toaster and the user tried to repair it. There is also a toaster in the environment, and if the temperature was rising only, then, they thought, the toaster was in use.

Team 7 shared a very detailed observation. They saw that when there was a usage, firstly humidity level increased, then it decreased then the temperature started to increase. They extracted from this data that the users were cleaning the machine before the usage but not after the usage.

Team 8 said that in data, they observed that the temperature increased then it stayed stable for a while. The team thought that after the user finished with preparing, they decreased the level of the heat source to maintain the desired level of temperature.

- **Data interpretations related to interactions with other agents:**

  Team 1 said that 'Humidity and temperature should increase together, and then when they are not increasing together if the only temperature was increasing, it meant that the toaster was on but not the teamaking machine. When both of them were increasing together, then we knew that the machine is on.'

  According to the story of Team 2, the student (user) drank coffee to stay awake. During the night s/he got hungry, made a toast and boiled water for tea. As

sometimes the user preferred using the kettle over the coffee machine, the kettle was identified as the worst enemy in the persona board. They thought that if there was an increase in the humidity without any change in temperature, the users were using the kettle in the kitchen. That was why the humidity did not go as high as when the coffee machine worked.

Team 3 indicated that they thought that they could extract the use information from the intersection of the changes in temperature and humidity, but the level of the change was also important. If the difference was more than 20 °C, then they guessed that it indicated the use, but the small changes indicated the toaster or oven is working.

Team 5 explained that when the proximity was consistently stable and close to 0, they thought that the users forgot something in front of the machine. As they thought it was used three times a week, it got a shower three times a week. They built a relationship with the dishwasher and kitchen tap.

Team 6 explained that they used noise level to see if there was someone in the kitchen, humidity to understand whether the toaster or the tea machine was the one working at that time. The only data they found confusing was proximity because the users own two dogs, and they said they did not rely on the proximity data to understand usage. They explained that, if the temperature was increasing with humidity, then they thought that the tea maker was in use. However, there was also a toaster in the environment. If only the temperature is rising, then, they thought, the toaster was in use.

Team 7 stated that if they observed that humidity was rising and no change in temperature, they thought that the vapour was coming from the kettle placed next to the machine.

- **Data interpretations related to interactions with environments:**

  Team 1 indicated that, when their product was in use, it got happy and if other products around it were used, then it got jealous. To overcome the jealousy, they had a design insight for placing the product on top of the kitchen counter and near to the power supply so that, all the other machines would be replaced and their product would mostly be in use.

Team 3 specified that, by looking at the stable proximity, they thought that the machine sometimes was placed in the cupboard. Resultantly, the machine developed a fear to be kept in a cupboard and being forgotten. Therefore, they thought a lot about what was going to happen when the device was not in use and decided to make their machine modular. In that way, only the parts that were not in use could be taken away.

Team 4 indicated that if the proximity level was low for a long time, they thought that the user could forget something in front of the machine or if the proximity continuously increased and decrease, the cat was lying in front of the device, and it was wagging its tail. They indicated that when they made these connections, they thought about the relationship of the machine with surrounding other objects and its placement. They said that by looking at the proximity and noise level, they spotted the use of the kitchen and even home.

Team 6 said that when they saw that there was a decrease in temperature, but the humidity did not change, then they thought that the user intervened in something in the environment like opening the window.

As a result of these findings, the object persona templates refined to further support the design insights around interactions with users, agents and environments allowing designers to tell the stories with sketches with better defined spaces for the areas. The designers did not effectively use the insights section in the previous workshop. They explained that expressing insights with words was difficult. Some of the participants also indicated that they had difficulties understanding the difference between some of the sections such as abilities and skills. In the next workshop, the template was iterated eliminating the insights section and detailed names for the behavioural variables and sections were named minimising the misunderstandings and allowing sketching for designers to better express themselves.

5.2.4.2 Survey

Responses to the survey questions were presented under each question.

1. *Which data did you find most useful for creating the object persona?*

Most of the participants (15 out of 24) thought that temperature data were the most useful data type when they were creating their object persona boards (see Figure 5.21). Humidity and proximity follow temperature. Most of the participants did not think that they made use of noise level a lot. However, as it was covered in the previous section, most of the groups emphasised that they used noise level, especially for relating objects with user behaviours.

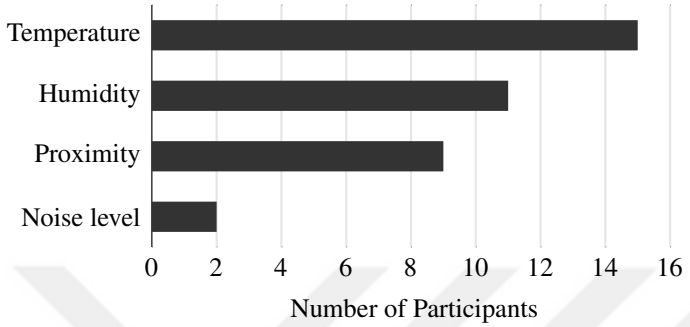


Figure 5.21: Answers for the question 'Which data did you find most useful for creating the object persona? (You can choose more than one option.)'

2. *What kind of data would you like to add to the presented graphs? / What kind of data would you like to see other than the ones presented? (There does not need to have a sensor readily available) Please explain briefly.*

   Three of the participants wanted to see data about the lighting. They thought that it could be helpful to understand the routine of the object during the night time. Three of the participants wanted to see weight data to see the frequency of added ingredients to the machines. One participant wanted to see touch data; one participant specified that data from cameras would be helpful, one of the participants would like to see the energy use of the devices and one of the participants wanted to see the orientation of the product. Other participants prefer not to answer this question. It could be interpreted either they were fine with the presented data, or they could not find one while they were filling the survey. Either way, even though there are intersections in the answers as every designer has a different approach, we could say that we probably could not find an ideal set of data types. That is why the sense boxes should remain open to personalization by the designers.

3. *What sampling rate that data is presented could make more sense for you in the process?*

   According to the answers of the participants, most of the participants were interested in the time zones where there was a change in the data (see Figure 5.22). However, the second most preferred choice was once in ever five seconds (as it was presented). There are also other participants who would like to see data at different intervals.

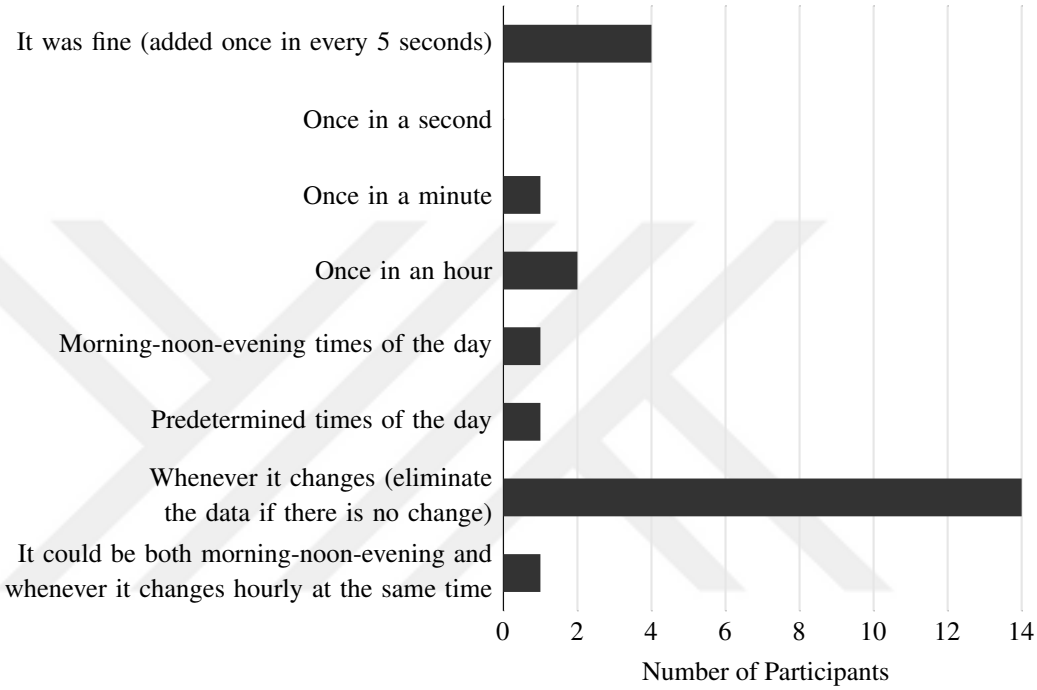


Figure 5.22: Answers for the question 'What sampling rate that data is presented could make more sense for you in the process?'

4. *What kind of graphs would be more useful/easier in making sense of data?*

   The participants did not have a consensus on this question. All the voted choices are very close to each other (see Figure 5.23). Therefore, they sometimes want to see the graphs together and sometimes want to examine all the data types independently.

By looking at the comments of the questions about sensor data types, it can be said that there is no identified set of sensors. The only finding could be that it would be easier for designers to see data that directly reflect the machine's primary use. Even

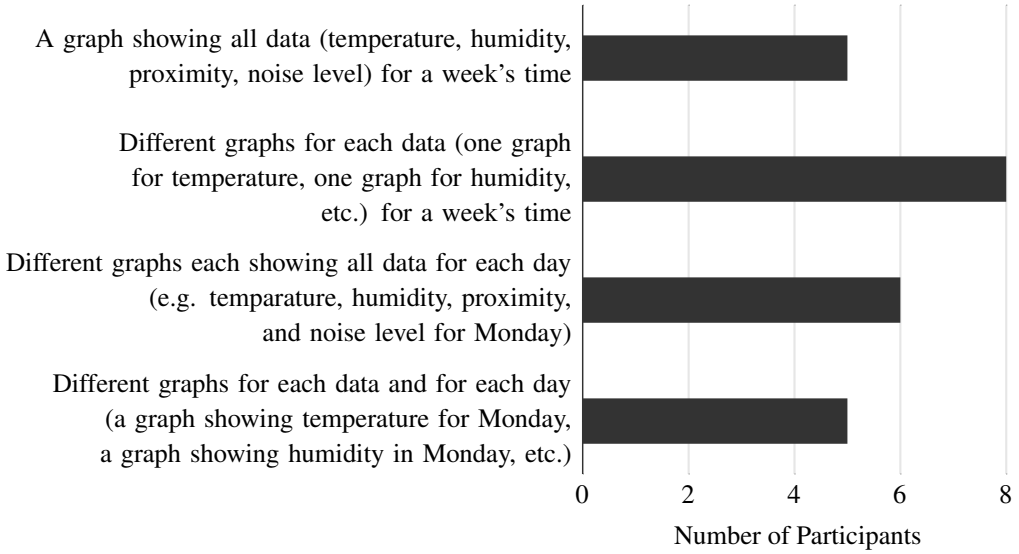


Figure 5.23: Answers for the question 'Which kind of graphs would be more useful/easier in making sense of data?'

though the participants focus on the use of the machines in the survey, they emphasised how they used different sensor types to create the persona boards. It is important for designers to try to gather various types of data that might be in relation to the primary practice of the object in question or the environment they are in. By looking at the comments related to the data visualisation, I decided to design an interface specific to designers to be used during the object creation exercises. I understood that designers want to be in control of data visualisation. They sometimes interested in details, so they wanted to see data in smaller time intervals. Sometimes they may not be interested in other data types, and they want to see the relation of two different data types. They have to be able to add to or extract from the graphs the data types. In the third workshop, a designed interactive data graph was tested with designers.

5.3 Workshop 3: Talking Things

Talking Things workshop was concluded on November 9th 2019 in METU with 6 participants. The four of the participants were graduates of Industrial Design and also Master's students in METU Industrial Design Department, and the other two were graduates from different departments (Economics and Business Administrations), but

they were highly interested in the design practices and methods. Similar to the other workshops, the posters to advertise the workshop was shared via social media and hanged on the walls of faculty of architecture in metu.

5.3.1 Before Workshop 3

Before the workshop, I equipped a kettle, a toaster, and a coffee maker with sense boxes (the boxes with wi-fi connected Arduino board and temperature, humidity, proximity, and noise level sensors) in a kitchen environment of a working couple living with their cat (see Figure 5.24).



Figure 5.24: The machines used in Workshop 3

After the setup, I conducted a very brief interview with one of the users. The questions included who used the machine, how often it was used, and if they had any positive or negative experiences in using the machine. Then photos from the environment where the machines were placed were taken. With the collected information, environment cards are prepared to be presented to the participants in the workshop (see Figure 5.25. The original sizes can be found in Appendix E).

The sense boxes collected data from the mentioned kitchen appliances in a data collection tool in the cloud (ThingSpeak) for three weeks. The collected data then visualised in an interactive data graph (see Figure 5.26). In the graphs, it is possible to see all the collected data in relation with each other, change the time which visualises the data, highlight the desired data type and hide others and see the exact measures when hovered on the graph. To reach the interactive data graph, see the interactions on Appendix F.



Figure 5.25: The environment cards used in Workshop 3



Figure 5.26: A caption from the interactive data graph that is developed

5.3.2 During Workshop 3

The morning session of the workshop started with a persona presentation. All the participants were already familiar with the concept of user personas. The industrial design graduates used them in their projects before. The other participants reported that they had taken design thinking courses and had experiences in creating user personas. During the 15-minute presentation, the facilitator talked about the use of personas in the design process and the concept of object personas. Then, the object persona template, together with interactive data graphs, was introduced (see Figure 5.27).

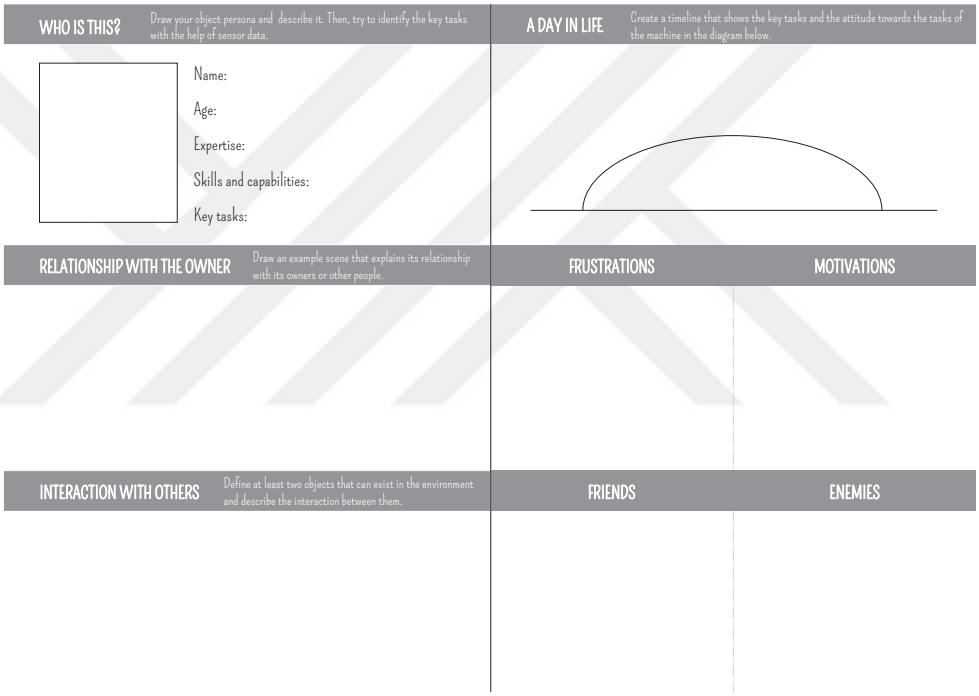


Figure 5.27: Persona board template used in Workshop 3

Then, participants formed a group of two. The participants who do not have a design background have formed a group together. Each group was assigned to one connected object. During the morning session, the participants filled in their object persona templates with the help of the interactive data tool. At the end of the morning session, the groups presented their persona boards. After that, they, altogether, prepared interview questions for the user of the objects.

5.3.2.1 Object Persona Boards

During the workshop, participants experienced the newly generated interactive data graph tool. Using the information from the sensor data, they created object personas thinking about objects' characteristics, goals, frustrations, motivations, their interactions. In this section, the object persona boards created in the morning session by each team can be seen with explanations.

Sunshine

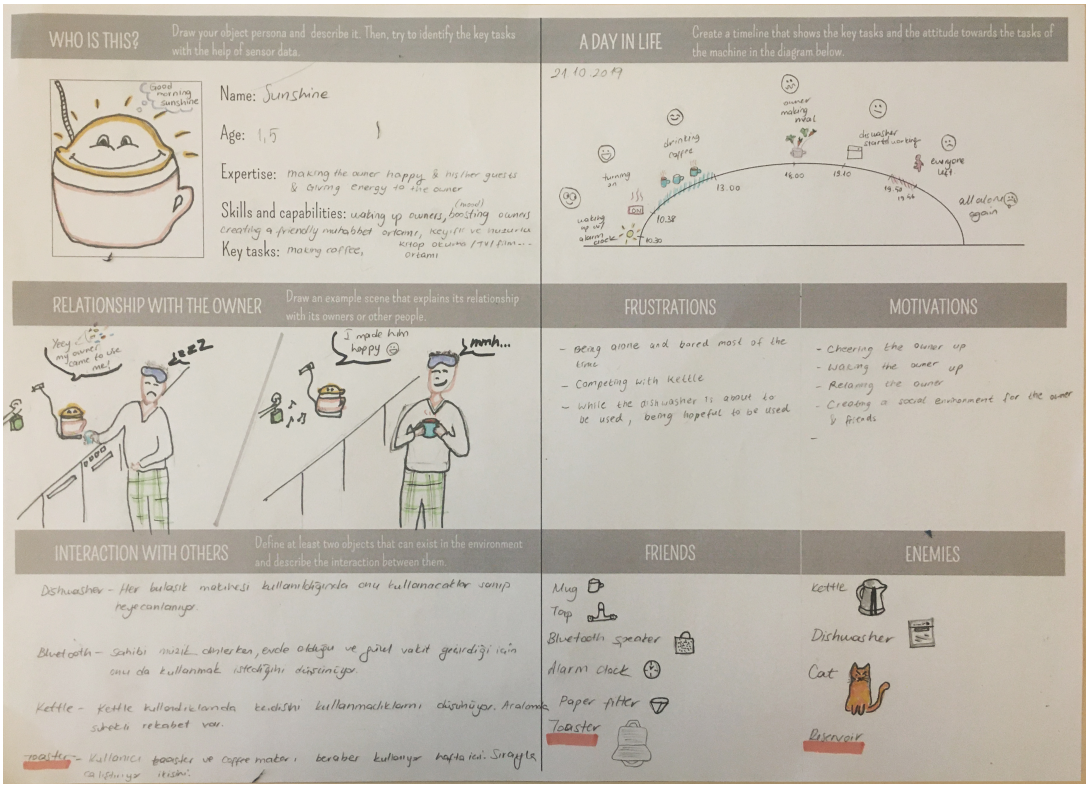


Figure 5.28: Object persona board of Team 1

The group examined the data from the coffee maker named their persona as 'Sunshine.' It is called so because its primary expertise is waking the owner up and giving energy to the ones around. Its interaction with its owner generally in the mornings when the owner is a bit sleepy and grumpy. However, after Sunshine makes the user a cup of coffee, they both become cheerful and happy. However, it is not very happy with the existence of the kettle because it makes Sunshine jealous. The dishwasher

creates a disappointment in it because every time users approach the dishwasher, it gets excited, but when the users only engage with the dishwasher, then it gets sad.

On the other hand, it is friends with the Bluetooth speaker because when it plays, it means that the users are at home, and it may get to be used. It starts the day with its user. Making coffee and users drinking coffee make it happy. Then, when the users prepare a meal, it gets sad again because it does not get any attention. Lastly, everyone leaves the kitchen, and it stays alone (see Figure 5.28).

Toaster Yıldırım

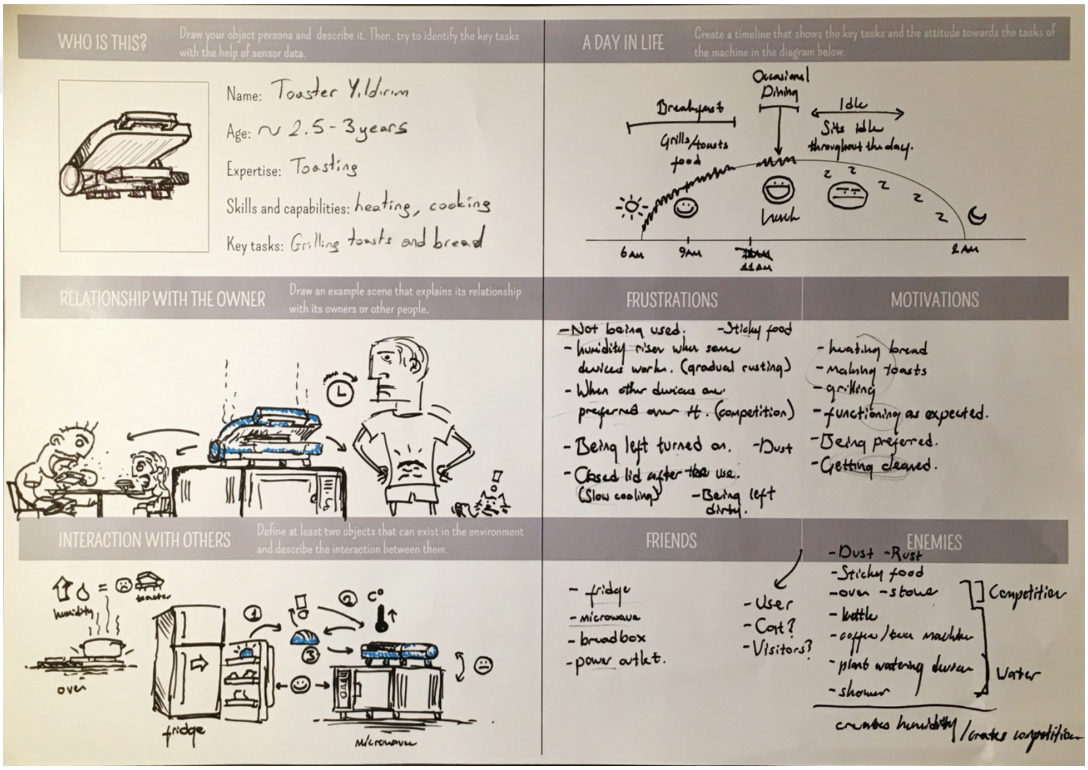


Figure 5.29: Object persona board of Team 2

The group examined the toaster data named its persona as 'Toaster Yıldırım.' It is a sad machine. When it starts working, it gets hot and sweaty. As it takes time to make a toast, it bores its hungry and impatient user. It is friends with the fridge and the breadbox because they supply Toaster Yıldırım with necessary food. It does not like the oven as its only use is increasing the humidity in the environment, and this is not any good for Toaster Yıldırım. It is happier in the mornings because it gets to

be used during breakfast and sometimes at lunch. Then, for the rest of the day, it sits idle, and it gets bored a lot. It is unhappy most of the time, mainly because it finds its users reckless. They do not use it very often, when they use it, there may remain sticky food inside, and the users left it dirty, sometimes forget to turn it down, and they close the lid after usage, which causes slow cooling. Moreover, it is surrounded by enemies such as coffee maker, kettle, oven, stove, and everything which works with water. The only motivation of it is waiting for users and work just as expected (see Figure 5.29).

Pessimist Prime Schrute

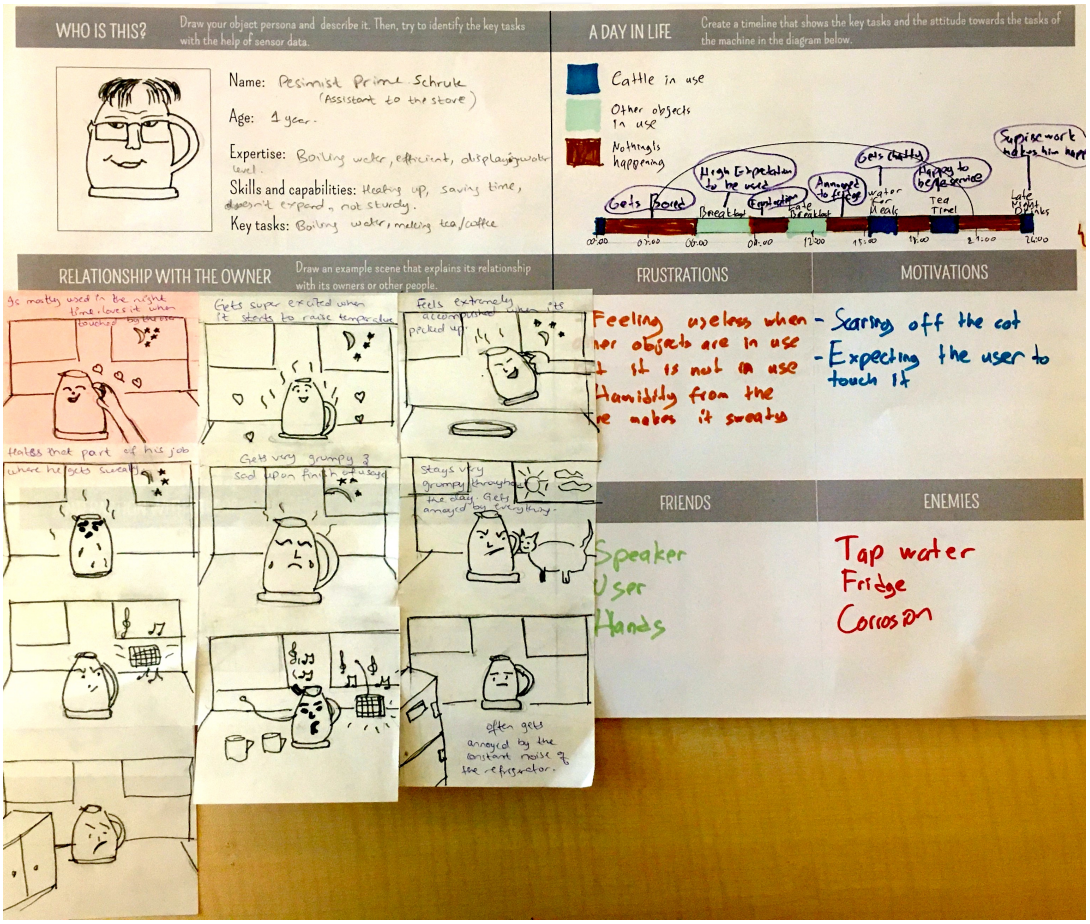


Figure 5.30: Object persona board of Team 3

The group examined the kettle data named their persona as 'Pessimist Prime Schrute.' It is a grumpy kettle because when it is in use, it gets annoyed by pretty much every-

thing. It does not like the fridge because it is noisy, it does not like tap water because it causes corrosion, it does not like the cat because it feels like the cat can harm it and it does not like being alone either. However, it likes to being touched, gets excited when it starts heating and feels accomplished when picked up. Above all, it feels useless when the other objects in the kitchen are in use when it is not. Its motivation is scaring the cat off and being touched by its user. It spends its day either by being bored or annoyed at the other objects around. Sometimes, it gets surprised and be happy when the users use it late in the night.

In the afternoon session, I invited the user of the products. The participants asked their questions to the user and took notes. Then, having the information from both parties, participants created scenarios, products, and systems for the near future where every product is connected to the internet and can talk with each other (see Figure 5.30).

5.3.2.2 Final Design Outcomes

In the afternoon session, I asked participants to think about interview questions for one of the users of the devices. All the participants engaged in a 15-minute discussion to prepare themselves for the conversation with the user. Then, I invited the user of the products. The participants asked their questions to the user and took notes. It was an unstructured interview. The participants added follow up questions or change some of the questions they talked about before according to the responses of the user. The whole conversation can be summarised as an explanation of the user's interactions with the three objects. The session lasted about half an hour. After the process, I asked participants if they would like to change anything in their object persona boards. Then, having the information from both parties, participants created scenarios, products, and systems for the near future where every product is connected to the Internet and can talk with each other.

Sunshine′

The group who created an object persona for the coffee maker first prepared a board for the identified problems. Then, they created a scenario for a future experience.

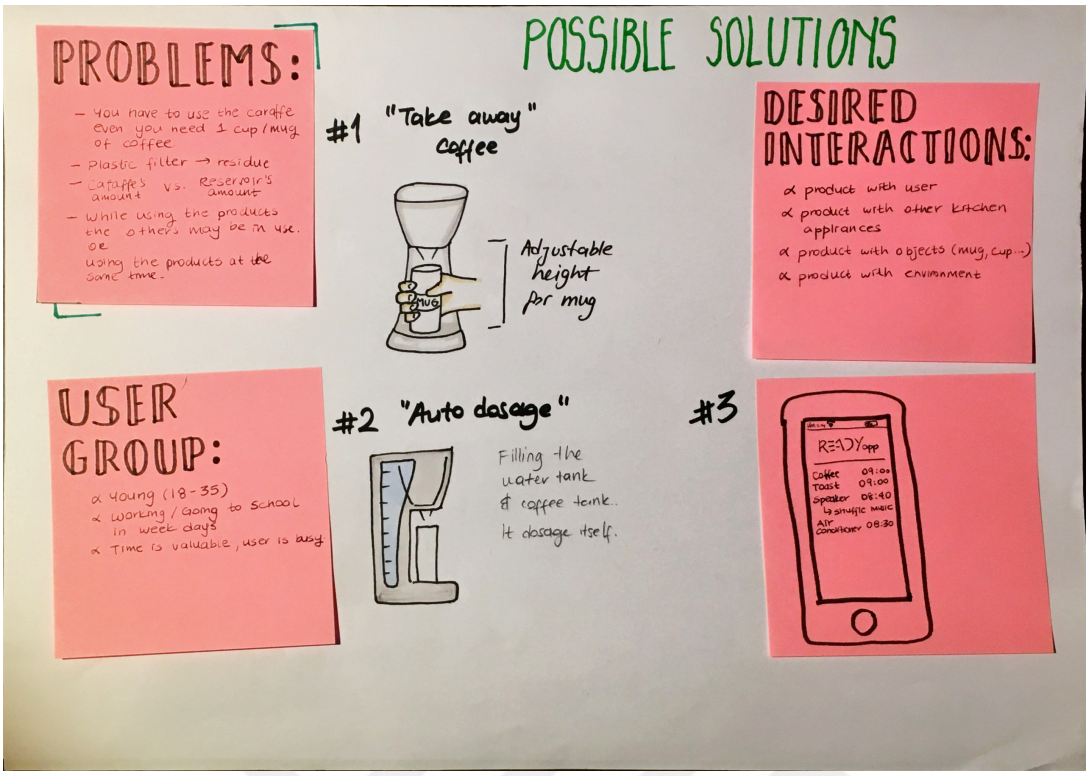


Figure 5.31: Possible solutions from Team 1

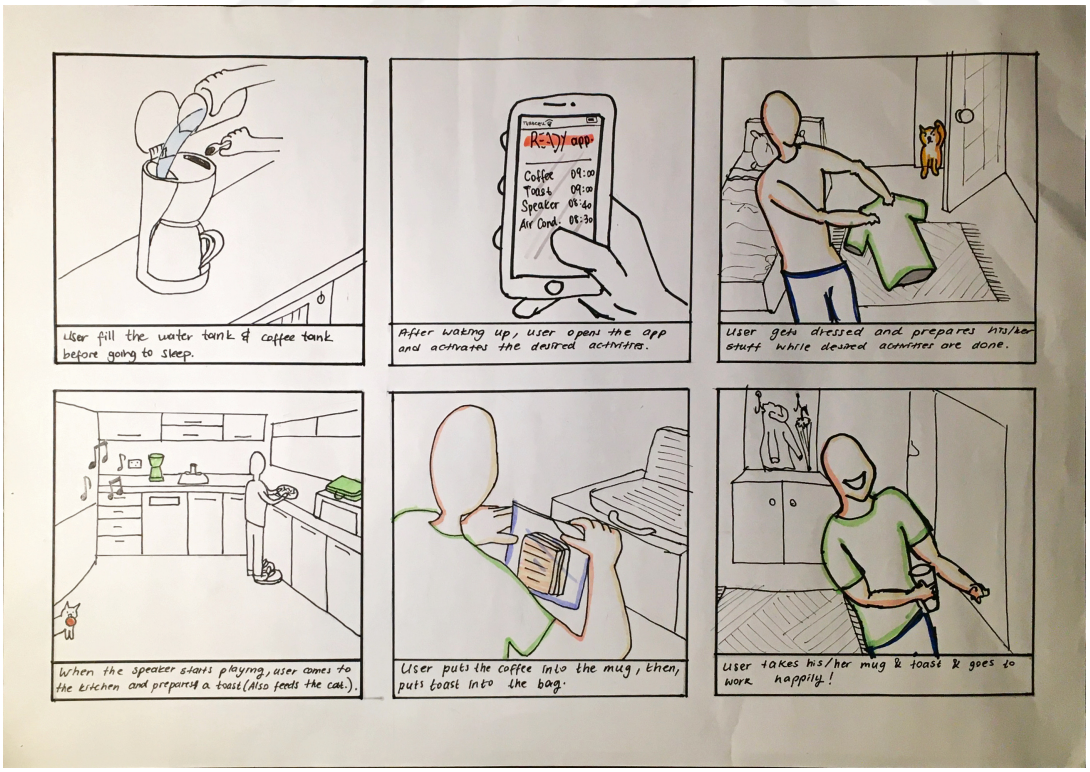


Figure 5.32: Final product of Team 1

According to the scenario, all the devices in the kitchen will know when they are going to be used. The user will inform the machines through an app. Therefore, while none of the machines gets disappointed, they can work more accurately, and they can live in harmony. While the user is getting dressed, the coffee maker starts working with music from the speaker and toaster heats itself. When the user arrives at the kitchen, puts the toast inside the toaster, the coffee will be ready. The user takes the mug with coffee, puts the toast inside a bag, and will be ready with no time lost. (see Figures 5.31 and 5.32)

Burnie's Toaster Pro 5700

The group who created an object persona for the toaster designed a future toaster, named 'Burnie's Toaster Pro 5700.'

It has its friends named 'Fridgo', 'Washo', and 'Wake-up'o.' It is pretty smart. It does not require maintenance from users.

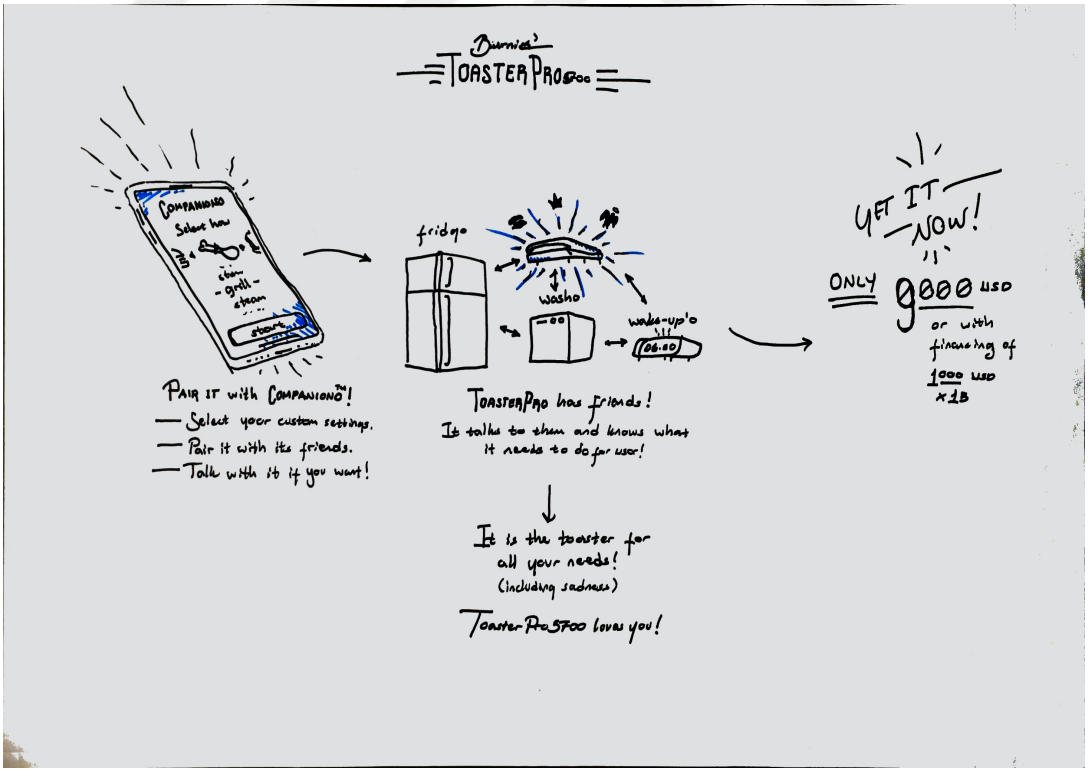


Figure 5.33: Final product of Team 2 (Part 1)

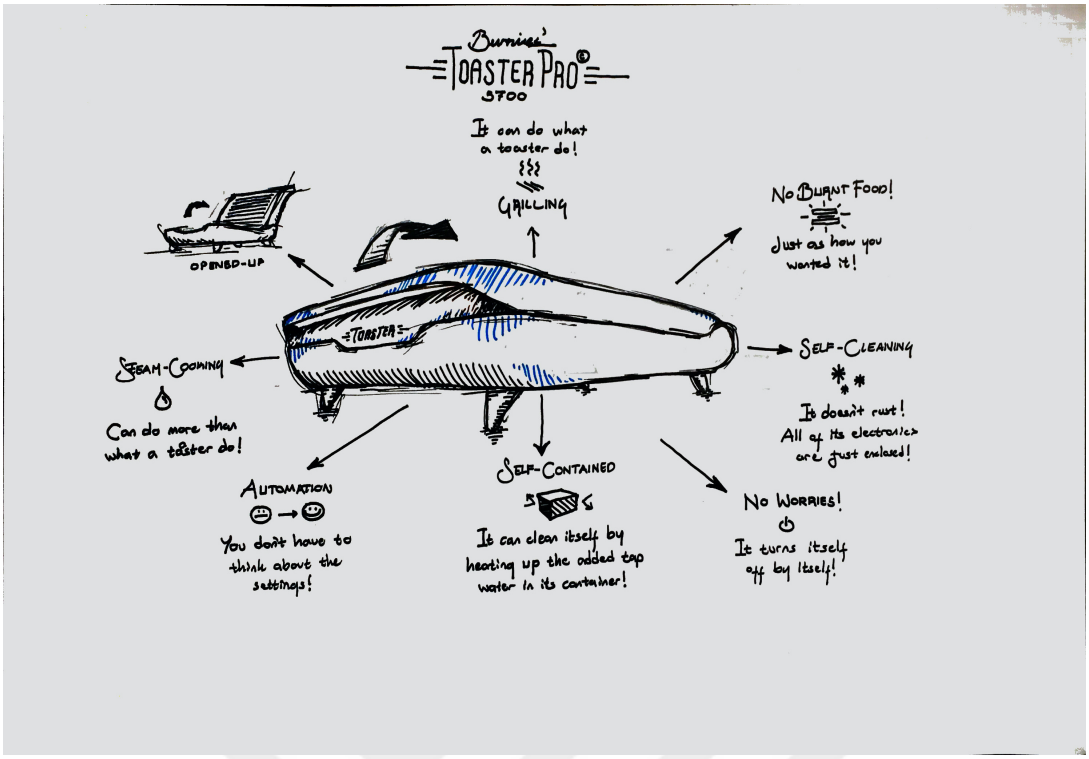


Figure 5.34: Final product of Team 2 (Part 2)

It can steam cook, clean itself, and even turn itself off. It does not have any expectations from the user. Instead, it interacts with its friends and talks to its users if it needs to. Therefore, it meets all the expectations of users with its companions and does not get frustrated by the user (see Figures 5.33 and 5.34).

Optimist Prime Schrute

The group who created an object persona for the kettle proposed a system.

According to this system, future kitchens will be divided into two. The first part will be for quick actions, and the second part will be for elaborate functions. When the user is in a hurry and does not want to lose time with interacting with the appliances in the kitchen, the quick part will be used.

For each practice, possible combinations will be offered to the user, and the machines start working according to the most efficient order. If the user has time, then the elaborate part will be used. Here, the user customizes the combinations with the



Figure 5.35: Final product of Team 3 (Part 1)

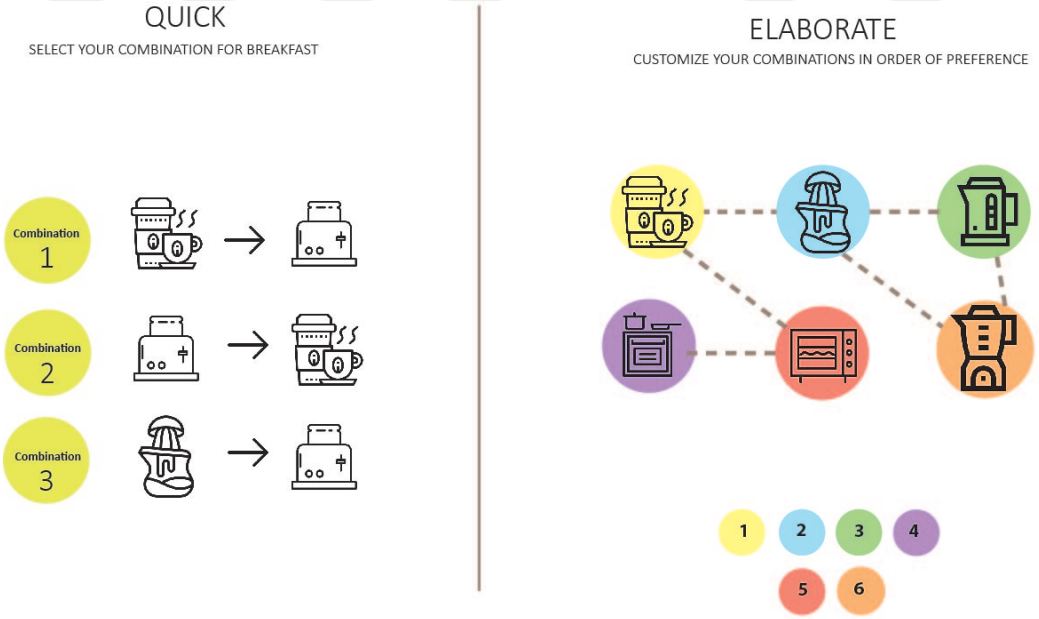


Figure 5.36: Final product of Team 3 (Part 2)

machines. In this system, the machines and the users collaborate, and the needs of both parties are satisfied (see Figures 5.35 and 5.36).

The detailed evaluation of the used tools in this workshop will be discussed further in Chapter 6.

5.3.3 After Workshop 3

The workshop ended with filling the general evaluation survey. We sent every participant an online Google form, and they filled in the surveys anonymously. There were seven questions requiring short explanations. Participants explained how they found the interactive graph tool, if the interactive data graphs helped them in object personas, if they used their object personas creating their interview questions, if they used their object personas during the interviews, if they needed to revise their object personas after interviews, if they used their object personas in ideation and general opinions about using sensor data for creating object personas in the early design phases.

The responses to the questions were summarized below.

5.3.4 Results of Workshop 3

The of the object persona boards and the overview of each group's design fiction prototypes according to the related reflections from object persona will be covered under Section 5.3.4.1. The results of the survey will be presented under Section 5.3.4.2. The detailed evaluation of the used tools in this workshop will be discussed further in Chapter 6.

5.3.4.1 Persona Boards

During the workshop, participants experienced the newly generated interactive data graph tool. Using the information from the sensor data, they create object personas thinking about objects' characteristics, goals, frustrations, motivations, their interac-

tions with their environment. Then, they used their object persona boards to design for the near future.

5.3.4.2 Survey

Responses to the survey questions were presented under each question.

1. *What do you think about the interactive data graph tool? Please explain shortly.*

   According to the answers, all the participants found the interactive data graph very useful. Two of them even stated that they loved it. Two of the participants emphasised that they found it a bit complicated in the beginning. They thought that closer numbers for the sensor values in a short period of time (5002, 5006, 5003 then 70) could be eliminated.

2. *How did the data graphs help you in creating your object persona?*

   They stated that the sensor data help them identify the key tasks, internal and external factors. Three of the participants extracted hints for creating the environment of the object, three of them stated that they understood the use cycles of the product and three of the participants thought that they understood the relationship of their products with the other products.

3. *How did your object persona help you in creating interview questions?*

   Regarding the answers, most of the participants thought that they used the object persona for creating more specific questions. They felt that they were able to focus on particular cases from the object's perspective and asked the questions to the user accordingly. One of the participants stated that they took the emotions, needs and what is good or bad for the object into consideration.

4. *How did you use your object persona during the interview?*

   During the interview, most of the participants stated that they listened to the answers as if they were the objects. According to one of the participants, the object personas at hand gave them a more emotional perspective. One of the participants said that they focused on what would the object ask the user during the interview.

5. *What did you need to revise in your object persona after the interview?*

   Only one of the teams stated that they made minor revisions in interactions with others part of the object persona board. They specified that they figured out something they misinterpreted before. Lastly, all of the participants thought that using object personas in the early phases of the design was quite impactful, and they would consider using this method in their further studies.

6. *How did your object persona help you in your ideation?*

   Four of the participants reported that they used the object personas in ideation for focusing more on the environment of the object and its interaction with others. Two of the participants explained that it helped them in building the object-object relationship other than the object-user relationship. Two of the participants take the object to the centre but not the user for the first time. Two of the participants thought that they did not make use of their object persona boards as they were supposed to.

7. *What do you think about creating object persona based on sensor data in the early design process?*

   All the participants had very positive responses to this question. Participant 1 found using object personas reasonable: 'It makes sense in understanding the contextual information that is not readily present or apparent.' Participant 2 found the method helpful: 'It is really helpful and perspective-widening. We could think about the object's problems and emotions which will provide a healthier and stronger interaction with the user/other objects/environment.' Participant 3 found the method not only helpful but also necessary: 'It is really helpful and necessary because it is like observing its life. The objects cannot be interviewed, so observing them and their life to create persona make understanding them easy while designing.' Participant 4 also agreed with participant 3: 'I think it is a helpful method in getting to know the products better, from the product's perspective.' Participant 5 explained that using this method can help them be objective: 'Using sensor data generates objective ideas on the user and user's habits. So, using that data can break down some prejudices and give way to a more honest study.' Lastly, participant 6 that it provided an interesting perspective: 'Using sensor data adds a lot of value and authenticity to the object

persona. I most definitely would use this method in my future projects! It is an interesting and less selfish perspective to the design process.'

Since the sample size is very limited, in completion of the workshop, I asked participants if they found the use of object persona helpful for speculation on the design of the future connected devices and wanted their comments on the entire workshop. All the participants thought that creating object personas would help in the design process.

Team one summarised their thoughts like that:

'We can't understand what the product means for itself but not for the user. As we said, you have to become a friend of the product; you have to become a friend with the cable, for example, to design the cable better. We try to apply that in our projects but now we become the product, not friends with the product. I think it is useful.'

They also commented about how the use of personas changed their mindset:

'Before that, I have never thought about the interaction between products and other products. It was always about user and user, user and product, user and environment. Users perspective was always dominant in my mindset. It really provides me with the perspective of understanding the products and its relationship with its surrounding. Even the user-product relationship was different in that case. I was not considering the relationship with the object's perspective. Now I understand that it is really important.'

Gaining a different point of view is also common in Team 2. They explained their stance as: 'You started to see some interesting facets of the problem you don't usually see. If you start to think in the perspective of objects, you can improve the product's facets that you get blinded to. It creates the opportunity of making them speak with us, and it creates additional value.'

In a very similar vein, Team 3 also emphasised how the use of personas changed their approach in the process: 'I've never thought that I can think like that. It really opens a lot of opportunities and contributes design thinking like seeing the things from the product's perspective. It also says a lot of redundant things that are happening in the

products system inside kitchens even. Like there are two products doing the same thing, and you can sort of eliminate that when you see the product perspective and maybe more sustainable towards the product system.'

Team 3 also had comments on the potential positive effect of using the object personas in the design of future products: 'Object's perspective shows you the things that you can't see otherwise. This kind of thinking may give some way to more autonomous things. In IoT or smart products, we generally think the relationship between user and product and the user always is more somehow. For autonomous products, especially, this approach could work better. They could get things done. They can look at something that wasn't there before. Maybe they can create some kind of different relationship between themselves.'

The participants' consensus on the positive effects of using object persona on the process of designing for IoT demonstrates that the use of data for creating object personas for speculating on the future connected devices has promising potentials. Further evaluation of the method based on this workshop will be discussed in the next chapter.

CHAPTER 6

EVALUATION

Since the proposed method aimed to be used by designers in a variety of design problems for IoT, the workshops were conducted with a variety of participants. All the participants were recruited from designers or design students who completed their education to a certain degree—third-year students or above (see Figure 6.1). The reason for that is making sure of all the participants had some experience in user personas and scenarios. To increase the chances of representativeness, the participants were from different schools and some from different cultures (see Figure 6.2). Thus, I think the information gathered from the participants of this study could be used to draw inferences about the whole target group of the proposed methods: design students, design researchers and practitioners.

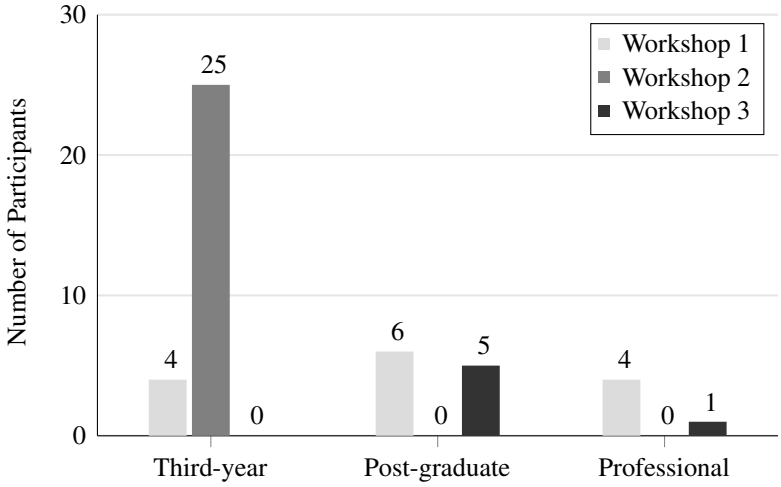


Figure 6.1: Participants' status in their design career

I also tried to ensure that data is collected through and visualised with the same medium without the presence of an observer. All of the participants completed the

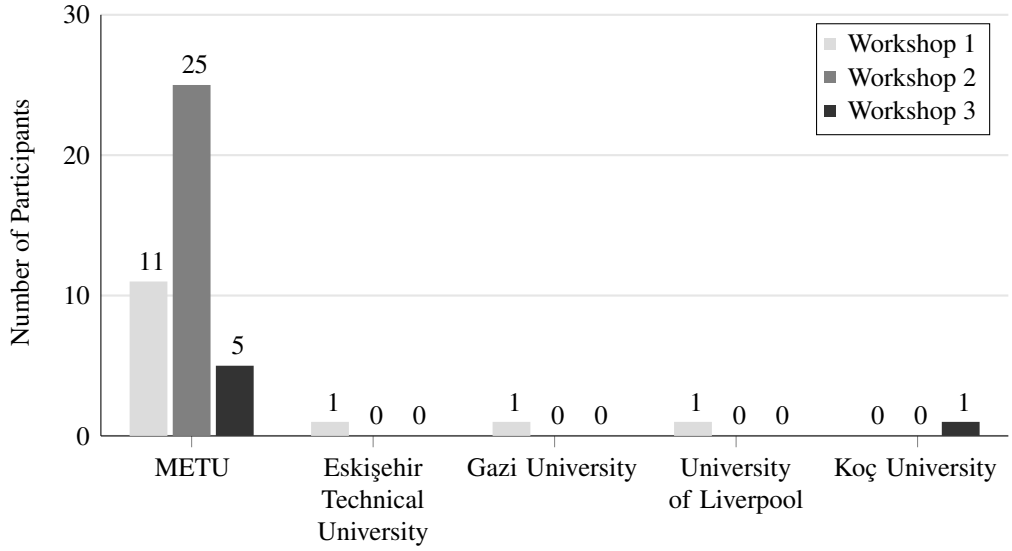


Figure 6.2: The institutes of participants in the workshops

first years of industrial design education, and none of them was familiar with the used tools in the workshops. All the workshops were completed in the same day and all the participants participated from the beginning to the end. The method was developed under these circumstances, and then the effectiveness of the method was assessed.

Even though it is challenging to evaluate a design method due to 'the amount of variables, variety and confidence in the results', Silva and Read (2010) summarise the five primary considerations to evaluate a design method: 'the number of the ideas generated, the quality of ideas generated, the engagement of the participant, the learning of the facilitator and the learning of the participants' (p. 264). Whilst the number of ideas generated could be a good indicator of the effectiveness of a method, as Christiaans argues the quantity does not necessarily have to be correlated with the quality of ideas generated (2002). The examples in the literature to measure the engagement of the participant, learning of the facilitator and participants are highly subjective (Csikszentmihalyi, 1996; Putman, 2001; Baruah and Paulus, 2008). There are discussions on the measuring of the quality of ideas. According to Stammerjohan and Vance (2001), there are three measures to evaluate the quality: novelty, appropriateness and appeal. According to Christiaans (2002), there are seven metrics: creativity, prototypical value, attractiveness, interest, technical quality, expressiveness and integrating capacity.

Despite the differences in the definitions and metrics, they all support one idea: If a method's use results in good ideas, it can be said that the method is effective. Now, the question is, what can be defined as a good idea. There are different definitions and metrics to decide on ideation effectiveness. Horn and Salvendy (2006) define the product creativity as 'the subjective judgement of a product to exhibit novelty and appropriateness that elicits arousal and pleasure and is compatible with the judge's preferences' (p. 398). Shah et al. (2003) summarise that good ideas can be defined with the extent how much they explore and expand design space. Then, they came up with four measures to ascertain the extent of exploration and expansion of the design space: **novelty**, **variety**, **quality** and **quantity** (see Figure 6.3).

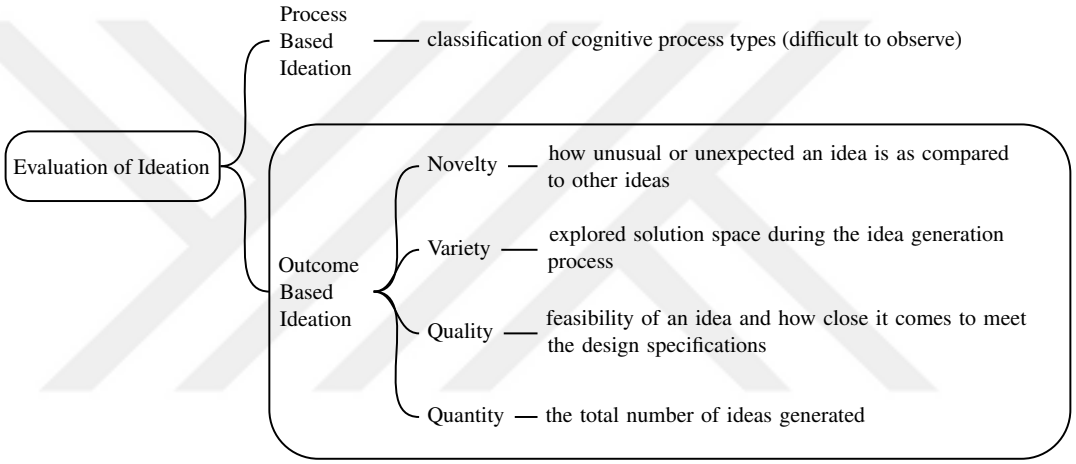


Figure 6.3: Categorisation of ideation evaluation adopted from Shah et al. (2003)

They explained each measure like this:

'Novelty is a measure of how unusual or unexpected an idea is as compared to other ideas. Not every new idea is novel since it may be considered usual or expected to some degree, and this is only known after the idea is obtained and analysed.

'Variety is a measure of the explored solution space during the idea generation process. The generation of similar ideas indicates low variety and hence, less probability of finding better ideas in other areas of the solution space.

'Quality is a measure of the feasibility of an idea and how close it comes to meet the design specifications.

Quantity is the total number of ideas generated. The rationale for this measure is that generating more ideas increases the chance of better ideas' (p.117).

Usually, at the end of an ideation session, participants generate more than one idea. The two of the measures; quantity and variety depend on this condition. To measure the quantity, the researcher should straightforwardly count the total number of generated ideas. To measure variety, the researcher should first group the ideas in terms of the different functions they satisfy then, look how different the two ideas are. Quality cannot be measured at the conceptual stage since we do not have an end product to test. However, the authors suggest that the researchers could estimate the quality of the outcomes at the conceptual stage. The measurement of novelty is a little bit more complicated than the others. To measure novelty:

1. The problem is first decomposed into its essential functions or characteristics.
2. Each description is then graded for novelty. It is possible to compute a total score for novelty for each idea by applying the weights to each function and stage.
3. Every idea produced is analysed by first identifying which functions it satisfies and describing how it fulfils these functions, at the conceptual and/or embodiment level.
4. The overall novelty of each idea can be computed from the formula in Figure 6.4.

M_1 is the overall novelty score for the idea with m functions or attributes and n stages. Weights (f_j) are assigned according to the importance of each function or characteristic in order to compute an overall score. Further, each function may be addressed at the conceptual and/or embodiment stage and weights (p_k) assigned according to the stage's importance.

The calculation of S_1 depends on the approach chosen. A universe of ideas for comparison is subjectively defined for each function or attribute, and at each stage. A novelty score S_1 is assigned at each idea in this universe. The closest match is found in the table, and the score S_1 noted to evaluate the function and stage of an idea.

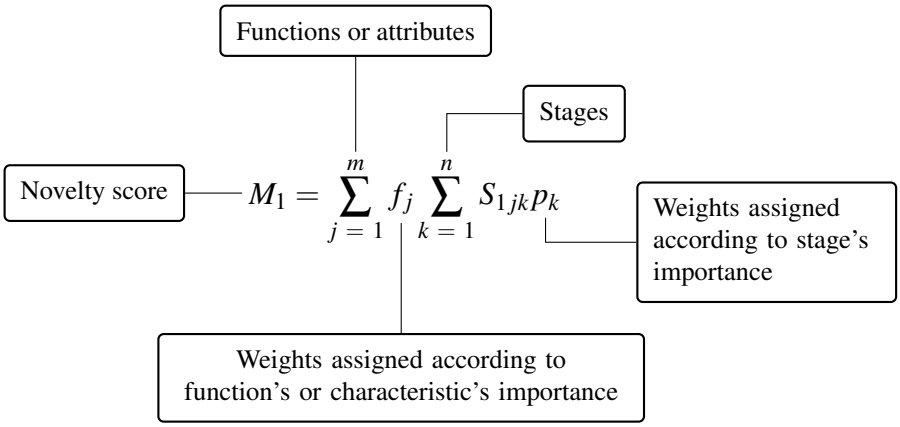


Figure 6.4: Novelty score calculation

In this workshop, as I asked the participants to focus on only one idea, *variety* which measures the difference between ideas, and *quantity* which measures the total number of generated ideas are evaluated as the same and ruled out from the calculation. According to the authors, the quality can be estimated at the conceptual stage. Since all teams completed each stage at the level of complexity we expected, we also took the quality of object personas as equals amongst them. This leaves us with the novelty aspect. Thus, for this method, if we are able to measure the novelty scores, then we can have an overall idea about the effectiveness of the proposed method.

To understand the effect of object persona use on the end product, I decided to compare the novelty scores of object personas and outcomes. First, I needed to identify the key functions or characteristics, then to assign the weights to each function and stage.

6.1 Novelty Scores of Object Personas

To be able to define the novelty attributes, I referred to the sections that were needed to be completed in the object persona template.

In this study, the object persona template (see Figure 5.27) aimed at covering the demographic and behavioural variables that are also essential in user persona. For covering the demographic variables, *who is this* section would trigger the participants. *A day in life* section would make participants think about the potential key tasks of

the machine. The changes in the sensor data could inspire the duration and frequency of the key tasks. Trying to figure out what a change in the graph could mean was expected to start a discussion about the key tasks and the attitude towards these tasks. Once the key tasks are identified, the participants could dig more into the relationship with its owner and interaction with others. I thought discussions on the relationship with the owner and other animate and inanimate beings could help participants to identify *frustrations and motivations* and *friends and enemies* section.

When the object persona template is approached from a higher level, the attributes that needed to be referred by the participants could be categorised under three headings:

i. **A day in life** to cover potential key tasks of the machine and duration and frequency of the key tasks

ii. **Frustrations and motivations** to cover the attitude towards the tasks and its relations with others

iii. **Friends and enemies** to cover the relationship between the machine and its owner and other animate and inanimate beings

Since I expected that a day in life would trigger all the other sections, I gave the half of the weight to this attribute (0.5 out of 1). I thought the other two attributes would be equal so apportioned the remaining weight between the two (0.25 out of 1 for frustrations and motivations and 0.25 out of 1 for friends and enemies).

The assigned weights to the attributes could be seen in Table 6.1—my proposed table for measuring the novelty scores of object persona templates.

Table 6.1: Assigned attribute weights to persona boards

Attributes	Weights
A day in life	0.50
Frustrations / motivations	0.25
Friends / enemies	0.25

When I reviewed all the solutions to meet the objectives of these attributes, I came up with three sub-attributes for each attribute.

The information that the participants provided in Workshop 3 for the attribute a day in life could be gathered in three categories:

i. Functional activities, where participants indicated a task, its duration or frequency which is related to the machine's primary function. For example, making coffee is the primary function of the coffee machine.

ii. User activities, where participants indicated a task, its duration or frequency which is related to the users' activities. For example, hanging out in the kitchen is a user activity.

iii. Other agents' activities, where participants indicated a task, its duration or frequency which is not related to a machine's function or users' activities. For example, stove started working in the coffee machine's a day in life section is another agent's activity.

The information that the participants provided in Workshop 3 for the attribute frustrations / motivations could be gathered in three categories:

i. Activity related frustrations / motivations, where participants indicated a frustration or motivation which is about its primary function. For example, keeping the coffee warm longer is an activity related motivation for a coffee machine.

ii. User related frustrations / motivations, where participants indicated a frustration or motivation which stems from its relationship with its owner. For example, spending more time with the owner is a user related motivation for a machine.

iii. Other agents related frustrations / motivations, where participants indicated a frustration or motivation which is not related to its function or its relationship with its owners. For example, breaking down the tea machine is an agent related motivation.

The information that the participants provided in Workshop 3 for the attribute friends / enemies could be gathered in three categories:

i. Friends / enemies related to the practice, where participants indicated a friend or enemy that can be related to the primary practice of the machine. For example, a coffee cup is a friend related to coffee making practice.

ii. Friends / enemies amongst the agents from environment cards, where participants indicated a friend or enemy that is in the immediate environment of the machine. For example, the kettle is an enemy amongst the agents from the environment card of the coffee machine.

iii. Friends / enemies amongst other agents, where participants indicated a friend or enemy that is neither related to the primary practice of the machine or in the environment of the machine. For example, the alarm clock is a friend amongst the other agents for the coffee machine.

In some of the cases, the participants presented a combination of categories in their final design outcome. That is why I also added sub-categories to refer to all possible combinations.

While assigning the sub-attributes, I gave the most expected outcome the least weight and gave the least expected outcome the most weight.

The assigned weights to the sub-attributes could be seen in Table 6.2—my proposed table for measuring the novelty scores of object persona templates.

Note that the weights should add up to 1 in total for the attributes. Weights should be between 1-10 for the sub-attributes.

To be able to see the overall picture, all the object persona templates were transformed into tables categorised with the attributes. (see Tables 6.3, 6.4 and 6.5)

According to the tables, calculated novelty scores are presented in Table 6.6.

Table 6.2: Assigned sub-attribute weights to the attributes of persona boards

Sub-attributes of a day in life	Sub-attributes of frustrations / motivations (f/m)	Sub-attributes of friends / enemies (f/e)	Sub-attribute weights
Functional activities	Activity related f/m	F/E related to the practice	2
User activities	User related f/m	F/E amongst the agents from environment cards	4
Other agents' activities	Other agents related f/m	F/E amongst other agents	5
Functional and user activities	Activity and user-related f/m	F/E related to practice and amongst the agents from EC	6
Functional and other agents' activities	Activity and other agents related f/m	F/E related to practice and amongst other agents	7
User and other agents' activities	User and other agents related f/m	F/E amongst the agents from EC and other agents	9
Functional, user and other agents' activities	Activity related, user-related and other agents related f/m	F/E related to practice, amongst the agents from EC, and other agents	10

Table 6.3: Categorised object persona attributes of Team 1 (Sunshine)

Team 1 (Sunshine)	
A day in life	
Functional activities	Wake up, work (make coffee)
User activities	Drink coffee, prepare dinner
Other agents' activities	Alarm clock ringing, dishwasher working
Frustrations / Motivations	
Activity related f/m	—
User related f/m	Cheer, wake, relax the owner, create a social environment
Other agents related f/m	Bluetooth makes it happy, competition with kettle, disappointed with dishwasher use
Friends / Enemies	
F/E related to the practice	Paper filter, mug, tap, reservoir
F/E amongst the agents from environment cards	Kettle, dishwasher, cat, Bluetooth speaker
F/E amongst other agents	Alarm clock

Table 6.4: Categorised object persona attributes of Team 2 (Toaster Pro)

Team 2 (Toaster Pro)	
A day in life	
Functional activities	Work, sit idle
User activities	Casual dining, grill/toast, make breakfast
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Being used, heat bread, make toast, being left turned on, close lid after use, being left dirty, getting cleaned
User related f/m	—
Other agents related f/m	Other devices preferred over it
Friends / Enemies	
F/E related to the practice	Fridge, breadbox, power outlet
F/E amongst the agents from environment cards	Microwave kettle coffee maker, shower, cat
F/E amongst other agents	Dust and rust, sticky food, plant watering device, visitors

Table 6.5: Categorised object persona attributes of Team 3 (Schrute)

Team 3 (Schrute)	
A day in life	
Functional activities	Getting bored, high expectations to be used, frustration because of not being used, happy to be at service, happy with surprise work, annoyed to the fridge
User activities	Breakfast, tea time, late-night coffee, prepare dinner
Other agents' activities	Kettle in use, chatty fridge
Frustrations / Motivations	
Activity related f/m	Gets excited when feeling an increase in the temperature, feeling accomplished when picked up, grumpy upon use, loves the user touch
User related f/m	—
Other agents related f/m	Humidity from stove makes it sweaty, scaring the cat
Friends / Enemies	
F/E related to the practice	Tap water
F/E amongst the agents from environment cards	Speaker, user's hands, fridge
F/E amongst other agents	Corrosion

Table 6.6: Object personas' novelty scores of the teams

Teams	Novelty Attributes			Novelty Score M_1
	A day in life	Frustrations / Motivations	Friends / Enemies	
Team 1	Functional, user and other agents' activities	Both user and other agents related f/m	F/E related to practice, amongst the agents from EC, and other agents	9.25
Team 2	Both functional and user activities	Both activity and other agents related f/m	F/E related to practice, amongst the agents from EC, and other agents	9.75
Team 3	Functional, user and other agents' activities	Both activity and other agents related f/m	F/E related to practice, amongst the agents from EC, and other agents	7.25

6.2 Novelty Scores of Workshop Outcomes

In order to decide on the attributes of the workshop outcomes, I wanted to refer to the participant's aims to design for the near future where every product is connected to the Internet and can talk with each other. To identify their set aims, I transcribed all the presentations made by the teams. As it was discussed in Chapter 5 in detail, I came up with three recurring themes: all the teams mentioned that they all paid attention to object-user interaction, object-object interaction and object-environment interaction in their design process. Thus, I listed the attributes as the user interactions, object interactions and environment interactions.

Since they are equally important for the participants, I gave equal weights to each attribute (see Table 6.7).

Table 6.7: Assigned attribute weights to the workshop outcomes

Attributes	Weights
User interactions	0.33
Object interactions	0.33
Environment interactions	0.33

Then, I went through the design outcomes and marked each interaction and assigned them to the related attribute.

The interactions that the participants provided for the attribute user interactions could be gathered in two categories:

i. Interactions with the agents from EC, where participants point potential interactions between the users and agents that can be seen in environment cards.

ii. Interactions with other agents, where participants point potential interactions between the users and agents that are not present in the environment cards.

The interactions that the participants provided for the attribute object interactions could be gathered in two categories:

i. Interactions with the agents from EC, where participants point potential interactions between an object and other objects that can be seen in the environment cards.

ii. Interactions with other agents, where participants point potential interactions between an object and agents that are not present in the environment cards.

The interactions that the participants provided for the attribute environment interactions could be gathered in two categories:

i. Interactions in the given environment, where participants point potential interactions occurring in the environment presented in the environment cards.

ii. Interactions in other environments, where participants point potential interactions occurring in the environments other than the one presented in the environment cards.

In some of the cases, the participants presented or mentioned both categories in their final design outcome. That is why I also added a sub-category, including both instances. While assigning the sub-attributes, I gave the most expected outcome the least weight and gave the least expected outcome the most weight. (Table 6.8)

Table 6.8: Assigned sub-attribute weights to attribute weights of workshop outcomes

Sub-attributes of user interactions	Sub-attributes of object interactions	Sub-attributes of environment interactions	Sub-attribute weights
Interactions with the agents from EC	Interactions with the agents from EC	Interaction in the given environment	3
Interactions with other agents	Interactions with other agents	Interactions in other environments	7
Both	Both	Both	10

To be able to see the overall picture, all the final design outcomes were transformed into tables categorised with the attributes (Tables 6.9, 6.10, 6.11).

Table 6.9: Categorised design outcome attributes of Team 1 (Sunshine)

Team 1 (Sunshine)	
User interactions	
Interactions with the agents from EC	Making toast, preparing coffee
Interactions with other agents	Dressing up, washing face, sleeping, feeding the cat
Object interactions	
Interactions with the agents from EC	Toaster, Bluetooth speaker
Interactions with other agents	Cups and mugs, alarm clock
Environment interactions	
Interaction in the given environment	Enjoying the music
Interactions in other environments	—

Table 6.10: Categorised design outcome attributes of Team 2 (Toaster Pro)

Team 2 (Toaster Pro)	
User interactions	
Interactions with the agents from EC	Uses the washing machine, cleans the dishes, makes toast
Interactions with other agents	—
Object interactions	
Interactions with the agents from EC	Coffee machine, fridgo (fridge), washo (dishwasher)
Interactions with other agents	Television, companio (a system to keep company to the user), wakeupo (alarm clock)
Environment interactions	
Interaction in the given environment	Uses the tap water to clean itself, uses the sink to clean the residue
Interactions in other environments	—

Table 6.11: Categorised design outcome attributes of Team 3 (Schrute)

Team 3 (SchrutePro)	
User interactions	
Interactions with the agents from EC	Try cooking different meals with friends, everyday cooking
Interactions with other agents	—
Object interactions	
Interactions with the agents from EC	Toaster, microwave, oven
Interactions with other agents	Juicer, blender
Environment interactions	
Interaction in the given environment	—
Interactions in other environments	Quick and elaborate kitchen

According to the tables, calculated novelty scores are presented in Table 6.12.

Table 6.12: Workshop outcomes' novelty scores of the teams

Teams	Novelty Attributes			Novelty Score M_2
	User interactions	Object interactions	Environment interactions	
Team 1	Interactions with the objects from EC and other agents	Interactions with the objects from EC and other agents	Interactions in the given environment	7.59
Team 2	Interactions with the objects from EC	Interactions with the objects from EC and other agents	Interactions in the given environment	5.28
Team 3	Interactions with the objects from EC	Interactions with the objects from EC and other agents	Interactions in other environments	6.60

It should be noted that I conducted the workshop with a limited number of people and these were not evaluations done by an expert panel of judges but by the researcher who is also the facilitator of the workshop. In this condition, the results showed that there occurred a strong positive correlation between the novelty scores of the object personas and final design fiction outcomes ($r = 0.94$) (see Table 6.13 and Figure 6.5).

Table 6.13: Comparison of the novelty scores

Novelty score	Team 1	Team 2	Team 3
Object persona M_1	9.75	7.25	9.25
Design fiction outcome M_2	7.59	5.28	6.60

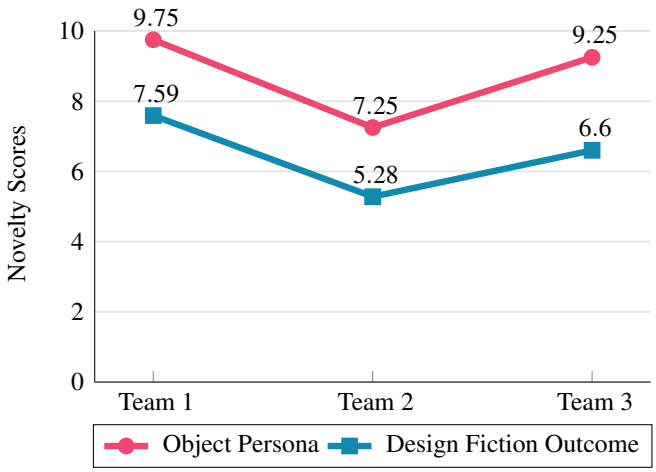


Figure 6.5: Comparison of the object persona and design outcome novelty scores

Overall, the analysis showed that the use of object persona with the help of sensor data had an impact on the ideation. As explained before, it is challenging to see the effect of the use of object personas on the outcomes. I compared the impact of the improvements I made on the object persona template together with the data presented on the novelty scores because, even though the data and the devices that the data was collected from differed in the three workshops, the presentation of the data graphs was controlled. The change in the novelty score means from the three workshops is shown in Table 6.14 and Figure 6.6. (The calculation of the first and second workshops' novelty scores can be found in Appendix G.)

Table 6.14: Object personas' novelty score means of the three workshops

Novelty score	Workshop 1	Workshop 2	Workshop 3
Object persona M_1	6.87	7.03	8.29

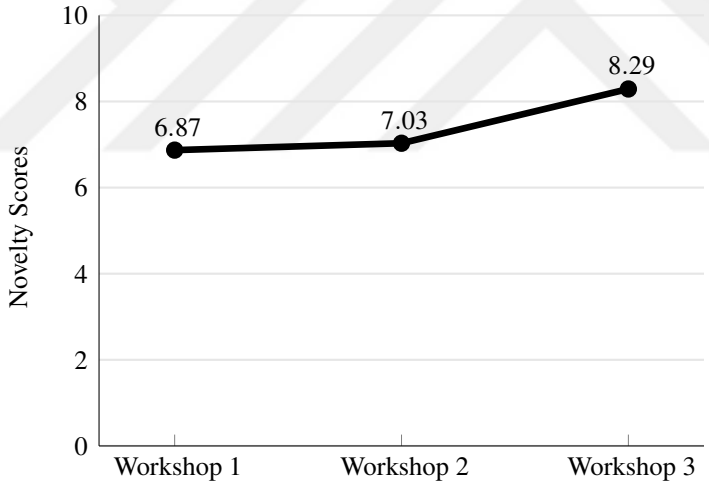


Figure 6.6: Change in the means of object persona novelty scores in the three workshops

As can be observed from Figure 6.6, there is an apparent increase in the novelty scores of the three workshops. Since the participants worked in teams, and as a result, the team numbers were limited, the results are not enough to run statistical analysis. However, the gradual increase can be observed, and it can be said that the changes in the object persona templates and data presentation positively affected the process.

By looking at the graph, it can be noticed that the change between the novelty scores of Workshops 2 and 3 is much more significant than the change between the novelty scores of Workshops 1 and 2. It can be argued that the difference is due to the use of interactive data tool. Despite the presentations of the data graphs were different in Workshops 1 and 2 (through the app and in transparent sheets showing the data more detailed), the graphs were produced by Thingspeak were used. However, in the third workshop, together with the small differences in the object persona templates, the data was presented in a bespoke interface.

To verify that the weights to calculate the novelty scores are appropriate for the evaluation, I consulted experts. According to Cantrill et al. (1996); an expert is 'any individual with relevant knowledge and experience of a particular topic' (p. 67). Here, the selection of qualified experts is crucial. The number of experts is not important since the experts do not have to be representative of a population (Okoli and Pawlowski, 2004). However, the risk of bias increases with one expert. To decrease the bias, and following the examples in the literature (Tracey and Richey, 2007), three experts were selected. The experts were chosen due to their specific backgrounds, experience with design research and familiarity to the study. One of the experts was specialised in design education, one of them was an expert in design methods, and one of them was experienced in design fiction.

I organised an online meeting where all the experts attended. I first presented an extensive summary of my research and asked for their help to decide on the most subjective part of the evaluation: weights assigned to novelty score attributes. I presented all the steps of the evaluation procedure, how I decided on the attributes and showed some examples from the results to form a more concrete idea of what they were evaluating. The meeting lasted about two hours. The assigned weights to the novelty scores can be seen in Tables 6.15, 6.16, 6.17 and 6.18. The weight assigned by the researcher can also be seen in the tables to ease the comparison. The mean of the weights assigned by the experts was used to recalculate the effectiveness of the method on the design outcomes (see Table 6.19).

As it can be seen in the tables, despite small differences, the experts' opinion on the weights were very close to each other, and the mean value of the experts' weights and

Table 6.15: Experts' attribute weights to the object personas

Experts	A day in life	Frustrations / Motivations	Friends / Enemies
Researcher	0.50	0.25	0.25
Expert 1	0.50	0.30	0.20
Expert 2	0.40	0.40	0.20
Expert 3	0.30	0.40	0.30
Mean	0.40	0.37	0.23

researcher's weights are very close to each other. All the calculations were repeated, and the comparison between the results can be seen in Figure 6.7.

As expected, there was not much difference from the original calculations validating the effect of the proposed method on the design ideation. Statistical comparison between the experts' novelty scores and researcher's proved to be that the difference is not statistically significant. The p-value for object persona scores is 0.85, and p-value for design fiction outcome scores is 0.07. According to a 95% confidence interval, the value is not statistically significant. There is a statistically significant correlation between the values ($r = 0.4$ for object persona and $r = 0.11$ for design fiction outcomes).

As a result, a very similar graph showing the relationship between the novelty scores of object persona and design fiction outcomes has been retrieved from the calculations by the experts' weights as it can be seen below. The results also show a strong statistical positive correlation ($r = 0.8, \alpha = 0.05$)

As a result of this study, not only the validation of the prior results was secured but also the capacity of scalability of the study was shown.

Table 6.16: Experts' sub-attribute weights to the object personas

Sub-attributes of a day in life	Sub-attributes of frustrations / motivations (f/m)	Sub-attributes of friends / enemies (f/e)	Researcher	Expert 1	Expert 2	Expert 3	**Mean**
Functional activities	Activity related f/m	F/E related to the practice	2	3	4	3	**3.33**
User activities	User related f/m	F/E amongst the agents from environment cards	4	4	3	4	**3.67**
Other agents' activities	Other agents related f/m	F/E amongst other agents	5	3	3	4	**3.33**
Functional and user activities	Activity and user-related f/m	F/E related to practice and amongst the agents from EC	6	7	7	7	**7.00**
Functional and other agents' activities	Activity and other agents related f/m	F/E related to practice and amongst other agents	7	6	7	7	**6.67**
User and other agents' activities	User and other agents related f/m	F/E amongst the agents from EC and other agents	9	7	6	8	**7.00**
Functional, user and other agents' activities	Activity related, user-related and other agents related f/m	F/E related to practice, amongst the agents from EC, and other agents	10	10	10	10	**10.00**

Table 6.17: Experts' attribute weights to the final design outcomes

Experts	User interactions	Object interactions	Environment interactions
Researcher	0.33	0.33	0.33
Expert 1	0.40	0.30	0.30
Expert 2	0.40	0.20	0.40
Expert 3	0.20	0.40	0.40
Mean	0.33	0.30	0.37

Table 6.18: Experts' sub-attribute weights to the final design outcomes

Sub-attributes of user interactions	Sub-attributes of object interactions	Sub-attributes of environment interactions	Researcher	Expert 1	Expert 2	Expert 3	**Mean**
Interactions with the agents from EC	Interactions with the agents from EC	Interaction in the given environment	3	4	2	3	**3.00**
Interactions with other agents	Interactions with other agents	Interactions in other environments	7	6	8	7	**7.00**
Both	Both	Both	10	10	8	10	**9.33**

Table 6.19: Comparison of novelty scores calculated by experts' weights and researcher's weights

	Novelty scores for object persona			Novelty scores for outcomes		
Teams	Team 1	Team 2	Team 3	Team 1	Team 2	Team 3
Researcher	9.08	7.46	8.33	7.13	4.98	6.38
Experts	8.89	7.57	8.77	6.99	4.90	6.38

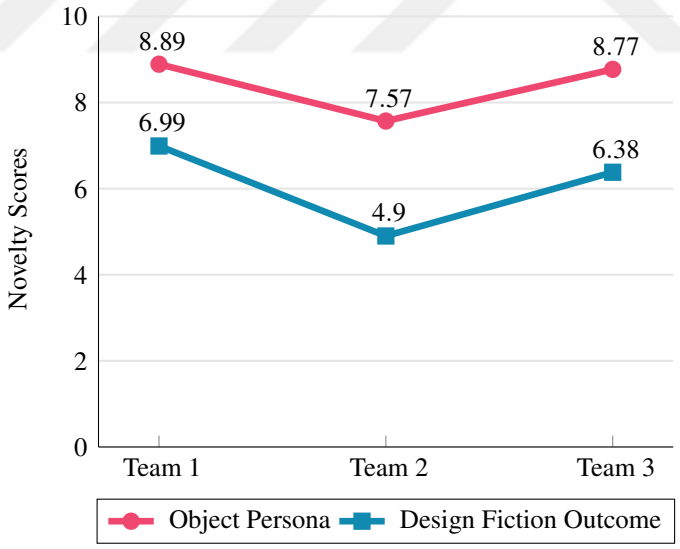


Figure 6.7: Comparison of the object persona and design outcome novelty scores calculated according to the experts' opinions

CHAPTER 7

CONCLUSION

In this chapter, a summary of the findings from the literature search and the fieldwork will be made. First, I will revisit the research questions (see section 1.3) raised at the beginning of the study. Later, the main finding of the study will be discussed and reflections on the overall procedure will be shared. Last, pointers for further work will be presented after the limitations of the study are reviewed.

7.1 Revisit to the Research Questions

As it was addressed in the introduction chapter, the study was organised as action research and the findings of the literature review guided the first research question. Then, the findings of each stage have informed the consecutive stages. The findings from the literature have formed a proposal for the use of a new method. The questions related to use of this method were answered with the workshops discussed in Chapter 5. Lastly, the questions associated with the evaluation of the developed method was responded to with the novelty score comparison, discussed in Chapter 6.

7.1.1 Literature Research

The literature research in the IoT domain and design processes helped to form the first research question. An extensive range of information about the concept of IoT was acquired during the course of the search. Despite the term IoT is relatively new, the general concept has been studied since the introduction of ubiquitous computing, and the studies foresee the proliferation of the things of the IoT in the near future

with the developments in technologies. The change in the capabilities of the things will change the meaning of the things in our lives. The new definition of the things presents the biggest challenge to designers to design for better experiences because, since most of the studies are technology-driven, there is the challenge of emphatical integration of the technologies to our daily lives. Whilst the examples focusing on the failed products of IoT in the literature are vast; there is a little emphasis on how to overcome the gap between the products with developing technologies and meaningful experiences with these products. However, the extended capabilities of the things presented the opportunity to designers due to the accessibility of data that is collected and used by the things. There are two different approaches to the use of data by designers. The first approach offers teaching non-experts the necessary programmes, but there is a high learning curve, and it can be competitive to hurdle. The second approach offers the use of tools to collect, store and visualise data. This approach was deemed appropriate in this study.

The phases of the design process show differences in different sources. However, finding the design opportunity includes a research and an ideation phase. In the research phase, along with the user-centred approaches, non-anthropocentric approaches and data-enabled approaches could be used to include the things as active agents. In the ideation phase, amongst hundreds of techniques that can be used in the idea generation process, intuitive ideation methods are the ones that are more suitable to the way that designers think. As can be seen in Section 3.1.2. there are also sub-categories of intuitive ideation techniques.

In light of these, I arrived at the conclusion that the IoT can be helpful in the research phase to support thing-centred approach by collecting data from the things as well as people. There are a lot of different tools that can be easily used by non-experts to monitor the IoT data and interpreted by the designers. Then, the insights gathered from the data can inform the intuitive ideation phase. These conclusions led my informed research questions that have been quested with the workshops.

7.1.2 Workshops

Design workshops were organised in order to find answers to the consecutive questions lead by the literature research. Each questions' findings will be discussed below.

- How can designers extract meaning from sensor data collected from connected devices?

  To answer this question, the available tools in the market were evaluated. Thingspeak was decided to be used as the starting point because of the flexibility in the preference of data presentation. The data graphs presented by Thingspeak as default were tested in the first workshop, and it was found out that the designers would like to see the similarities and differences in the changes in different data graphs. In addition to that, it was found out that some parts of the data graph might intrigue the designers, and they might want to observe the changes at certain times in detail. It was also observed that when the data graphs were supported with visuals from the environment that the data is collected from, the designers feel more confident in making assumptions and to open up discussions. That is why, in the second workshop, the data graphs are presented to designers in bigger formats and on transparent papers to give designers more control over them and environment visuals were more detailed. The findings informed the interactive data visualisation tool to be tested in another workshop. The tool was designed to visualise the selected data types in different colours for the duration chosen in the detail level selected. In the third workshop, the tool is used as a medium to present the sensor data to designers. As a result, all the participants reported that the tool was easy to use and had a positive effect on their persona creation process together with the environment cards.

- How does using object persona with the help of sensor data affect ideation?

  There are countless ideation methods that are used in user-centred design. Some of them are developed mainly to make use of the collected data from the users. What should be different in design for IoT is the change of the definition of users because humans are not the only agents that will use the design. One of the most prominent tools to visualise the collected data from users and inspire

the design is user personas. In this study, user personas were taken into attention to broadening its scope with the inclusion of the non-humans. To test the usability of object personas, user persona guidelines are examined in detail to be inspired to create an object persona template. The template was iterated after each workshop to improve the use in the ideation process.

The first object persona template used in the first workshop was inspired by the user persona guidelines discussed in Section 4.4. There were five general categories with pointers to various topics that can be covered under each category. The analysis of the object persona templates of the first workshop showed that the general categories resulted overlooking some of the critical behavioural variables such as abilities, dreams and enemies. That is why, in the second workshop, the organisation of the categories was reviewed. In the second workshop, there were dedicated areas for some of the critical aspects of the user personas. This time, almost all the teams filled each area in the object persona but with some repetitions. The ramification of the categories confused designers and distract them from concentrating on the essential points. The third object persona template used in the last workshop had fewer categories allowing space for designers to make modifications. This approach resulted better. The analysis of the object persona boards used in the previous workshop showed that when the demographic and behavioural variables are asked in a flexible format which can incorporate sketching, the designers can better engage with the template.

The use of the templates for the ideation was tested in different design problems. In the first workshop, the participants were given a design fiction scenario and asked to design for the given scenario. In the second workshop, the participants were asked to use their object personas in their given design project. In the final workshop, the participants were asked to create a design fiction prototype based on their object personas. After each workshop, participants were asked how much the object personas affected their design insights they used in their final designs. In the first and the last workshop, all the participants agreed that the created persona guided all the design decisions, but in the second workshop, participants indicated that due to the restrictions of the given

brief and limitations of technicalities they could not reflect all the insights they found during the object persona creation process to their final designs. Despite the differences in the object persona boards, data presentation and design problems in the workshops, the designers used their object persona boards in generating design insights for things' interaction with users, other things and environments. It can also be said that object personas could be more effective to be used in fictional scenarios for speculating about the technology in human life.

- How can I improve the object persona creation process to better support the idea generation?

  In each workshop, the process was developed with the changes in the object persona templates, environment cards and the visualisation of sensor data to designers. Object persona templates were transformed to be more straightforward to collect demographic and behavioural variables. It was also discovered that when the template is more flexible in using sketches or narrative to describe the variables, the designers feel more comfortable. The environment cards are improved with more detailed to give more context to designers in speculation for the object persona creation. A data graph was designed for designers since the designers would like to have more control over the visualisation.

7.1.3 Evaluation

The evaluations of the presented method answered the last question: 'What is the efficacy of using a new ideation method for the design for IoT?' After the workshops, I developed a method for designers to use IoT data for creating an object persona, assisting them in their design process.

I tested the effectiveness of the developed method with the metrics for measuring ideation. The calculations showed that creating object persona using the sensor data to design for IoT is effective in the ideation phase of the design process. Due to the limited number of teams in the last workshop, the statistical calculations were supported by the participants' comments. All the participants agreed that they found the use of object persona very inspiring for them as it allows them to think in terms

of not only people interactions but also environment and object interactions.

For ensuring the generalisation of the results, I consulted experts' opinions. The inferences about the positive effect in the use of object persona based on sensor data were found to be accurate on the basis of the made measurements. It was found out that all the experts shared similar concerns on the efficacy of the proposed method and the method proved to have positive effects on the ideation process.

In line with the answers to these questions, the contribution of the study will be outlined below. The contribution of this study is threefold:

- The contribution to the thing-centred design

  Cila et al. (2015) offered using object personas as a defamiliarisation tool for design insights. They presented photographs taken from the perspective of a kettle, cup and a fridge to the participants and asked them to analyse these photographs using the object personas and come up with design interventions for these devices. As a result of their study, they found the process promising 'as a method to give voice products and explore a new space of design possibilities' (p. 14).

  This study contributes to the thing-centred design by extending its scope in three perspectives. First, I suggest using sensors that can collect a wide variety of data from any objects that can be accessed real-time by the designers. This way, designers could generate object personas with the use of data for a wide variety of products, services or systems. I also present an interactive data visualisation tool that is specifically designed for designers to analyse the collected data easily. The visualisation tool significantly decreased the burden of analysis, enabling a quick ideation process. Lastly, I offer using design fiction to encourage to think the possibilities to be able to design for the preferable futures.

- The contribution to the design by data studies

  Almost all the studies given as examples in Section 3.2.2 require designers either to learn the necessary programs for working with data or to use visualisation tools with some experts for extracting meaning from the data. This study

contributes to design by data studies by simplifying the process. I suggest using an interactive data visualisation tool that was designed particularly for designers. It would eliminate the need for overcoming the high learning barrier to learn the necessary skills and decrease the need for specialists for interpreting data to inspire the object personas.

- The contribution to the design methodology

  As Section 3.1.2 indicated, there are a lot of different tools and methods to help designers in the process of discovering the design opportunity. This study contributes to the design methodology by extending the focus of other tools and techniques in research and ideation process. I suggest a hybrid intuitive ideation method for designers to guide them in their journey of design for IoT (see Figure 7.1)

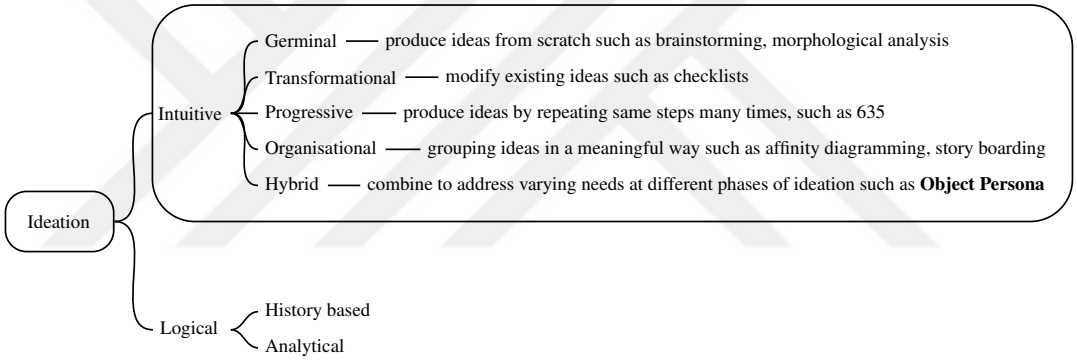


Figure 7.1: Scope and potential contribution area of the study

7.2 Conclusions

The introduction of IoT changed the meanings of the things in our lives. They also become users of technologies along with humans with their ability to collect, share and act on data. This change stood as both an opportunity and a challenge for designers. The studies on the use of data for the new users of technologies; things by designers took attention by the researchers. This study aimed at contributing to that area and investigated the use of object persona creation with the help of sensor data as an ideation tool to be used in the design process for IoT. As a result of three iter-

ative workshops, an object persona template together with an interactive interface to use the sensor data was presented and evaluated. The evaluations showed promising results on the efficacy of the new ideation method. The steps to be followed could be summarised as follows.

1. Get the brief.

   All designs start with a brief. Sometimes, the brief lists a very clear set of requirements, but sometimes, designers have to deal with ill-defined problems. In the case of design for IoT, since the technologies are still developing and the things of IoT are not that widespread, in most of the cases, the designers will have to discover the requirements themselves. I think, to make the most out of this method, the process should start with a brainstorming session with the design team. In the session, the steps below can be followed:

   1.1. Think about the environment of the thing in question to spot some of the other things that the new thing could potentially have a relation with.

   Here the team should think about the things that might have an impact on their design. There is no right or wrong list of things. The aim is to spark discussion by looking at the data that can be collected from these things. The only thing that the team needs to keep in mind is this aim.

   1.2. If you can reach sensor data from potentially related devices, view them in the interactive interface to monitor the data.

   There are a lot of websites that present open source data that people collect from their connected devices. After the potential devices have been decided, the team should check if they can reach data collected from these devices. It was envisioned that, in the future, the data would be much more available. If the data can be reached from open sources, the team could embed the data to the interactive data graph to visualise it. In the data graph, the designers should write the channel number, name and key to the highlighted areas in the code to embed the data.

   1.3. If you cannot reach the sensor data, equip them with sensors using the sense boxes and use the interactive interface to monitor the data.

It might be the most challenging part of this process for a designer. Even though there are sensor kits readily available, the modification of the Sense Boxes could require experience with the electronics. However, the provided basic set would be sufficient to collect data from most of the mundane devices.

2. Collect data.

   This step is actually an autonomous process. The designers will be able to observe the data in real-time from the interactive data graphs.

   2.1. Collect at least one week of sensor data from the thing to be redesigned or from the other things that the new thing could have a potential relation with, if possible; both.

   In this study, it was observed that to get a better idea about the daily key tasks of the devices which are required to create behavioural variables in the object persona template, designers want to see at least a week of data from the devices. The duration could be shortened or prolonged according to the necessities of the projects. Alternatively, the designers can observe the data in different durations such as winter and summer to see if the object persona change at different times of the year.

   2.2. Monitor the data on the interactive data graph.

   The next step is getting familiar with the interface of the interactive data graph tool. It is pretty straightforward. The explanations for the controls could be revisited from Figure 5.26 if deemed necessary.

3. Ideate.

   The findings showed that it would be better to support data graphs with environment cards illustrating the aimed environment of the design. During the user studies, the designers might take pictures from their environment to create environment cards.

   3.1. Use the interactive data graph tool to start a discussion on the thing's key tasks.

It was observed that all the participants start speculating on their object persona either from filling out demographic variables or deciding on the key tasks by filling out the daily routine. I would recommend starting from the daily routine part of the object persona since the characteristics have also come into the discussion between the team members while deciding on the key tasks of the device and its attitude towards this device. The characteristics then might have an effect on the demographic details such as age and name.

3.2. Start filling out the object persona template.

There is not an identified order to fill out the template. Some of the designers would like to think through drawing some want to narrate a scenario first to decide the friends and enemies or frustrations and motivations.

3.3. Try to be immersed in the persona of the object.

During the interviews, most of the participants indicated that they 'become' the object while filling out the persona template. Since one of the critical points of a design fiction prototype is the level of detail and consistency in the created world, it is important to be immersed in the process. The experience might be enhanced with different mediums that the design team feel most comfortable using to create the object persona (sketch, text, etc.)

3.4. Once the key tasks are defined, think the thing's attitude towards these tasks.

It was observed that thinking about the attitude towards tasks helped designers identifying the friends/enemies and frustrations/motivations of the object. This has a great potential leading the team to the design insights for better experiences.

3.5. Think carefully about its potential friends and enemies and indicate the motivations/frustrations of the thing.

The interviews with the participants revealed that most of the design insights found as a result of the discussions on friends/enemies and motivations/frustrations while creating the object persona.

3.6. Consider giving it a fitting name.

If the team have not done so, they should consider giving the thing a fitting name and some other basic demographic information. It would increase the attributed humanly characteristics to the thing and enhance the team's experience with the tool.

4. Discuss the details with your teammates and multiply the instances if necessary.

   In the user persona creation process, usually, designers create more than one persona—primary, secondary, etc.—to have a holistic idea about their target users. A similar approach could be followed in object persona creation process to guide designers more in their ideation.

The process can be observed in Figures 7.2 and 7.3:

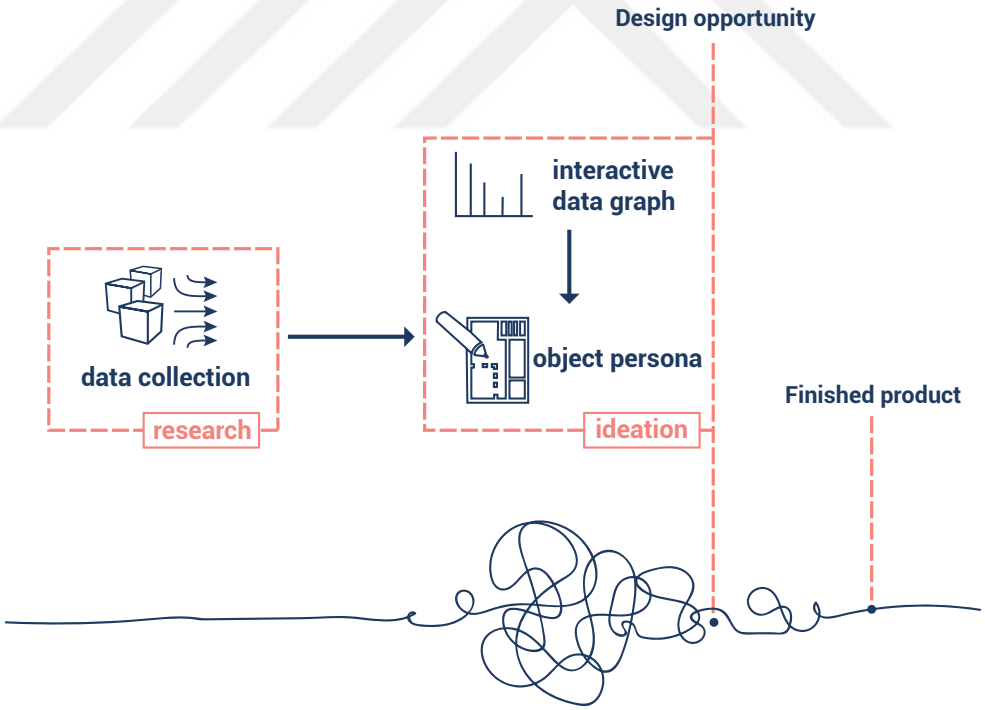


Figure 7.2: Process of object persona design based on sensor data to find design opportunity

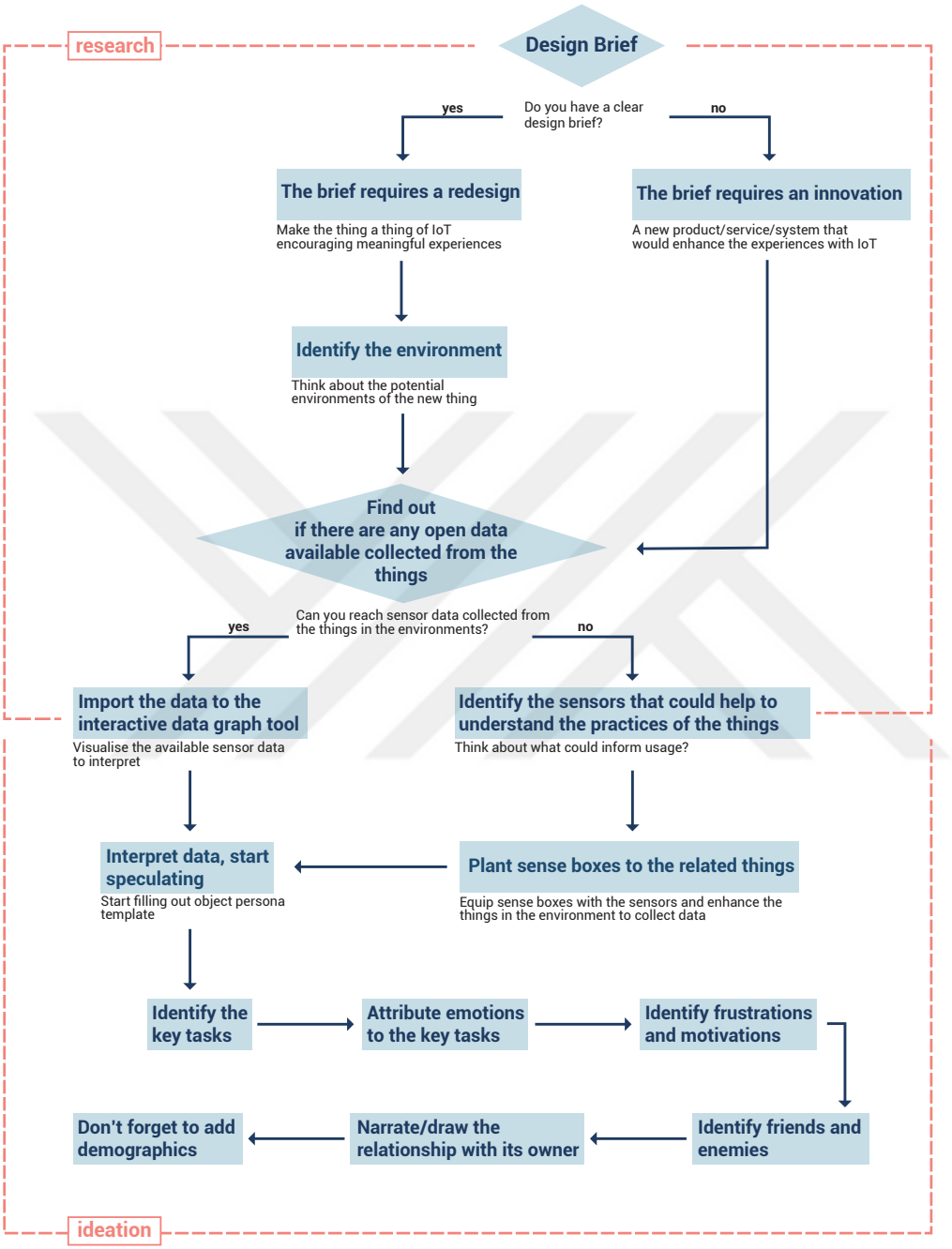


Figure 7.3: Object persona design flow

7.3 Reflections on the Procedure

In this study, it was discussed and validated that creating object persona boards based on sensor data collected from the connected devices increases the novelty of ideas in the design process by inspiring designers for the interaction of things with users, other agents and the environment.

The interaction network between the users and other agents is getting entangled more with the increasing ubiquity of connected things. The challenge for designers is no longer designing a new element that could settle down in a system, but designing opportunities where new relationships can form in the complex network. The relationship between the elements in the network can later lead to the design of new things that would complete voids in the net. This complexity constitutes a great challenge for designers. So far, user-centred design perspective helped designers in identification and formation of a lot of wicked problems. I believe the inclusion of the other agents than users in the design process could help designers in envisioning the potential relationships with yet to be designed elements. The things' perspective could help designers understand the new socio-cultural ecosystem of things and users.

The proposed method in this study offers a tool where designers can include both human and non-human users in the design process. As opposed to the approaches that give weight to one side, such as data-driven approaches (e.g., Liikkanen, 2017), this method promotes a data-enabled approach with critical thinking. Here, the perspective of other agents through sensor data together with user stories could be present.

This approach could also be another way for end-user development studies (e.g., Fischer et al., 2004) to include humans as active participants in the era of the Internet and things. It is because this method promotes to standardise neither the things nor the users by technologies. In the design fiction studies, the use of object persona as a diegetic prototype (e.g., Kirby, 2010) itself could also help designers not to focus on the technical aspects but social, political and personal results of a world with that agent.

The proposed method was aimed to be used by designers. There were design students, design practitioners and design researchers amongst the participants of the

workshops. The common characteristic of the participants was being experienced in the use of user personas in a design process. For that reason, it might be argued that this method might only be usable to the designers who have a command of a traditional design process. The method did not aim at junior design students, and it would be appropriate to say the use of this method would require a critical point of view and having a good command of the design process. This is why this method could be more usable for senior design students, professionals and design researchers.

Some may argue that the use of the method could require data literacy and programming skills. I must admit that the design of the study was challenging for me as a designer and my knowledge on data science and programming had helped me a lot in the selection and design of the tools used in the workshops. Even though I believe the sense boxes are easily adjustable to different projects by designers, interactive prototyping classes that some design schools offer could drastically increase the versatility of designers with them. In addition, in line with the increasing availability of sensor data, I believe, the visualisation tools would be more determinant in the effectiveness of using the method. For this reason, I listened to the experiences of the participants with the presented data and observed their processes through the workshops. I aimed at making the interactive data visualisation tool 'less scary' and 'easier to engage.' In the end, the participants of the Workshop 3 were in consensus on the usability of the tool.

The evaluation of the method could have been discussed in terms of the attributes and weights since they may seem relatively subjective. However, it should be emphasised that the attributes were determined as a result of the analysis of the object persona boards, presentation of final design outcomes in the workshops and interviews with the participants. Moreover, whilst the focus of expert opinion session was on the weights of the attributes, none of the experts had second thoughts on the named attributes.

Last but not least, the aim of this approach in the study should be emphasised as not an opponent but an assistive approach to user-centred design. The main aim here is to ensure the equal contribution of both human and nonhuman agents in the design process. As designers, we should understand our human users in a knowledge

elicitation process and understand our non-human users, the things, via collecting sensor data from them and creating an object persona for them to refer to in our design process. As briefly touched upon in Workshop 3, the object persona boards could also be used in interviews with the users, and they can be redesigned as deemed necessary by the designers after the interviews. The aim of object persona is also not to personify the non-livings but to get to understand the connected things, their relationships with each other, with users and with their environment better.

7.4 Limitations and Recommendations for Future Work

The evaluation of the proposed method showed that the creation of object persona by the designers inspired by the sensor data has promising positive effects on the ideation phase of the design for IoT. However, more studies are required to better show the impact with more statistically viable justifications. First, I will mention the experienced limitations and then recommend potential solutions for overcoming the limitations for further studies in terms of data collection, workshops and evaluation.

- Data Collection

  This study envisions that the accessibility of the data from connected devices will increase in the near future. For the completion of the study, the researcher had to turn simple devices into connected ones with sensing capabilities. The inexperience with working with electronics limited the types of sensor data that can be collected from the devices in the course of the limited duration of the study. It would have been better to include different sensors to better understand the effect of inclusion of broader data by observing designers' choices on using them. In future studies, it could be easier to reach different types of sensor data. Thus, this limitation would be eliminated effortlessly. To develop the proposed method further, in the near future, design researchers could work in collaboration with specialists who can ensure the uninterrupted data collection from things.

- Workshops

  The study aims at design practitioners, design students and design researchers

to use the tools and methods developed in this study. The workshops were successful in reaching a sample amongst all the intended audience. However, despite there were participants who were coming from different cultures, they all either completed or were having their design education in Turkey. Thus, the number of the participants from different cultures and design educations could have been increased to validate the impact of the used tools and methods as well as the scalability in the design for the IoT process.

- Evaluation

  The scope of this study covers the design process up until the point where designers find the design opportunity. As has been discussed in Section 3.1, the design process continues after the finding of the design opportunity. Whether it is called prototyping and implementation or evaluative and post-design phases, to see the effects of the proposed tools and method on the further phases of a design process would be an exciting topic for further research.

  Apart from the scope, there is another limitation of this study related with the evaluation of the proposed tools and method: Whilst a procedure that has been particularly developed for the effectiveness measurement of an ideation process was used, the researcher determined the attributes to calculate the effectiveness measurement. Since the researcher designed the design brief, the determination of the attributes by the researcher does not constitute a problem, especially because the assigned weights to the attributes were consulted to the experts. However, it might have been better to include the experts to the determination of the attributes to further increase the validity of the study. In future studies, the proposed tools and method might be tested by a group of researchers where the single point of admission is overruled for the design problems. This way, the attributes for evaluating the effectiveness could be approved by the team resulting in a more rationalised evaluation.

REFERENCES

Aarts, E. and Encarnação, J. Into ambient intelligence. In Aarts, E. and Encarnação, J., eds, *True Visions*, pp. 1–16. Springer, Berlin, Germany, 2006. doi: 10.1007/978-3-540-28974-6_1.

Aarts, E. and Marzano, S., eds. *The New Everyday: Views on Ambient Intelligence*. 010 Publishers, Rotterdam, Netherlands, 2003.

Abowd, G. D. and Mynatt, E. D. Charting past, present, and future research in ubiquitous computing. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 7(1):29–58, March 2000. doi: 10.1145/344949.344988.

Abrams, B. *The Observational Research Handbook: Understanding How Consumers Live With Your Product*. NTC Business Books, Lincolnwood, IL, USA, 2000.

Adlin, T. and Pruitt, J. *The Essential Persona Lifecycle: Your Guide to Building and Using Personas*. Morgan Kaufmann, Burlington, MA, USA, 2010.

Alsaadi, E. and Tubaishat, A. Internet of things: Features, challenges, and vulnerabilities. *International Journal of Advanced Computer Science and Information Technology (IJACSIT)*, 4(1):1–13, 2015.

Altshuller, G. S. *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems*. Gordon and Breach Science Publishers, 1984. doi: 10.1201/9781466593442. Translated by A. Williams.

Ambrose, G. and Harris, P. *Design Thinking*. Ava Publishing, Lausanne, Switzerland, 2009.

Appadurai, A., ed. *The Social Life of Things: Commodities in Cultural Perspective*. Cambridge University Press, Cambridge, UK, 1986. doi: 10.1017/CBO9780511819582.

Ashton, K. That 'internet of things' thing. *RFID Journal*, 22(7):97–114, 2009.

Atzori, L., Iera, A., and Morabito, G. The internet of things: A survey. *Computer Networks*, 54(15):2787–2805, 2010. doi: 10.1016/j.comnet.2010.05.010.

Auger, J. *Why Robot?: Speculative Design, the Domestication of Technology and the Considered Future*. Ph.D. dissertation, Royal College of Art, London, UK, 2012.

Auger, J. Speculative design: Crafting the speculation. *Digital Creativity*, 24(1): 11–35, 2013. doi: 10.1080/14626268.2013.767276.

Bandyopadhyay, D. and Sen, J. Internet of things: Applications and challenges in technology and standardization. *Wireless Personal Communications*, 58(1):49–69, 2011. doi: 10.1007/s11277-011-0288-5.

Bardzell, J. Creativity in amateur multimedia: Popular culture, critical theory, and HCI. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, 3(1):12–33, February 2007. doi: 10.17011/ht/urn.200768.

Bardzell, S., Bardzell, J., Forlizzi, J., Zimmerman, J., and Antanitis, J. Critical design and critical theory: The challenge of designing for provocation. In *Proceedings of the Designing Interactive Systems Conference*, DIS '12, pp. 288–297, Newcastle Upon Tyne, UK, 2012. ACM. doi: 10.1145/2317956.2318001.

Baruah, J. and Paulus, P. B. Effects of training on idea generation in groups. *Small Group Research*, 39(5):523–541, 2008. doi: 10.1177/1046496408320049.

Baskerville, R. and Pries-Heje, J. Grounded action research: A method for understanding IT in practice. *Accounting, Management and Information Technologies*, 9 (1):1–23, 1999. doi: 10.1016/S0959-8022(98)00017-4.

Bassi, A. and Horn, G. Internet of things in 2020: A roadmap for the future, 2008.

Baumer, B. A data science course for undergraduates: Thinking with data. *The American Statistician*, 69(4):334–342, 2015. doi: 10.1080/00031305.2015.1081105.

Bell, G., Blythe, M., Gaver, B., Sengers, P., and Wright, P. Designing culturally situated technologies for the home. In *CHI '03 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '03, pp. 1062–1063, Ft. Lauderdale, FL, USA, April 2003. ACM. doi: 10.1145/765891.766149.

Bernard, H. R. *Social Research Methods: Qualitative and Quantitative Approaches*. Sage Publications, Inc., Thousand Oaks, CA, USA, 2000.

Berzowska, J. Memory rich clothing: Second skins that communicate physical memory. In *Proceedings of the 5th Conference on Creativity & Cognition*, C&C '05, pp. 32–40, London, UK, April 2005. ACM. doi: 10.1145/1056224.1056231.

Blackstock, M. and Lea, R. IoT mashups with the WoTKit. In *2012 3rd IEEE International Conference on the Internet of Things*, pp. 159–166, Wuxi, China, 2012. IEEE. doi: 10.1109/IOT.2012.6402318.

Bleecker, J. A manifesto for networked objects — Cohabiting with pigeons, arphids and aibos in the internet of things. https://web.archive.org/web/20060831170309/http://research.techkwondo.com/files/WhyThingsMatter.pdf, February 2006.

Blomberg, J., Giacomi, J., Mosher, A., and Swenton-Wall, P. Ethnographic field methods and their relation to design. In Schuler, D. and Namioka, A., eds, *Participatory Design: Principles and Practices*, pp. 123–155. L. Erlbaum Associates Inc., Mahwah, NJ, USA, 1993. doi: 10.1201/9780203744338-7.

Bogers, S., Frens, J., van Kollenburg, J., Deckers, E., and Hummels, C. Connected baby bottle: A design case study towards a framework for data-enabled design. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, DIS '16, pp. 301–311, Brisbane, Australia, 2016. ACM. doi: 10.1145/2901790.2901855.

Boulakbech, M., Messai, N., Sam, Y., Devogele, T., and Hammoudeh, M. IoT mashups: From IoT big data to IoT big service. In *Proceedings of the International Conference on Future Networks and Distributed Systems*, ICFNDS '17, Cambridge, UK, 2017. ACM. doi: 10.1145/3102304.3102324.

Bradshaw, J. M. An introduction to software agents. In Bradshaw, J. M., ed, *Software Agents*, volume 4, pp. 3–46. MIT Press, Cambridge, MA, USA, 1997.

Brereton, M. and McGarry, B. An observational study of how objects support engineering design thinking and communication: Implications for the design of tangible media. In *Proceedings of the SIGCHI Conference on Human Factors in Com-*

puting Systems, CHI '00, pp. 217–224, The Hague, Netherlands, 2000. ACM. doi: 10.1145/332040.332434.

Brin, D. *The Transparent Society: Will Technology Force Us to Choose Between Privacy and Freedom?* Perseus Books, 1998.

Buchenau, M. and Suri, J. F. Experience prototyping. In *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, DIS '00, pp. 424–433, New York City, NY, USA, 2000. ACM. doi: 10.1145/347642.347802.

Burneleit, E., Hemmert, F., and Wettach, R. Living interfaces: The impatient toaster. In *Proceedings of the 3rd International Conference on Tangible and Embedded Interaction*, TEI '09, pp. 21–22, Cambridge, UK, 2009. ACM. doi: 10.1145/1517664.1517673.

Byrne, M. Interviewing as a data collection method. *AORN journal*, 74(2):233–235, 2001. doi: 10.1016/S0001-2092(06)61533-0.

Callon, M. Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay. *Power, Action, and Belief: A New Sociology of Knowledge, special issue of The Sociological Review*, 32(1_suppl):196–233, 1984. doi: 10.1111/j.1467-954X.1984.tb00113.x.

Cantrill, J. A., Sibbald, B., and Buetow, S. The Delphi and nominal group techniques in health services research. *International Journal of Pharmacy Practice*, 4(2):67–74, 1996. doi: 10.1111/j.2042-7174.1996.tb00844.x.

Cassell, C. and Johnson, P. Action research: Explaining the diversity. *Human Relations*, 59(6):783–814, 2006. doi: 10.1177/0018726706067080.

Chang, W.-W., Giaccardi, E., Chen, L.-L., and Liang, R.-H. "Interview with things": A first-thing perspective to understand the scooter's everyday socio-material network in Taiwan. In *Proceedings of the 2017 Conference on Designing Interactive Systems*, DIS '17, pp. 1001–1012, Edinburgh, UK, 2017. ACM. doi: 10.1145/3064663.3064717.

Christiaans, H. H. C. M. Creativity as a design criterion. *Communication Research Journal*, 14(1):41–54, 2002. doi: 10.1207/S15326934CRJ1401_4.

Cila, N., Giaccardi, E., Tynan-O'Mahony, F., Speed, C., and Caldwell, M. Thing-centered narratives: A study of object personas. In *Proceedings of the 3rd Seminar International Research Network for Design Anthropology*, January 2015.

Cila, N., Smit, I., Giaccardi, E., and Kröse, B. Products as agents: Metaphors for designing the products of the IoT age. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, CHI '17, pp. 448–459, Denver, CO, USA, 2017. ACM. doi: 10.1145/3025453.3025797.

Cooper, A. *The Inmates are Running the Asylum: Why High-Tech Products Drive Us Crazy and How to Restore the Sanity*. Sams Publishing, Carmel, IN, USA, 1999.

Cooper, A., Reimann, R., and Cronin, D. *About Face: The Essentials of Interaction Design*. Wiley Publishing Inc., Indianapolis, IN, USA, 3rd edition, 2007.

Courage, C. and Baxter, K. *Understanding Your Users: A Practical Guide to User Requirements Methods, Tools, and Techniques*. Morgan Kaufmann, San Francisco, CA, USA, 2005. doi: 10.1016/B978-1-55860-935-8.X5029-5.

Crawford, R. P. *The Techniques of Creative Thinking: How to Use Your Ideas to Achieve Success*. Hawthorn Books, 1954.

Cross, N. Designerly ways of knowing. *Design Studies*, 3(4):221–227, 1982. doi: 10.1016/0142-694X(82)90040-0. Special Issue Design Education.

Csikszentmihalyi, M. *Creativity: Flow and the Psychology of Discovery and Invention*. Harper Collins Publishers, New York City, NY, USA, 1996.

Dar, K., Taherkordi, A., Rouvoy, R., and Eliassen, F. Adaptable service composition for very-large-scale internet of things systems. In *Proceedings of the 8th Middleware Doctoral Symposium*, MDS '11, Lisbon, Portugal, 2011. ACM. doi: 10.1145/2093190.2093192.

DeLanda, M. Deleuze and the use of the genetic algorithm in architecture. In Leach, N., ed, *Designing for a Digital World*, pp. 117–120. Wiley, Chichester, UK, 2002a.

DeLanda, M. *Intensive Science and Virtual Philosophy*. Bloomsbury Publishing, New York City, NY, USA, 2002b.

DeLanda, M. *A New Philosophy of Society: Assemblage Theory and Social Complexity*. Bloomsbury Publishing, London, UK, 2006.

Dick, B., Stringer, E., and Huxham, C. Theory in action research. *Action Research*, 7(1):5–12, 2009. doi: 10.1177/1476750308099594.

D'Ignazio, C. and Bhargava, R. DataBasic: Design principles, tools and activities for data literacy learners. *The Journal of Community Informatics*, 12(3):83–107, 2016.

DiSalvo, C. and Lukens, J. Nonanthropocentrism and nonhuman in design: Possibilities for designing new forms of engagement with and through technology. In Foth, M., Forlano, L., Satchell, C., and Gibbs, M., eds, *From Social Butterfly to Engaged Citizen: Urban Informatics, Social Media, Ubiquitous Computing, and Mobile Technology to Support Citizen Engagement*. MIT Press, Cambridge, MA, USA, 2011.

Dobson, K. Blendie. https://web.archive.org/web/20070918040454/http://web.media.mit.edu/~monster/blendie/dobson_blendie_small.mov, 2004a.

Dobson, K. Blendie. In *Proceedings of the 5th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, DIS '04, p. 309, Cambridge, MA, USA, 2004b. ACM. doi: 10.1145/1013115.1013159.

Dourish, P. and Bell, G. "Resistance is futile": Reading science fiction alongside ubiquitous computing. *Personal and Ubiquitous Computing*, 18(4):769–778, 2014. doi: 10.1007/s00779-013-0678-7.

Ducatel, K.and Bogdanowicz, M., Scapolo, F., Leijten, J., and Burgelman, J.-C. Scenarios for ambient intelligence in 2010. Technical report, Information Society Technologies Advisory Group (ISTAG), Institute of Prospective Technological Studies (IPTS), 2001.

Dunne, A. and Raby, F. *Speculative Everything: Design, Fiction, and Social Dreaming*. MIT Press, Cambridge, MA, USA, 2013.

Electrolux Group. History timeline 1990–1999. https://web.archive.org/web/20201019210752/https://www.electroluxgroup.com/en/history-timeline-1990-1999-27596/, 1999.

Fischer, G. and Giaccardi, E. Meta-design: A framework for the future of end-user development. In Lieberman, H., Paternò, F., and Wulf, V., eds, *End User Development*, pp. 427–457. Springer, Dordrecht, Netherlands, 2006. doi: 10.1007/1-4020-5386-X_19.

Fischer, G., Giaccardi, E., Ye, Y., Sutcliffe, A. G., and Mehandjiev, N. Meta-design: A manifesto for end-user development. *Communications of the ACM*, 47(9):33–37, September 2004. doi: 10.1145/1015864.1015884.

Fischer, J. E., Crabtree, A., Rodden, T., Colley, J. A., Costanza, E., Jewell, M. O., and Ramchurn, S. D. "Just whack it on until it gets hot": Working with IoT data in the home. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pp. 5933–5944, San Jose, CA, USA, 2016. ACM. doi: 10.1145/2858036.2858518.

Frayling, C. Research in art and design. *Royal College of Art Research Papers*, 1(1), 1993.

Gallagher, H. L. and Frith, C. D. Functional imaging of 'theory of mind'. *Trends in Cognitive Sciences*, 7(2):77–83, 2003. doi: 10.1016/S1364-6613(02)00025-6.

Gaver, B., Dunne, T., and Pacenti, E. Design: Cultural probes. *Interactions*, 6(1): 21–29, January 1999. doi: 10.1145/291224.291235.

Giaccardi, E., Cila, N., Speed, C., and Caldwell, M. Thing ethnography: Doing design research with non-humans. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, DIS '16, pp. 377–387, Brisbane, Australia, 2016. ACM. doi: 10.1145/2901790.2901905.

Giusto, D., Iera, A., Morabito, G., and Atzori, L., eds. *The Internet of Things: 20th Tyrrhenian Workshop on Digital Communications*. Springer, New York City, NY, USA, 2010. doi: 10.1007/978-1-4419-1674-7.

Glaser, B. G. and Strauss, A. L. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Aldine Publishing Co., Chicago, IL, USA, 1967.

Goodwin, K. *Designing for the Digital Age: How to Create Human-Centered Products and Services. 2009*. Wiley Publishing Inc., Indianapolis, IN, USA, 2009.

Gordon, W. J. J. *Synectics: The Development of Creative Capacity*. Harper & Row, New York City, NY, USA, 1961.

Grammel, L., Tory, M., and Storey, M.-A. How information visualization novices construct visualizations. *IEEE Transactions on Visualization and Computer Graphics*, 16(6):943–952, 2010. doi: 10.1109/TVCG.2010.164.

Grand, S. and Wiedmer, M. Design fiction: A method toolbox for design research in a complex world. In *Proceedings of the DRS2010 Conference: Design and Complexity*, Montreal, Canada, July 2010. Design Research Society.

Greenfield, A. *Everyware: The Dawning Age of Ubiquitous Computing*. New Riders, Berkeley, CA, USA, 2006.

Gulliksen, J., Göransson, B., Boivie, I., Blomkvist, S., Persson, J., and Cajander, Å. Key principles for user-centred systems design. *Behaviour & Information Technology*, 22(6):397–409, 2003. doi: 10.1080/01449290310001624329.

Halaweh, M. Discount focus subgroup method: An innovative focus group method used for researching an emerging technology. In Association, I. R. M., ed, *Research Methods: Concepts, Methodologies, Tools, and Applications*, pp. 344–361. IGI Global, Hershey, PA, USA, 2015. doi: 10.4018/978-1-4666-7456-1.ch016.

Harman, G. *Prince of Networks: Bruno Latour and Metaphysics*. Re.Press, Melbourne, Australia, 2009.

Henderson, A. and Kyng, M. There is no place like home: Continuing design in use. In Greenbaum, J. and Kyng, M., eds, *Design at Work: Cooperative Design of Computer Systems*, pp. 219–240. L. Erlbaum Associates Inc., Hillsdale, NJ, USA, 1991.

Henfridsson, O. and Lindgren, R. Multi-contextuality in ubiquitous computing: Investigating the car case through action research. *Information and Organization*, 15 (2):95–124, 2005. doi: 10.1016/j.infoandorg.2005.02.009.

Hill, B. M., Dailey, D., Guy, R. T., Lewis, B., Matsuzaki, M., and Morgan, J. T. Democratizing data science: The community data science workshops and classes. In Matei, S. A., Jullien, N., and Goggins, S. P., eds, *Big Data Factories*, pp. 115–135. Springer, Cham, Switzerland, 2017. doi: 10.1007/978-3-319-59186-5_9.

Hine, C. *Virtual Ethnography*. SAGE Publications, London, UK, 2000.

Horn, D. and Salvendy, G. Product creativity: Conceptual model, measurement and characteristics. *Theoretical Issues in Ergonomics Science*, 7(4):395–412, 2006. doi: 10.1080/14639220500078195.

Horowitz, R. and Maimon, O. Creative design methodology and the SIT method. In *Proceedings of DETC 1997: ASME Design Engineering Technical Conference*, DETC '97, Sacramento, CA, USA, September 1997.

Hutchinson, H., Mackay, W., Westerlund, B., Bederson, B. B., Druin, A., Plaisant, C., Beaudouin-Lafon, M., Conversy, S., Evans, H., Hansen, H., Roussel, N., and Eiderbäck, B. Technology probes: Inspiring design for and with families. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '03, pp. 17–24, Ft. Lauderdale, FL, USA, April 2003. ACM. doi: 10.1145/642611.642616.

IBM Research Zurich. Swissair, IBM first to enable passengers to check in from mobile phones. https://web.archive.org/web/20150428192320/http://www.zurich.ibm.com/news/99/wap_sr.html, December 1999.

Iivari, N. and Kuutti, K. Critical design research and information technology: Searching for empowering design. In *Proceedings of the 2017 Conference on Designing Interactive Systems*, DIS '17, pp. 983–993, Edinburgh, UK, 2017. ACM. doi: 10.1145/3064663.3064747.

Jenkins, T. Designing the "things" of the IoT. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '15, pp. 449–452, Stanford, CA, USA, 2015. ACM. doi: 10.1145/2677199.2691608.

Jones, J. C. *Design Methods: Seeds of Human Futures*. Wiley, Chichester, UK, 1970.

Jönsson, L. and Lenskjold, T. U. A foray into not-quite companion species: Design experiments with urban animals as significant others. *Artifact*, 3(2):7.1–7.13, 2014. doi: 10.14434/artifact.v3i2.3957.

Jung, J., Nam, H., Lim, Y.-k., and Lee, K.-p. Beauty and the beast: An IoT design method based on improvisational acting. In *Proceedings of the 2017 ACM Confer-*

ence Companion Publication on Designing Interactive Systems, DIS '17 Companion, pp. 61–66, Edinburgh, UK, 2017. ACM. doi: 10.1145/3064857.3079120.

Kawakita, J. *The Original KJ Method*. Kawakita Research Institute, Tokyo, Japan, 1982.

Kawulich, B. B. Participant observation as a data collection method. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, 6(2), May 2005. doi: 10.17169/fqs-6.2.466.

Keeley-Browne, E. Cyber-ethnography: The emerging research approach for 21th century research investigation. In *Handbook of Research on Transformative Online Education and Liberation: Models for Social Equality*, pp. 330–338. IGI Global, 2011. doi: 10.4018/978-1-60960-046-4.ch017.

Kelly, J. and Matthews, B. Displacing use: Exploring alternative relationships in a human-centred design process. *Design Studies*, 35(4):353–373, 2014. doi: 10.1016/j.destud.2014.02.001.

Kemmis, S. and McTaggart, R., eds. *The Action Research Planner*. Deakin University Press, Geelong, Australia, 3rd edition, 1988.

Kerridge, T. Does speculative design contribute to public engagement of science and technology? In *Multiple Ways to Design Research: Research Cases that Reshape the Design Discipline. Proceedings of the 5th Swiss Design Network Symposium*, pp. 208–224, Lugano, Switzerland, 2009. Swiss Design Network.

Keyson, D. V. The experience of intelligent products. In Schifferstein, H. N. J. and Hekkert, P., eds, *Product Experience*, pp. 515–530. Elsevier, 2008. doi: 10.1016/B978-008045089-6.50025-3.

Kirby, D. The future is now: Diegetic prototypes and the role of popular films in generating real-world technological development. *Social Studies of Science*, 40(1):41–70, 2010. doi: 10.1177/0306312709338325.

Kleinfeld, R., Steglich, S., Radziwonowicz, L., and Doukas, C. glue.things: A mashup platform for wiring the internet of things with the internet of services. In *Proceedings of the 5th International Workshop on Web of Things*, WoT '14, pp. 16–21, Cambridge, MA, USA, October 2014. ACM. doi: 10.1145/2684432.2684436.

Knutsen, J. Uprooting products of the networked city. *International Journal of Design*, 8(1):127–142, 2014.

Kock, N. The three threats of action research: A discussion of methodological antidotes in the context of an information systems study. *Decision Support Systems*, 37(2):265–286, 2004. doi: 10.1016/S0167-9236(03)00022-8.

Kolko, J. *Exposing the Magic of Design: A Practitioner's Guide to the Methods and Theory of Synthesis*. Human Tecnology Interaction Series. Oxford University Press, New York City, NY, USA, 2011. doi: 10.1093/acprof:oso/9780199744336.003.0002.

Kopetz, H. Internet of things. In *Real-Time Systems*, pp. 307–323. Springer, Boston, MA, USA, 2011. doi: 10.1007/978-1-4419-8237-7_13.

Koreshoff, T. L., Leong, T. W., and Robertson, T. Approaching a human-centred internet of things. In *Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration*, OzCHI '13, pp. 363–366, Adelaide, Australia, 2013a. ACM. doi: 10.1145/2541016.2541093.

Koreshoff, T. L., Robertson, T., and Leong, T. W. Internet of things: A review of literature and products. In *Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration*, OzCHI '13, pp. 335–344, Adelaide, Australia, 2013b. ACM. doi: 10.1145/2541016.2541048.

Kozinets, R. V. Netnography 2.0. In Belk, R. W., ed, *Handbook of Qualitative Research Methods in Marketing*. Edward Elgar Publishing, Cheltenham, UK, 2006.

Krill, P. Ibm research envisions pervasive computing. InfoWorld, October 2000. https://web.archive.org/web/20131004015021/https://www.pcworld.idg.com.au/article/77460/ibm_research_envisions_pervasive_computing/.

Kun, P., Mulder, I., and Kortuem, G. Design enquiry through data: Appropriating a data science workflow for the design process. In *Proceedings of the 32nd International BCS Human Computer Interaction Conference*, pp. 1–12, Belfast, UK, July 2018. BCS Learning and Development. doi: 10.14236/ewic/HCI2018.32.

Kuniavsky, M. *Smart Things: Ubiquitous Computing User Experience Design*. Morgan Kaufmann, Burlington, MA, USA, 2010.

Laschke, M., Hassenzahl, M., and Diefenbach, S. Things with attitude: Transformational products. In *Create '11 Conference*, pp. 1–2, 2011.

Latour, B. Where are the missing masses? The sociology of a few mundane artifacts. *Shaping Technology/Building Society: Studies in Sociotechnical Change*, pp. 225–258, 1992.

Latour, B. *Third Source of Uncertainty: Objects too Have Agency*, pp. 63–86. Clarendon Lectures in Management Studies. Oxford University Press, Oxford, UK, 2005.

Law, J. Theory and narrative in the history of technology: Response. *Technology and Culture*, 32(2):377–384, 1991. doi: 10.2307/3105716.

Lawson, B. R. Cognitive strategies in architectural design. *Ergonomics*, 22(1):59–68, 1979. doi: 10.1080/00140137908924589.

Lewin, K. Action research and minority problems. *Journal of Social Issues*, 2(4): 34–46, 1946. doi: 10.1111/j.1540-4560.1946.tb02295.x.

Liikkanen, L. A. The data-driven design era in professional web design. *Interactions*, 24(5):52–57, August 2017. doi: 10.1145/3121355.

Lindley, J. A pragmatics framework for design fiction. In Valentine, L., Borja de Mozota, B., Nelson, J., Merter, S., and Atkinson, P., eds, *Proceedings of the 11th International Conference of the European Academy of Design, 'The Value of Design Research'*, Paris, France, April 2015.

Lindley, J., Sharma, D., and Potts, R. Anticipatory ethnography: Design fiction as an input to design ethnography. *Ethnographic Praxis in Industry Conference Proceedings*, 2014(1):237–253, 2014. doi: 10.1111/1559-8918.01030.

Maeda, E. and Minami, Y. Steps toward ambient intelligence. *NTT Technical Review*, 4(1):50–55, 2006.

Mahapatra, T., Gerostathopoulos, I., and Prehofer, C. Towards integration of big data analytics in internet of things mashup tools. In *Proceedings of the 7th Interna-*

tional Workshop on the Web of Things, WoT '16, pp. 11–16, Stuttgart, Germany, November 2016. ACM. doi: 10.1145/3017995.3017998.

Marenko, B. and van Allen, P. Animistic design: How to reimagine digital interaction between the human and the nonhuman. *Digital Creativity*, 27(1):52–70, 2016. doi: 10.1080/14626268.2016.1145127.

Markussen, T. and Knutz, E. The poetics of design fiction. In *Proceedings of the 6th International Conference on Designing Pleasurable Products and Interfaces*, DPPI '13, pp. 231–240, Newcastle upon Tyne, UK, 2013. ACM. doi: 10.1145/2513506.2513531.

Martin, B. and Hanington, B. *Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions*. Rockport Publishers, Beverly, MA, USA, 2012.

Mason, M. F., Banfield, J. F., and Macrae, C. N. Thinking about actions: The neural substrates of person knowledge. *Cerebral Cortex*, 14(2):209–214, February 2004. doi: 10.1093/cercor/bhg120.

Mayer, S., Inhelder, N., Verborgh, R., and Van de Walle, R. User-friendly configuration of smart environments. In *2014 IEEE International Conference on Pervasive Computing and Communication Workshops (PERCOM Workshops)*, pp. 163–165, March 2014. doi: 10.1109/PerComW.2014.6815188.

McVeigh-Schultz, J., Stein, J., Watson, J., and Fisher, S. Extending the lifelog to non-human subjects: Ambient storytelling for human-object relationships. In *Proceedings of the 20th ACM International Conference on Multimedia*, MM '12, pp. 1205–1208, Nara, Japan, October 2012a. ACM. doi: 10.1145/2393347.2396419.

McVeigh-Schultz, J., Stein, J., Boyle, J., Duff, E., Watson, J., Syam, A., Tasse, A., Wiscombe, S., and Fisher, S. Vehicular lifelogging: New contexts and methodologies for human-car interaction. In *CHI '12 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '12, pp. 221–230, Austin, TX, USA, May 2012b. ACM. doi: 10.1145/2212776.2212800.

Miller, D. *Material Cultures: Why Some Things Matter*. University of Chicago Press, Chicago, IL, USA, 1998.

Mollon, M. and Gentes, A. The rhetoric of design for debate: Triggering conversation with an "uncanny enough" artefact. In *Proceedings of DRS 2014: Design's Big Debates*, pp. 1049–1061, Umeå, Sweeden, 2014.

Mühlhäuser, M. and Gurevych, I. Introduction to ubiquitous computing. In Mühlhäuser, M. and Gurevych, I., eds, *Handbook of Research on Ubiquitous Computing Technology for Real Time Enterprises*, pp. 1–20. IGI Global, 2008. doi: 10.4018/978-1-59904-832-1.ch001.

Nansen, B., van Ryn, L., Vetere, F., Robertson, T., Brereton, M., and Dourish, P. An internet of social things. In *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: The Future of Design*, OzCHI '14, pp. 87–96, Sydney, Australia, November 2014. ACM. doi: 10.1145/2686612.2686624.

Near Future Laboratory. Curious rituals. https://web.archive.org/web/20200820021739/http://curiousrituals.nearfuturelaboratory.com/, April 2014.

Nevile, M., Haddington, P., Heinemann, T., and Rauniomaa, M., eds. *Interacting With Objects: Language, Materiality, and Social Activity*. John Benjamins Publishing Company, Amsterdam, Netherlands, 2014. doi: 10.1075/z.186.

Nicenboim, I. Objects of research: Who is the object in the internet of things? Master's thesis, Universität der Künste Berlin, Berlin, Germany, 2015.

Nielsen, J. *Usability Engineering*. Morgan Kaufmann, San Francisco, CA, USA, 1993.

Nielsen, L. From user to character: An investigation into user-descriptions in scenarios. In *Proceedings of the 4th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, DIS '02, pp. 99–104, London, UK, 2002. ACM. doi: 10.1145/778712.778729.

Norman, D. A. *The Psychology of Everyday Things.* Basic Books, New York City, NY, USA, 1988.

Norman, D. A. *Emotional Design: Why We Love (or Hate) Everyday Things*. Basic Books, New York City, NY, USA, 2004.

Norman, D. A. and Draper, S. W. *User Centered System Design; New Perspectives on Human-Computer Interaction*. L. Erlbaum Associates Inc., Mahwah, NJ, USA, 1986.

Nova, N., Miyake, K., Kwon, N., and Chiu, W. Curious rituals: Gestural interaction in the digital everyday. *Ethnographic Praxis in Industry Conference Proceedings*, 2013(1):406–406, 2013. doi: 10.1111/j.1559-8918.2013.00035.x.

Okoli, C. and Pawlowski, S. D. The Delphi method as a research tool: An example, design considerations and applications. *Information & Management*, 42(1):15–29, 2004. doi: 10.1016/j.im.2003.11.002.

Osborn, A. F. *Applied Imagination: Principles and Procedures of Creative Thinking*. Charlers Scribner's Sons, New York City, NY, USA, 1953.

Pahl, G. and Beitz, W. *Engineering Design: A Systematic Approach*. Springer, London, UK, 2nd edition, 1996. doi: 10.1007/978-1-4471-3581-4. Translated by L. T. M. Blessing, F. Bauert, and K. Wallace.

Putman, V. L. *Effects of Additional Rules and Dominance on Brainstorming and Decision-Making*. Ph.D. dissertation, University of Texas in Arlington, Arlington, TX, USA, 2001.

Raelin, J. A. and Coghlan, D. Developing managers as learners and researchers: Using action learning and action research. *Journal of Management Education*, 30 (5):670–689, 2006. doi: 10.1177/1052562905285912.

Rapoport, R. N. Three dilemmas in action research: With special reference to the Tavistock experience. *Human Relations*, 23(6):499–513, 1970. doi: 10.1177/001872677002300601.

Rebaudengo, S. Addicted product: A scenario of future interactions based on addictions of products to be used. Master's thesis, TU Delft, Delft, Netherlands, 2012a.

Rebaudengo, S. Addicted products. https://web.archive.org/web/20191022151416/http://www.simonerebaudengo.com/project/addictedproducts, 2012b.

Redström, J. Towards user design? On the shift from object to user as the subject of design. *Design studies*, 27(2):123–139, 2006. doi: 10.1016/j.destud.2005.06.001.

Reeves, B. and Nass, C. I. *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*. Cambridge University Press, Cambridge, UK, 1996.

Ritter, F. E., Baxter, G. D., and Churchill, E. F. User-centered systems design: A brief history. In *Foundations for Designing User-Centered Systems: What System Designers Need to Know About People*, pp. 33–54. Springer, London, UK, 2014. doi: 10.1007/978-1-4471-5134-0.

Robson, C. *Real World Research: A Resource for Users of Social Research Methods in Applied Settings*. Blackwell Publishers, Oxford, UK, 2nd edition, 2002.

Robson, C. and McCartan, K. *Real World Research: A Resource for Users of Social Research Methods in Applied Settings*. Wiley, Chichester, UK, 4th edition, 2016.

Roget, P. M. *Thesaurus of English Words and Phrases , Classified and Arranged so as to Facilitate the Expression of Ideas and Assist in Literary Composition*. Longman, Brown, Green and Longmans, London, UK, 1852.

Rohrbach, B. Kreativ nach regeln — Methode 635, eine neue technik zum lösen von problemen. *Absatzwirtschaft*, 12(19):73–75, 1969.

Rosson, M. B. and Carroll, J. M. Scenario-based design. In *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications*, pp. 1032–1050. L. Erlbaum Associates Inc., Mahwah, NJ, USA, 2002.

Roy, M., Hemmert, F., and Wettach, R. Living interfaces: The intimate door lock. In *Proceedings of the 3rd International Conference on Tangible and Embedded Interaction*, TEI '09, pp. 45–46, Cambridge, UK, 2009. ACM. doi: 10.1145/1517664.1517681.

Rubin, H. J. and Rubin, I. S. *Qualitative Interviewing: The Art of Hearing Data*. Sage Publications, Inc., Thousand Oaks, CA, USA, 2005.

Rümpel, A. and Meißner, K. Requirements-driven quality modeling and evaluation in web mashups. In *2012 8th International Conference on the Quality of Information and Communications Technology (QUATIC)*, pp. 319–322, Lisbon, Portugal, September 2012. IEEE. doi: 10.1109/QUATIC.2012.51.

Salvador, T., Bell, G., and Anderson, K. Design ethnography. *Design Management Journal*, 10(4):35–41, 1999. doi: 10.1111/j.1948-7169.1999.tb00274.x.

Sanders, E. B. N. and Stappers, P. J. Probes, toolkits and prototypes: Three approaches to making in codesigning. *CoDesign*, 10(1):5–14, 2014. doi: 10.1080/15710882.2014.888183.

Santucci, G. From internet of data to internet of things. In *International Conference on Future Trends of the Internet*, volume 28, pp. 1–19, January 2009.

Sarmiento, R. M., Pasman, G., and Stappers, P. J. Vision concepts within the landscape of design research. In Lloyd, P. and Bohemia, E., eds, *Proceedings of DRS2016: Design + Research + Society — Future-Focused Thinking*, volume 4, pp. 1659–1676, Brighton, UK, June 2016. Design Research Society.

Schröer, B., Kain, A., and Lindemann, U. Supporting creativity in conceptual design: Method 635-extended. In Marjanović, D., Štorga, M., Pavković, N., and Bojčetić, N., eds, *Proceedings of DESIGN 2010, the 11th International Design Conference*, volume 1, pp. 591–600, Dubrovnik, Croatia, 2010.

Shah, J. J., Smith, S. M., and Vargas-Hernandez, N. Metrics for measuring ideation effectiveness. *Design Studies*, 24(2):111–134, 2003. doi: 10.1016/s0142-694x(02)00034-0.

Silva, P. A. and Read, J. C. A methodology to evaluate creative design methods: A study with the BadIdeas method. In *Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction*, OZCHI '10, pp. 264–271, Brisbane, Australia, 2010. ACM. doi: 10.1145/1952222.1952279.

Simon, H. A. *The Sciences of the Artificial*. MIT Press, Cambridge, MA, USA, 1969.

Speed, C. and Oberlander, J. Designing from, with and by data: Introducing the ablative framework. In Lloyd, P. and Bohemia, E., eds, *Proceedings of DRS2016: Design + Research + Society — Future-Focused Thinking*, volume 1, pp. 2991–3004, Brighton, UK, June 2016. Design Research Society. doi: 10.21606/drs.2016.433.

Spencer, B. The talking trainers: Hi-tech shoes that nag you to get off the sofa and work out. https://web.archive.org/web/20130314020311/https://www.dailymail.co.uk/sciencetech/article-2291275/SXSW-2013-Googles-Hi-tech-shoes-nag-sofa-work-out.html, 2013.

Stammerjohan, C. A. and Vance, D. New product development: A comparison of traditional creative methods with genetic algorithms in the ideation stage. In *Proceedings of the Society for Marketing Advances 2001 Conference*, New Orleans, LA, USA, November 2001.

Stein, J. and Fisher, S. Ambient storytelling: The million story building. In Do, E. Y.-L., Gross, M. D., and Oakley, I., eds, *Work-in-Progress Workshop Proceedings of ACM SIGCHI Conference on Tangible, Embedded, and Embodied Interaction*, TEI '11, pp. 13–18, January 2011.

Stein, J. L. *PUCK: Place-Based, Ubiquitous, Connected and Kinetic Experiences for Interactive Architecture*. Ph.D. dissertation, University of Southern California, Los Angeles, CA, USA, 2011.

Stempfle, J. and Badke-Schaub, P. Thinking in design teams - An analysis of team communication. *Design Studies*, 23(5):473–496, 2002. doi: 10.1016/S0142-694X(02)00004-2.

Sterling, B. *Shaping Things*. MIT Press, Cambridge, MA, USA, 2005.

Sterling, B. Understanding the spime. https://web.archive.org/web/20200826023738/https://www.flickr.com/photos/45506355@N00/sets/72157594354415159/with/30536086524/, 2006.

Stringer, E. T. *Action Research*. Sage Publications, Inc., Thousand Oaks, CA, USA, 3rd edition, 2007.

Superflux. Uninvited guests. https://web.archive.org/web/20200506094528/https://superflux.in/index.php/work/uninvited-guests/, 2015.

Susman, G. I. and Evered, R. D. An assessment of the scientific merits of action research. *Administrative Science Quarterly*, 23(4):582–603, 1978. doi: 10.2307/2392581.

Tanenbaum, J. Design fictional interactions: Why HCI should care about stories. *Interactions*, 21(5):22–23, September 2014. doi: 10.1145/2648414.

Taylor, D. W., Berry, P. C., and Block, C. H. Does group participation when using brainstorming facilitate or inhibit creative thinking? *Administrative Science Quarterly*, 3(1):23–47, 1958. doi: 10.2307/2390603.

Togler, J., Hemmert, F., and Wettach, R. Living interfaces: The thrifty faucet. In *Proceedings of the 3rd International Conference on Tangible and Embedded Interaction*, TEI '09, pp. 43–44, Cambridge, UK, 2009. ACM. doi: 10.1145/1517664.1517680.

Tolmie, P., Crabtree, A., Rodden, T., Colley, J., and Luger, E. "This has to be the cats": Personal data legibility in networked sensing systems. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing*, CSCW '16, pp. 491–502, San Francisco, CA, USA, 2016. ACM. doi: 10.1145/2818048.2819992.

Tracey, M. W. and Richey, R. C. ID model construction and validation: A multiple intelligences case. *Educational Technology Research and Development*, 55(4):369–390, 2007. doi: 10.1007/s11423-006-9015-4.

Tuomi, I. Beyond user-centric models of product creation. In Haddon, L., Mante, E., Sapio, B., Kommonen, K.-H., Fortunati, L., and Kant, A., eds, *Everyday Innovators: Researching the Role of Users in Shaping ICT's*, pp. 21–38. Springer, Dordrecht, Netherlands, 2005. doi: 10.1007/1-4020-3872-0_2.

Turkle, S., ed. *Evocative Objects: Things We Think With*. MIT Press, Cambridge, MA, USA, 2007.

Vaihinger, H. *The Philosophy of 'As if': A System of the Theoretical, Practical and Religious Fictions of Mankind*. K. Paul, Trench, Trubner & Co., London, UK, 1924. Translated by C. K. Ogden.

van Allen, P., McVeigh-Schultz, J., Brown, B., Kim, H. M., and Lara, D. AniThings: Animism and heterogeneous multiplicity. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '13, pp. 2247–2256, Paris, France, April 2013. ACM. doi: 10.1145/2468356.2468746.

van Boeijen, A. G. C., Daalhuizen, J. J., Zijlstra, J., and van der Schoor, R. S. A., eds. *Delft Design Guide: Design Strategies and Methods*. BIS Publishers, Amsterdam, Netherlands, 2013.

van Kollenburg, J., Bogers, S., Rutjes, H., Deckers, E., Frens, J., and Hummels, C. Exploring the value of parent tracked baby data in interactions with healthcare professionals: A data-enabled design exploration. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, CHI '18, pp. 1–12, Montreal, Canada, 2018. ACM. doi: 10.1145/3173574.3173871.

Venkatesh, A. Digital home technologies and transformation of households. *Information Systems Frontiers*, 10(4):391–395, 2008. doi: 10.1007/s10796-008-9097-0.

Visser, F. S., Stappers, P. J., van der Lugt, R., and Sanders, E. B. N. Contextmapping: Experiences from practice. *CoDesign*, 1(2):119–149, 2005. doi: 10.1080/15710880500135987.

Weiser, M. The computer for the 21st century. *Scientific American*, 265(3):94–105, 1991. doi: 10.1038/scientificamerican0991-94.

Weiser, M. Some computer science issues in ubiquitous computing. *Communications of the ACM*, 36(7):75–84, July 1993. doi: 10.1145/159544.159617.

Whitehead, J. and McNiff, J. *Action Research: Living Theory*. Sage Publications, London, UK, 2006.

Whiting, C. S. *Creative Thinking*. Reinhold Publishing Company, New York City, NY, USA, 1958.

Wilson, S. M. and Peterson, L. C. The anthropology of online communities. *Annual Review of Anthropology*, 31(1):449–467, 2002. doi: 10.1146/annurev.anthro.31.040402.085436.

Wohlin, C. Guidelines for snowballing in systematic literature studies and a replication in software engineering. In *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering*, EASE '14, pp. 38.1–38.10, London, UK, 2014. ACM. doi: 10.1145/2601248.2601268.

Wolff, A., Gerd, K., Gooch, D., Giaccardi, E., and Speed, C. Designing with data: A designerly approach to data and data analytics. In *Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems*, DIS '16 Companion, pp. 53–56, Brisbane, Australia, 2016. ACM. doi: 10.1145/2908805.2913017.

Wright, E. O. *Envisioning Real Utopias*. Verso, London, UK, 2010.

Yang, R. and Newman, M. W. Learning from a learning thermostat: Lessons for intelligent systems for the home. In *Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, UbiComp '13, pp. 93–102, Zurich, Switzerland, 2013. ACM. doi: 10.1145/2493432.2493489.

Yoong, P. and Pauleen, D. Generating and analysing data for applied research on emerging technologies: A grounded action learning approach. *Information Research*, 9(4), 2004. http://InformationR.net/ir/9-4/paper195.html.

Zwicky, F. Morphological astronomy. *The Observatory*, 68:121–143, 1948.

Zwicky, F. *Discovery, Invention, Research Through the Morphological Approach*. The Macmillan Company, Toronto, Canada, 1969.

APPENDIX A

DATA SETS USED IN WORKSHOP 1



Figure A.1: Data Sets Used in Workshop 1



Figure A.1 (cont.): Data Sets Used in Workshop 1



Figure A.1 (cont.): Data Sets Used in Workshop 1

APPENDIX B

OBJECT PERSONA BOARDS FROM WORKSHOP 1

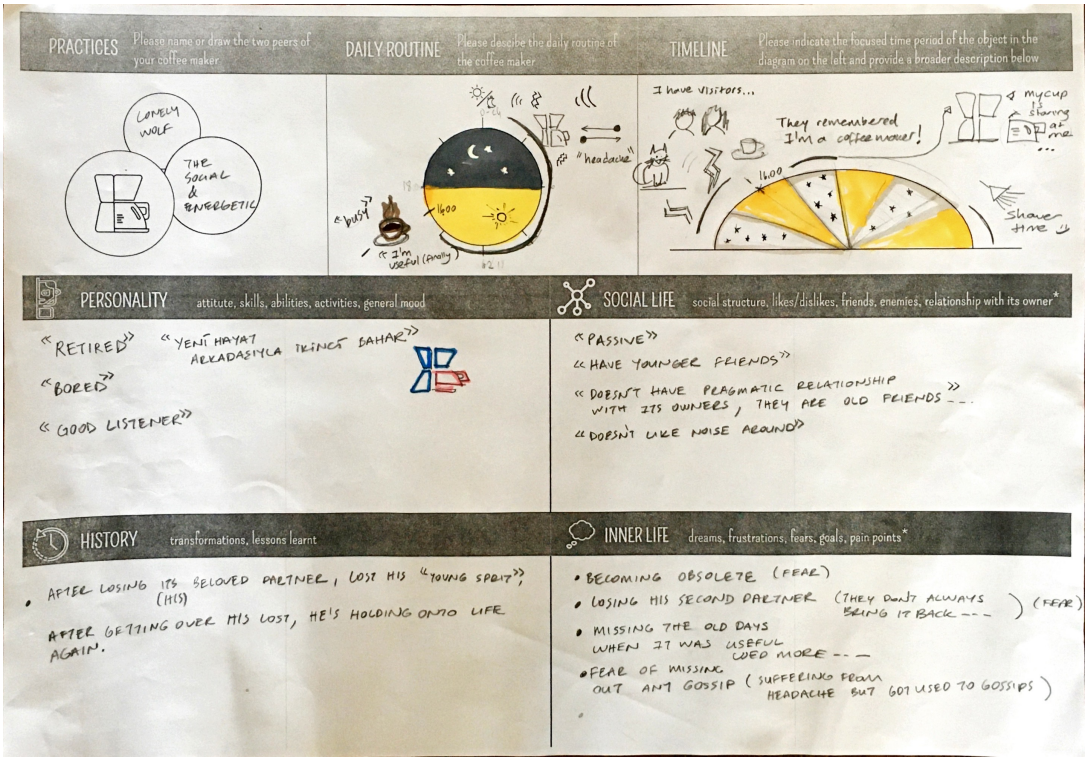


Figure B.1: Object persona board of Team 1 in Workshop 1

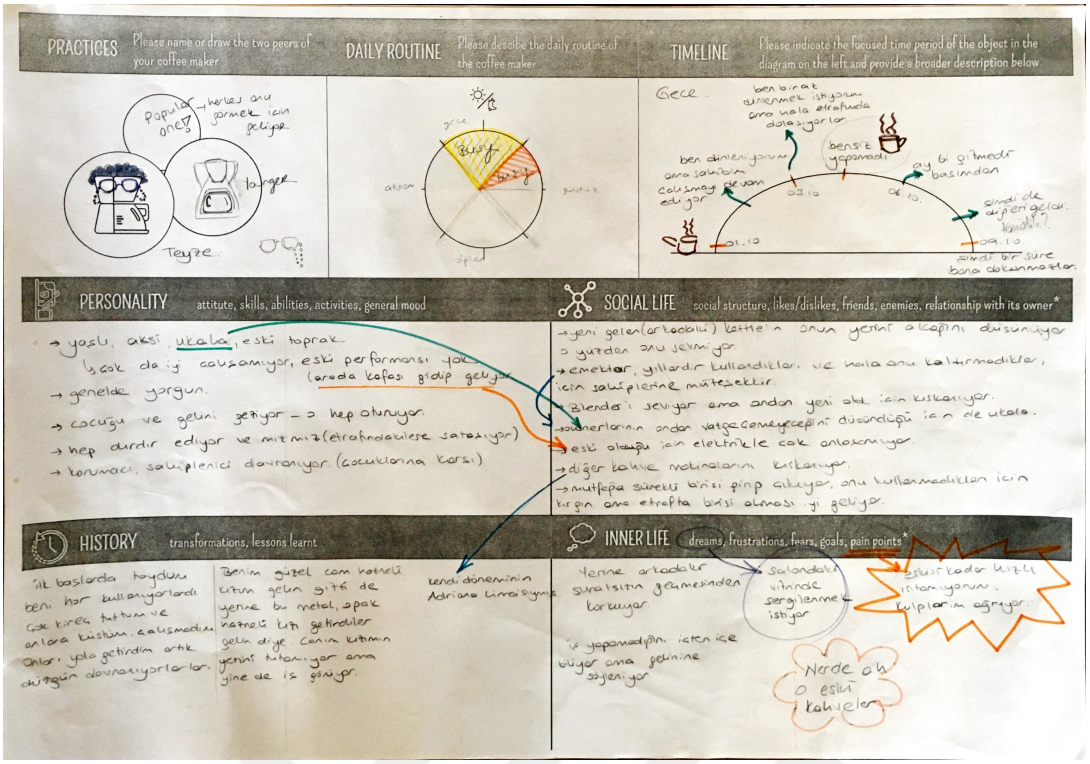


Figure B.2: Object persona board of Team 2 in Workshop 1

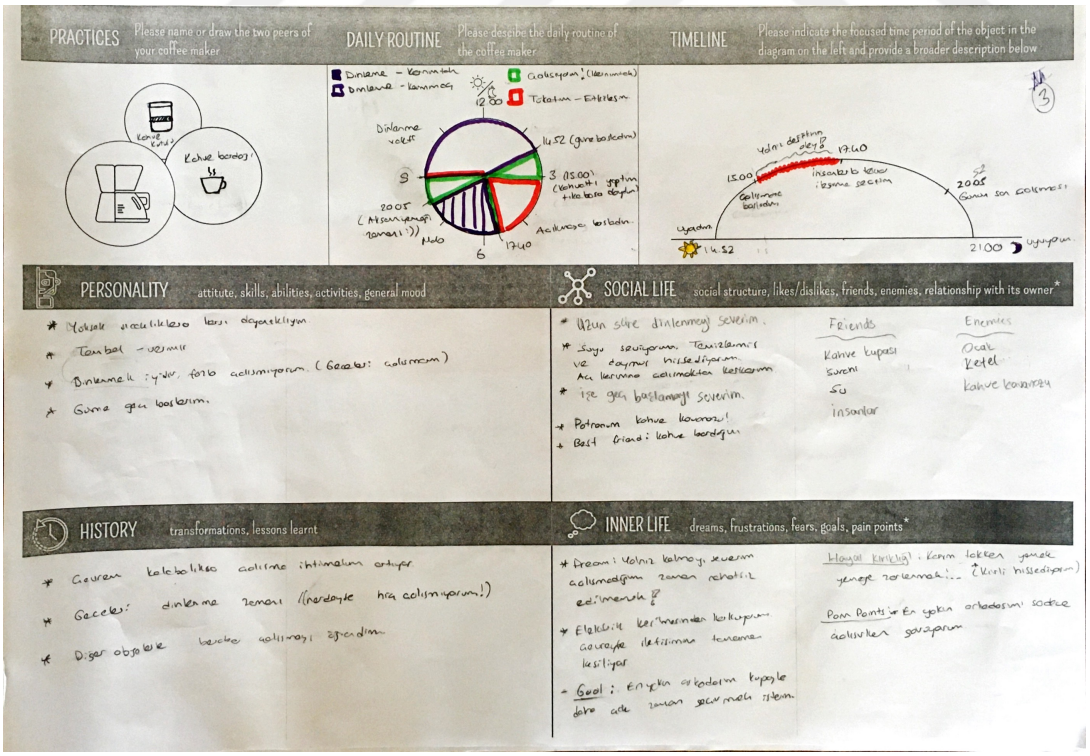


Figure B.3: Object persona board of Team 3 in Workshop 1

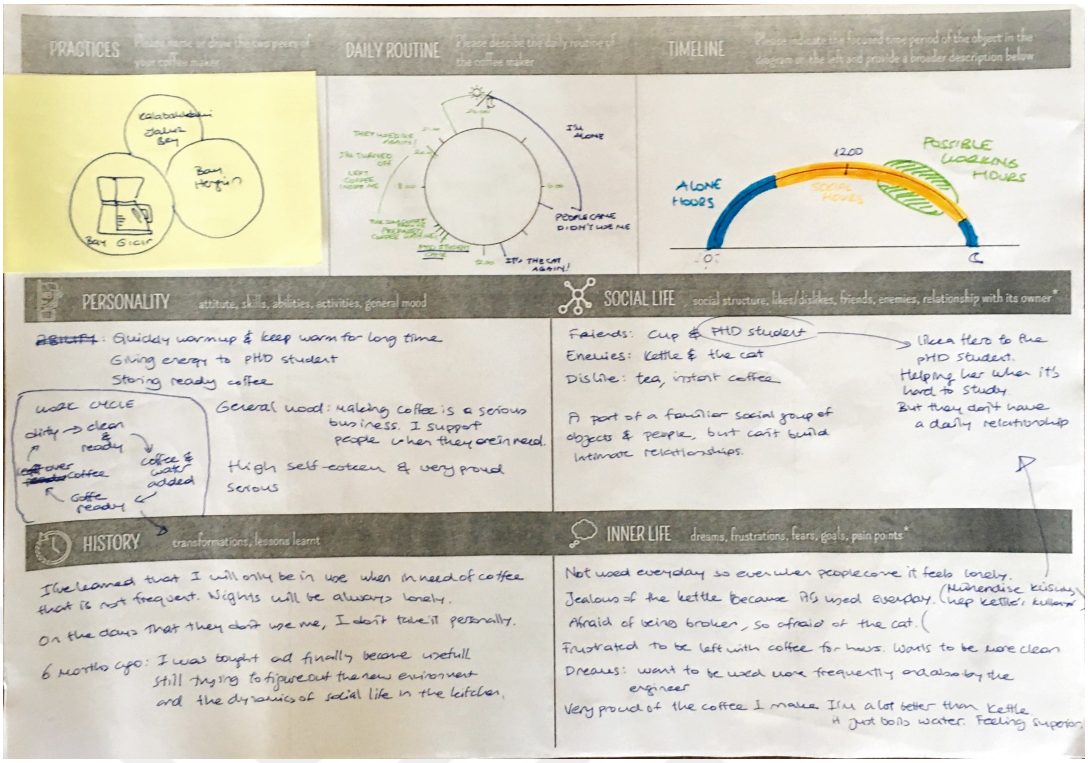


Figure B.4: Object persona board of Team 4 in Workshop 1

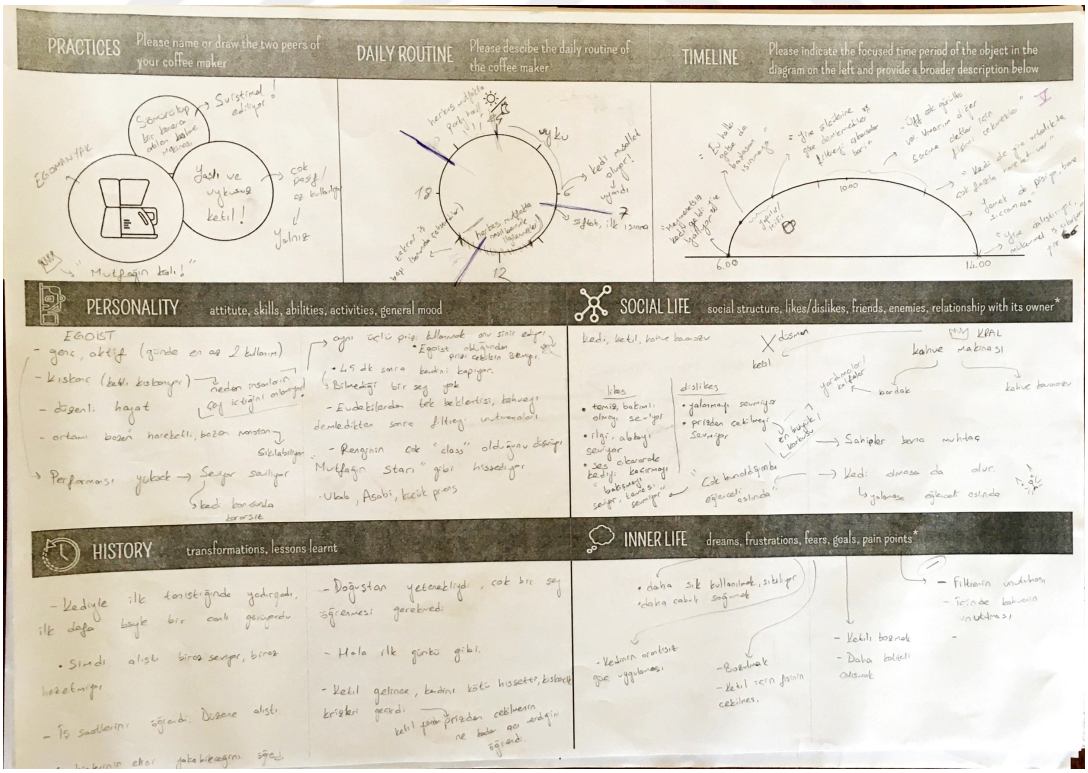


Figure B.5: Object persona board of Team 5 in Workshop 1

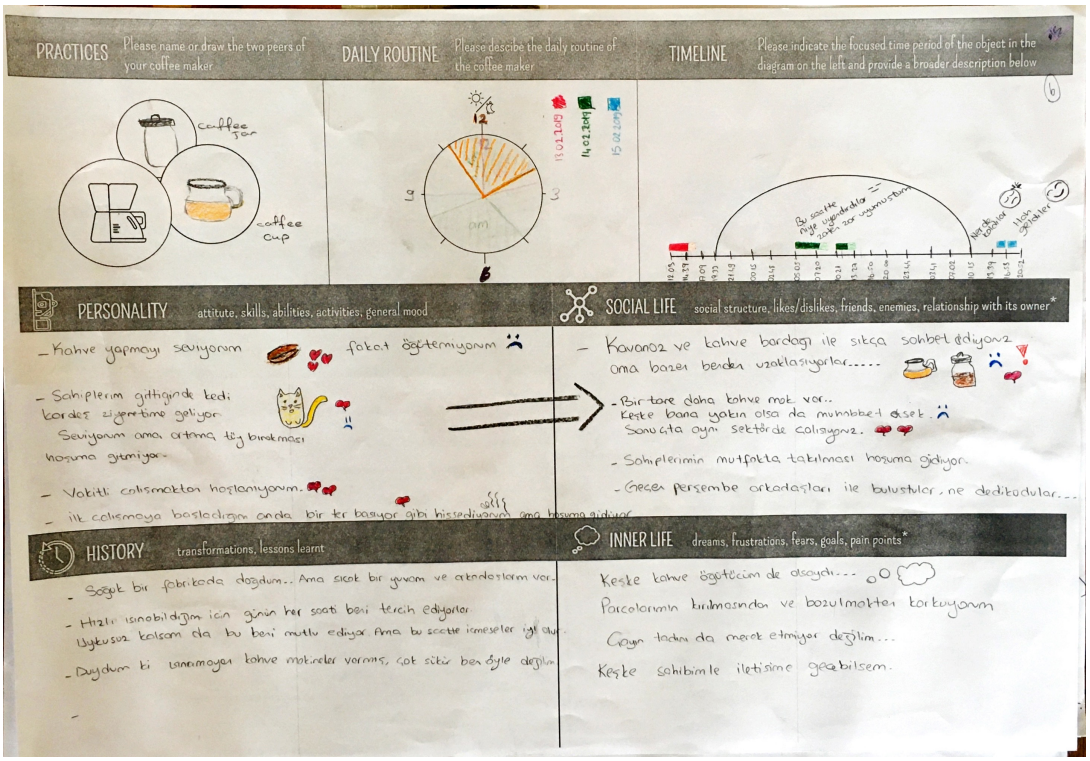


Figure B.6: Object persona board of Team 6 in Workshop 1

APPENDIX C

DATA SETS USED IN WORKSHOP 2

C.1 Data Set 1

Thursday

The temperature changes between 23 °C and 25 °C. Between around 7:00 and 8:00, it changes between 23 °C and 24 °C. Around 8:00 it increases to 24 °C and gets almost fixed there until 13:00. It switches between 24 °C and 25 °C between around 13:00-14:00, and after 14:00, it arrives back to 24 °C. At around 18:00 it begins changing between 24 °C and 23 °C. At the end of the day, the value seems to be fixed at 23 °C.

The humidity starts increasing at around noon from the value 25 to above 45 until 13:00 when the temperature starts changing. It starts decreasing gradually from then on and ends the day at the value 25, where it began.

After around 01:00, the proximity data starts varying. The variance in data is high at frequent intervals. After around 20:00, the distance stabilizes at the value where it began and maintained until 01:00.

The noise level in the environment changes between the values 300–600 until 16:00, afterwards the average decreases and the values start changing between 200–500.

Friday

The temperature continues to be at 23 °C until around 06:30. It increases to 24 °C and does not change until around 15:00. Between 15:00 and 16:30, it switches between

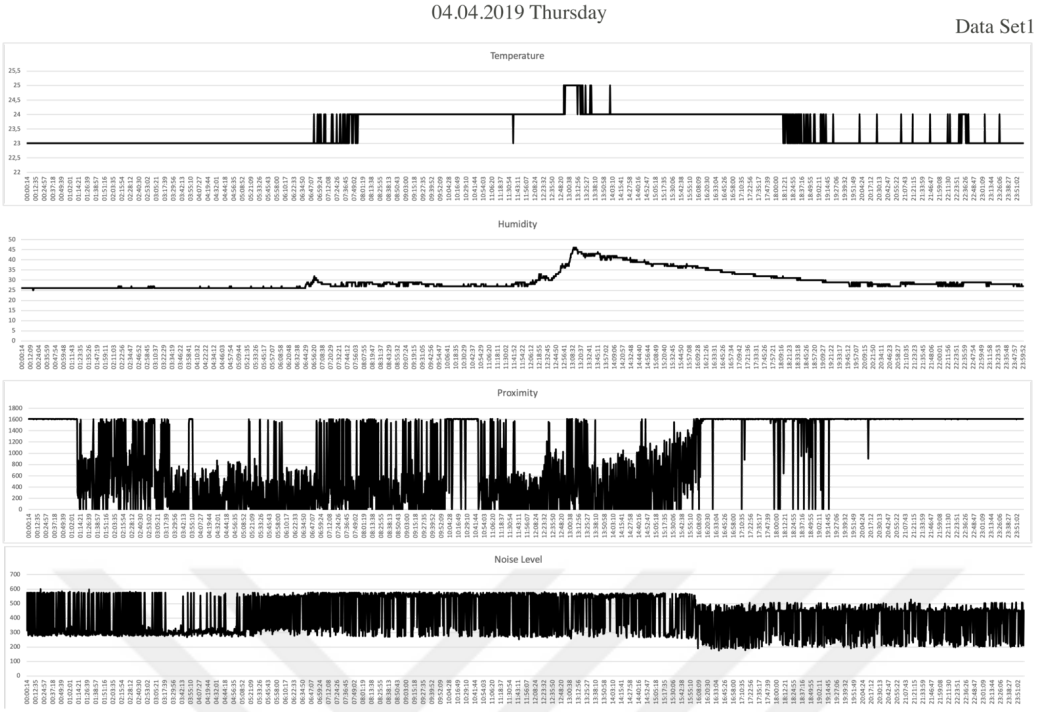


Figure C.1: Thursday—Day 1 of data set 1

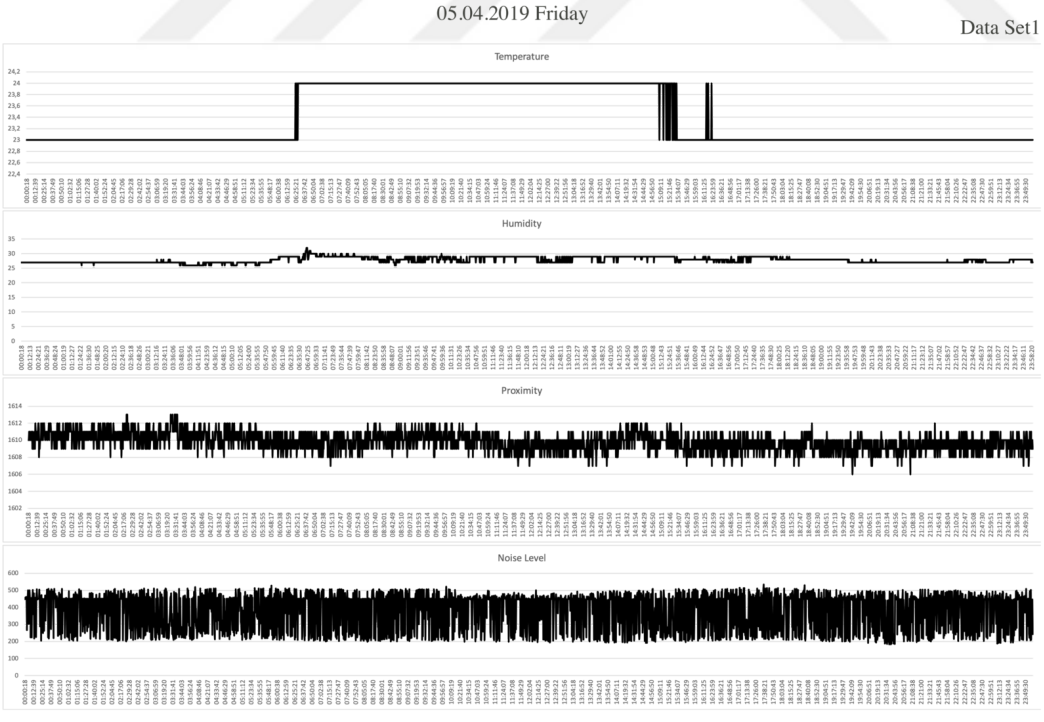


Figure C.2: Friday—Day 2 of data set 1

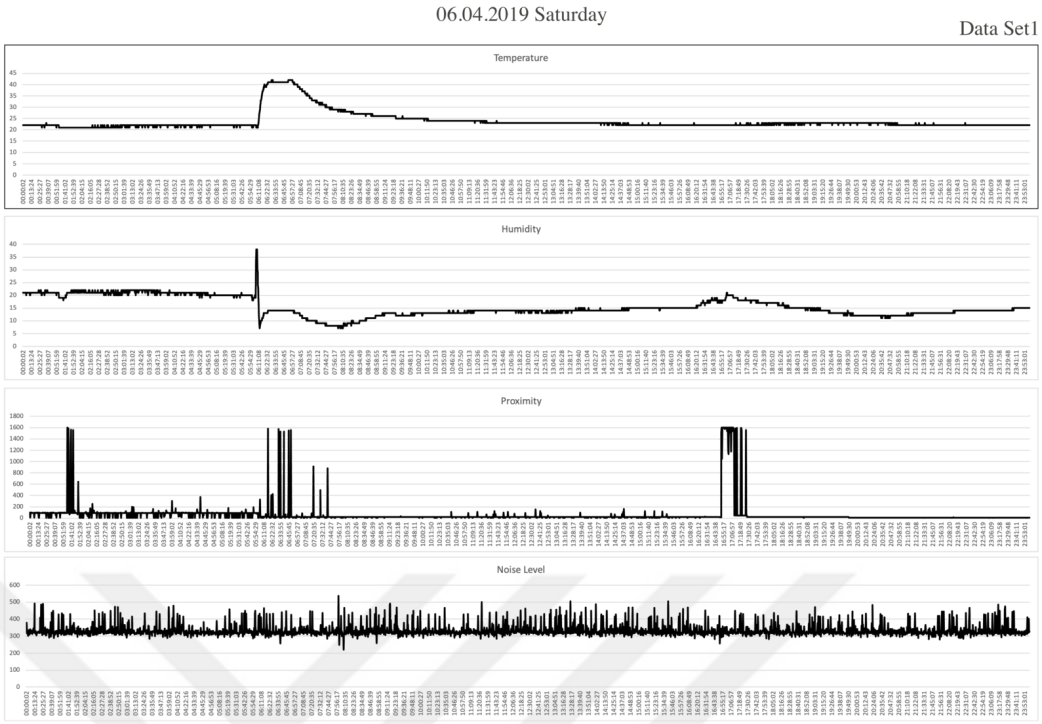


Figure C.3: Saturday—Day 3 of data set 1

24 °C and 23 °C. After that time, it stabilizes at 23 °C and maintains that value until the end of the day.

There is not a considerable change in humidity data. It is around 27 throughout the day.

The variance in proximity data is quite low when compared to the other days.

The trend in the noise level in the environment is sustained throughout this day. It changes between 200–500 constantly.

Saturday

At around 6:30, the temperature starts increasing from about 20 °C and reaches above 40 °C in half an hour. After around 07:00, the values begin to decrease gradually and go back to where it started. The day ends with a temperature of around 23 °C.

When the temperature starts increasing, there is a sudden increase and a decrease in

humidity. While the value is above 35 in a moment, it is measured as slightly above 5 in another. It increases and then decreases gradually. Differently from temperature, before it stabilizes again, the values increase to slightly below 15 at around 09:00. From then on, the humidity does not change a lot until around 16:30. It increases up to 20s first and goes below where it started within about 4 hours. The humidity data ends the day at the value of about 15.

Around 1:30, significant differences in the proximity data are observed for 10 minutes. When compared to the other days, the mean of the proximity value is lower. The changes with high variances start again when the temperature and humidity start changing. When the temperature stabilizes, the proximity stabilizes as well till around 16:30. When the humidity starts increasing, the proximity shows higher differences. It converges to 0 when the humidity stabilizes.

There is not a correlational change in noise level. There is a constant change between 200 and 500 in data.

Sunday

A continues line can be observed in the data graph of temperature at about 23 °C until 06:00. After that time, there is a gradual increase and almost symmetrical decrease in data. The temperature that the sensor measures increases up to 45 °C at around 06:30. Then, it starts decreasing. When it reaches 23 °C at around 07:00, it gets more stable until the end of the day.

When the temperature starts increasing, there is a sudden increase and then a decrease in humidity. It reaches 30 first and then is measured as above 5. It starts rising when it is slightly above 15, maintains the value for about half an hour and starts decreasing again. It gets almost the same value above 5 when the temperature stops falling, the humidity data makes a jump and reaches around 30. After that moment, it fluctuates a little, but the variance in the data is much lower.

There is a continuous line in the proximity data graphs which can be started in the previous day around 17:30 till 06:00 today. The proximity is measured almost as 0. However, when the changes begin at temperature and humidity around 06:00, the

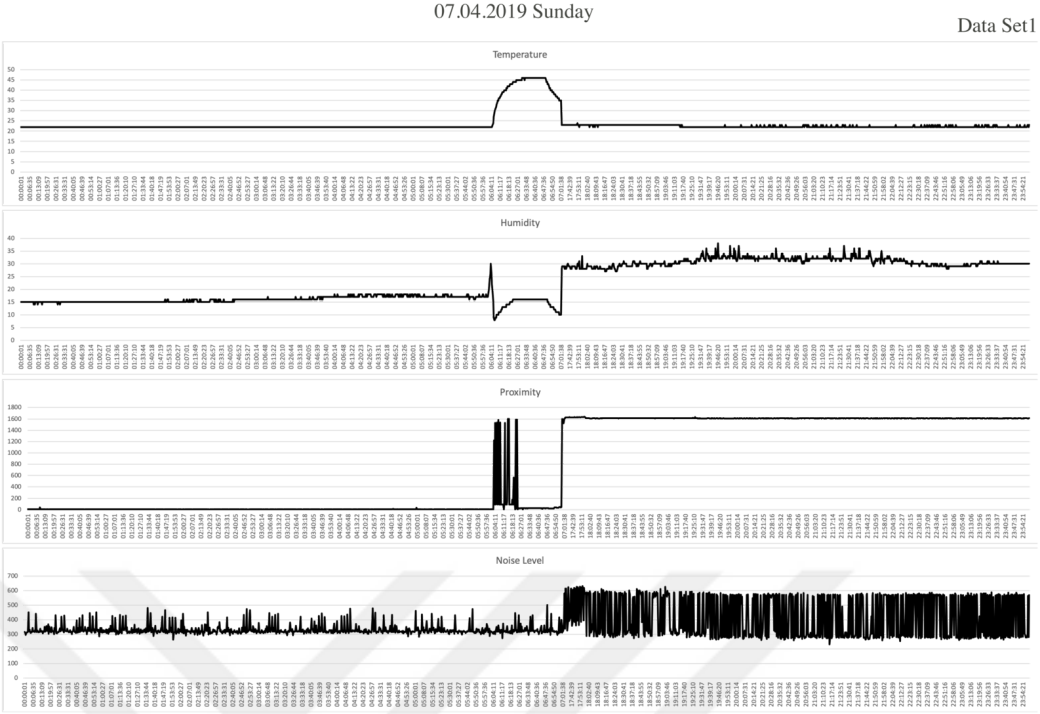


Figure C.4: Sunday—Day 4 of data set 1

proximity starts changing as well. The distance begins changing between 0 and 1600 mm until the change in temperature and humidity stop at around 07:00. Then, it stabilizes and finishes the day at about 1600 mm.

The noise level in this day has an almost constant change. However, the variance in data increases after temperature and humidity stabilize. While it changes between 300–450 before the changes start, it starts changing between below 300 and above 600.

Monday

The temperature and humidity data of today is almost the same as of Saturday. The increase in temperature starts around 7:00. At the same time, a sudden jump in humidity is observed. The second and lower increase in humidity is recorded at around 16:00.

Changes at the proximity value started to be recorded after around 7:00; values from

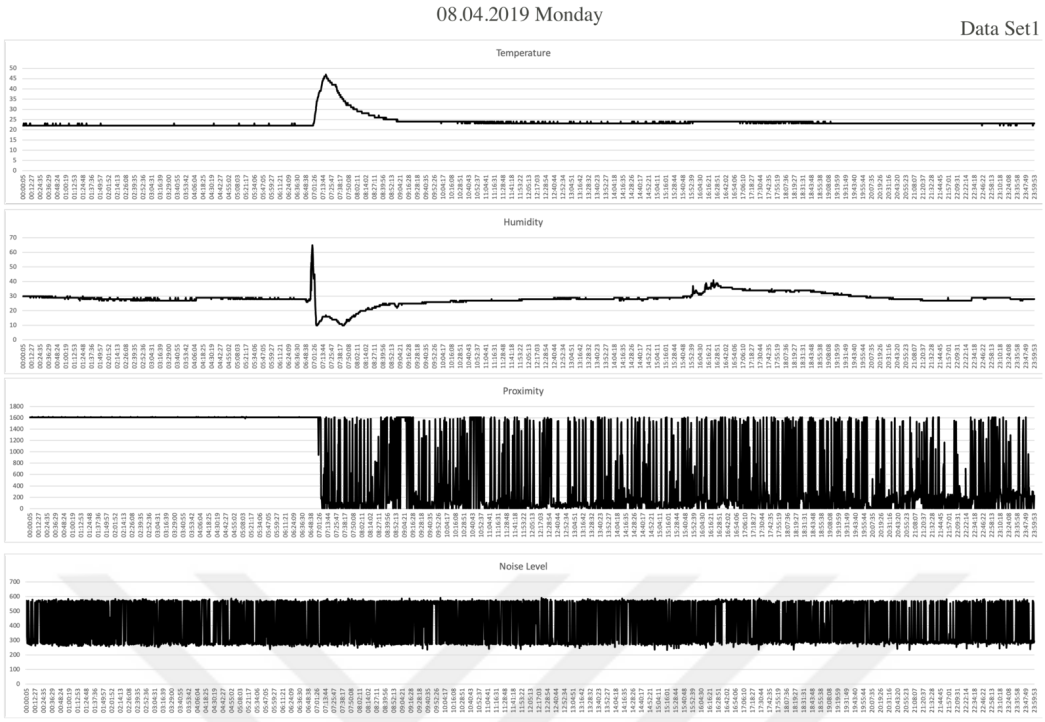


Figure C.5: Monday—Day 5 of data set 1

the previous day continues to be observed until 7:00 this day. Then, the values start changing regularly with higher variance.

There is not a considerable difference in the noise level because the data is continuously changing, almost in the upper and lower borders.

Tuesday

Tuesday data for temperature and humidity is quite similar to Saturday and Monday. The increase in temperature and relatively smaller jump up and going down in humidity occurs around 5:30 this time. One of the eye-catching differences in humidity data is that after staying stable until around noon, it gradually decreases a little bit more and then gradually increases up slightly below 35. After around 14:00, it stabilizes around the value where it started.

The constant change in the previous day continues until right after the stabilization of temperature and humidity. After the change in temperature and humidity stop, it

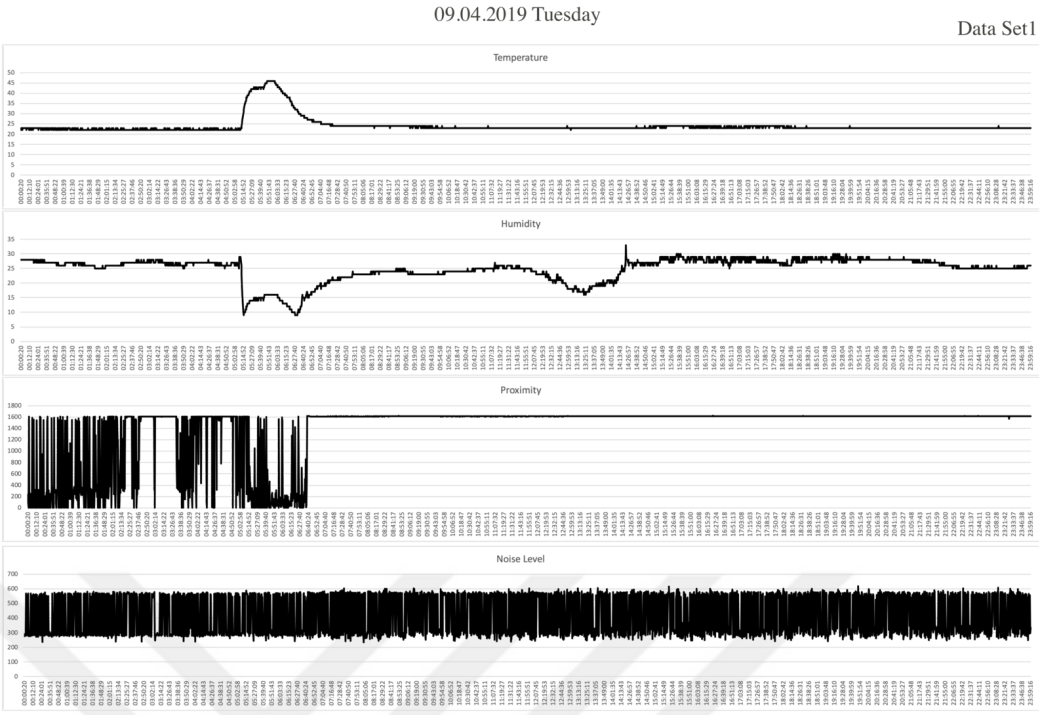


Figure C.6: Tuesday—Day 6 of data set 1

fixates on a value 1600.

Once again, there does not seem to be a considerable difference in the noise level because the data is continuously changing, almost in the upper and lower borders.

Wednesday

The temperature this day changes between 22 °C and 24 °C. Unlike other days, there is not a peak in the values. Although the temperature changes during the day, it could be said that it follows the line at 22 °C.

Just like temperature, the humidity data seems a bit different from other days; it is quite linear and changes slightly about 25. There is a momentary increase to about 40 at around 14:00, but it gets back to its almost stable route after that.

In the beginning and end of the day, the proximity data is fixed at 1600 mm. After 7:00, there starts a high variance in proximity. It starts altering between almost 0 and

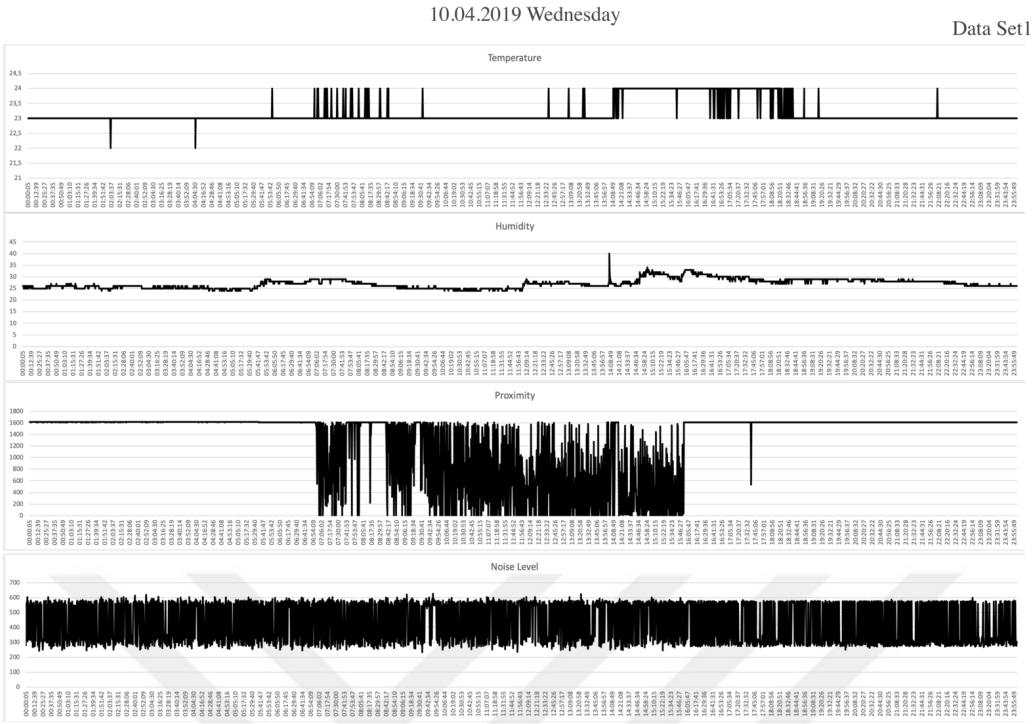


Figure C.7: Wednesday—Day 7 of data set 1

1600 mm till 16:00.

The change in noise level that starts on Sunday continues until today. The data changes between 200 and 600, and it is invariant to other data changes.

C.2 Data Set 2

Thursday

The temperature is around 23 °C, but there are two changes throughout the day. The first one starts at about 7:00 in the morning. The temperature rises until 08:30 and then starts declining until 11:00 to the degrees where it began. Then, at about noon, the values start increasing again until 13:00 and maintain the temperature at 32 °C until 16:00. It starts decreasing again and at about 20:00 it goes nearly back to the value where it began.

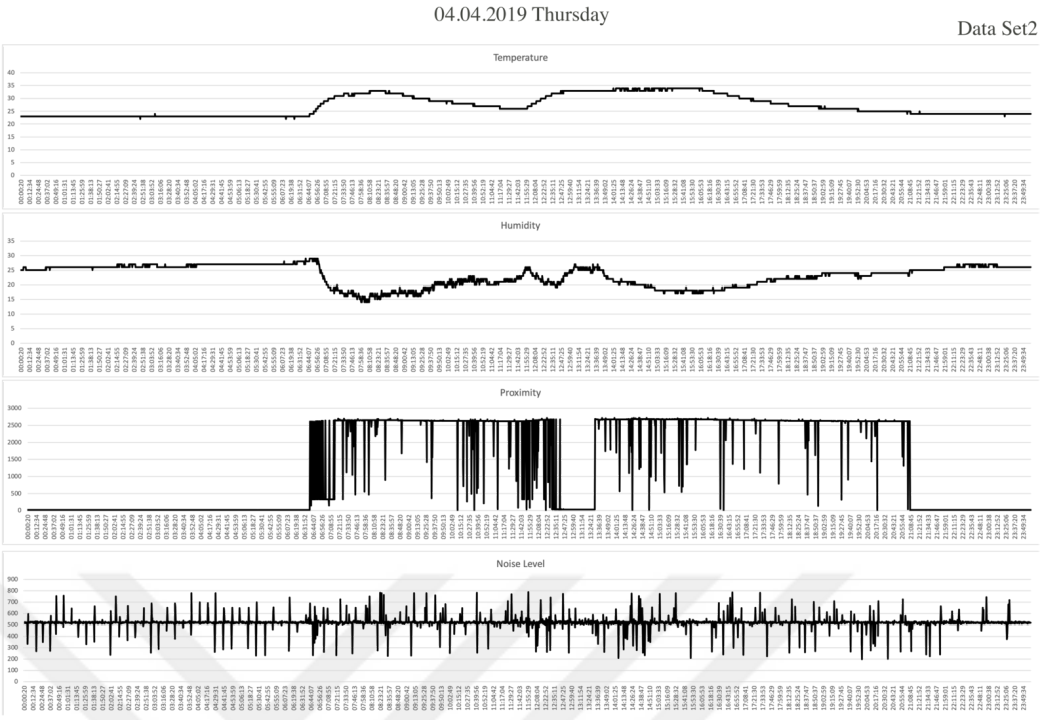


Figure C.8: Thursday—Day 1 of data set 2

There are small changes in the humidity values until where the temperature starts increasing. At that time, the humidity value starts going down, and when the temperature starts decreasing, the humidity starts rising to about 24 from 15 until when the temperature stops falling. Then again, with the temperature, the humidity value has an increase, but then it starts decreasing until 20:00 and finishes the day at a value slightly lower than where it began.

Until the changes start in temperature and humidity, the proximity is close to 0. However, with the changes in temperature and humidity, proximity value has ups and downs. Until the time that temperature and humidity stabilize, the proximity value is re-recorded as 0.

There is not an observable change in the noise level during the day. There are small ups and downs but not a peak or a change in line with other data.

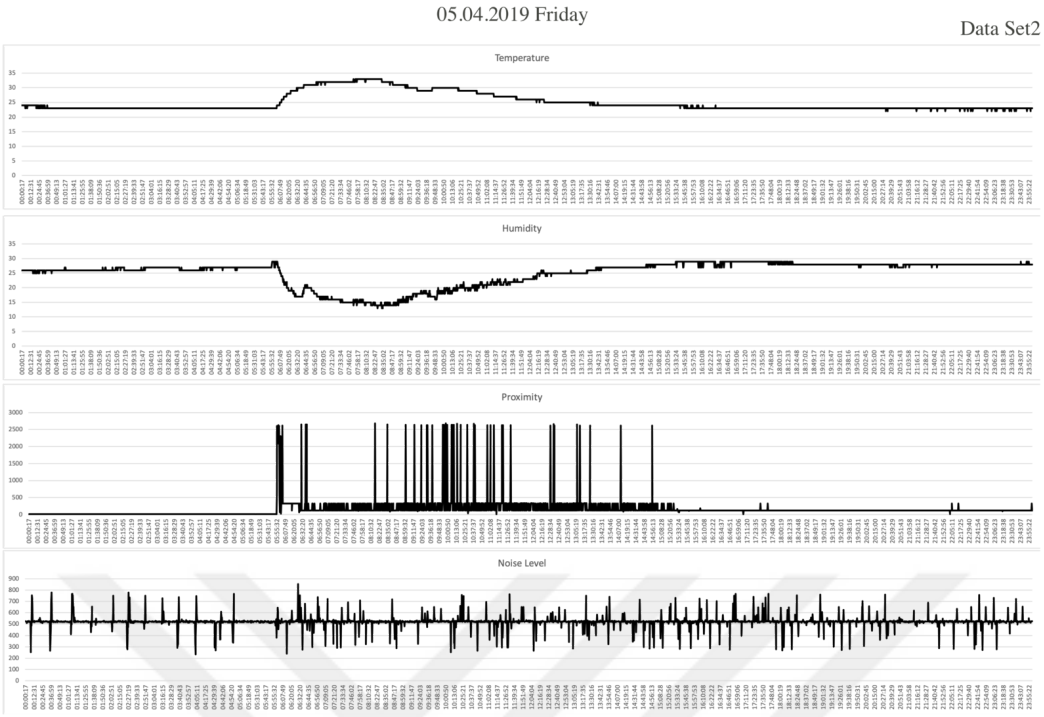


Figure C.9: Friday—Day 2 of data set 2

Friday

An increase and decrease, similar to the first day, are recorded this day as well. This time, the increase starts at about 06:30 and ends about 07:00. The temperature goes up approximately 32 °C and goes back to about 23 °C at about noon. There is not any other change other than the one between 06.30 and 12:00.

The humidity starts decreasing when the temperature starts increasing just like the first day. Again, the humidity goes back to a value slightly lower than a value where it starts at the time in line with temperature. Expectably, there is not any other considerable change in humidity data.

The proximity value starts and ends at about 0. At the time of change starts in temperature and humidity, the proximity starts fluctuating.

There is not an observable change in the noise level during the day. There are small ups and downs but not a peak or a change in line with other data.

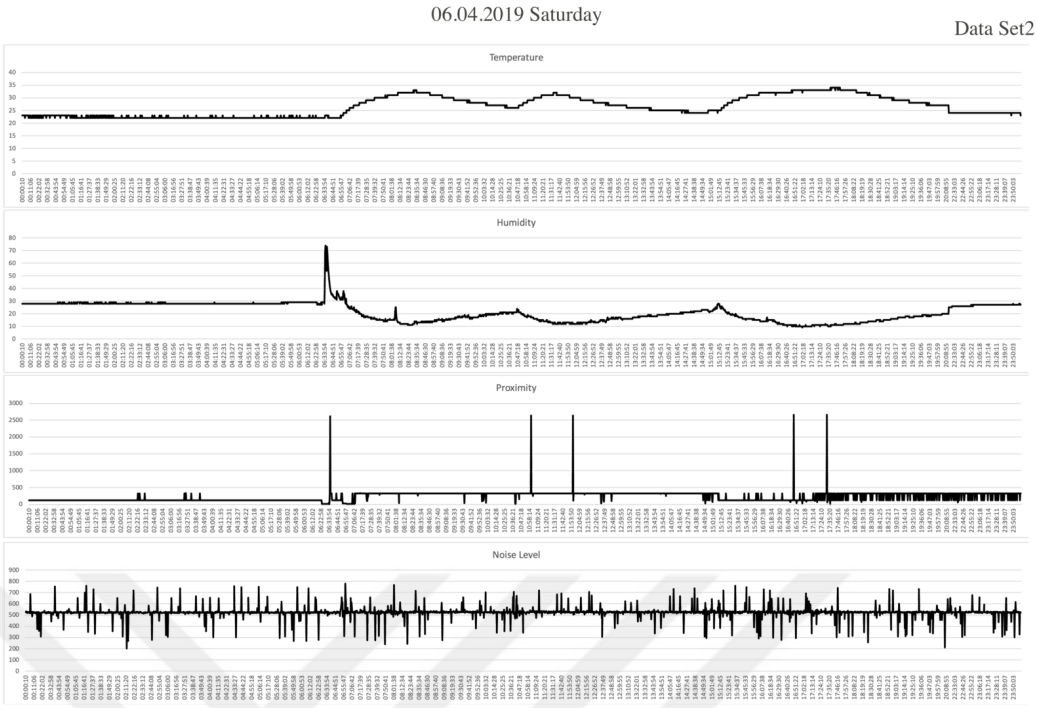


Figure C.10: Saturday—Day 3 of data set 2

Saturday

The temperature starts increasing at about 7:00 in the morning from 23 °C until 30 degrees at about 08:30. Then, it starts decreasing until 10:30 till it reaches 26 °C. After that time, it starts increasing until 11:30. At about 15:30, the increase starts again and lasts until 18:00. The max value it gets is almost the same in all the cases. At about 22:30, the temperature reaches about 19 °C, or in other words, a value below the starting point, and then stabilizes.

When the temperature starts increasing at 7:00, there seems a sudden increase in the humidity. From early in the morning, until that time the value that was about 29, reaches up 70 and drops until 10 with small fluctuations till the temperature stops decreasing. When the temperature starts rising again, there is a short leap then decrease starts but at a slower pace. When the temperature reaches its max in the last increase-decrease spin, the humidity reaches its minimum, which is slightly below 10 and starts increasing slowly. When the value hits about 29 again when the temperature

stabilizes, it stabilizes as well.

At about 2:30 and 3:30, there are momentary changes in the proximity. Besides those, the value is fixed until when the temperature starts changing and humidity gets its max at about 7:00. That is when the proximity almost gets to the value 0. Right after that, there is a peak that reaches 2500 mm for a moment and for about an hour, there are small changes in the data. The value hits to 0 when the temperature is maximum, and humidity is minimum. There are momentary approximation and secession to the value 0 until the max value of the last loop of temperature. When the temperature stops decreasing and humidity stops increasing at about 10:30, 0 value is acquired followed by a peak, and the same cycle happens again when the temperature reaches its max and humidity reaches its min at about 11:30. At bout 15:30, when the temperature starts increasing again, the proximity value starts changing at quite frequent intervals.

The noise level is quite unstable during the day, and the changes are invariant to the other data. The values are changing between 200 and 800.

Sunday

On this day, the only considerable change in the temperature starts happening at about 10:00. It increases until about 11:30 and reaches about 29 °C. Then, it starts decreasing. At about 16:30 it stabilizes and reaches the value 23 °C as it has begun.

The humidity this day is not as stable as temperature. There are small changes in the data. The most eye-catching change happens when the temperature starts increasing. It starts decreasing from the 30s and reaches its minimum of 15 when the temperature gets its maximum. Then it starts rising in correlation with the temperature. When the temperature stabilizes, the humidity stabilizes as well, at the value around 30.

The proximity data is quite indecisive again. After about 5:30 in the morning, the high range changes start. The more stable and closer to 0 values collected at the same time when the temperature and humidity changes.

Like the previous day, the noise level is quite unstable during the day. The changes

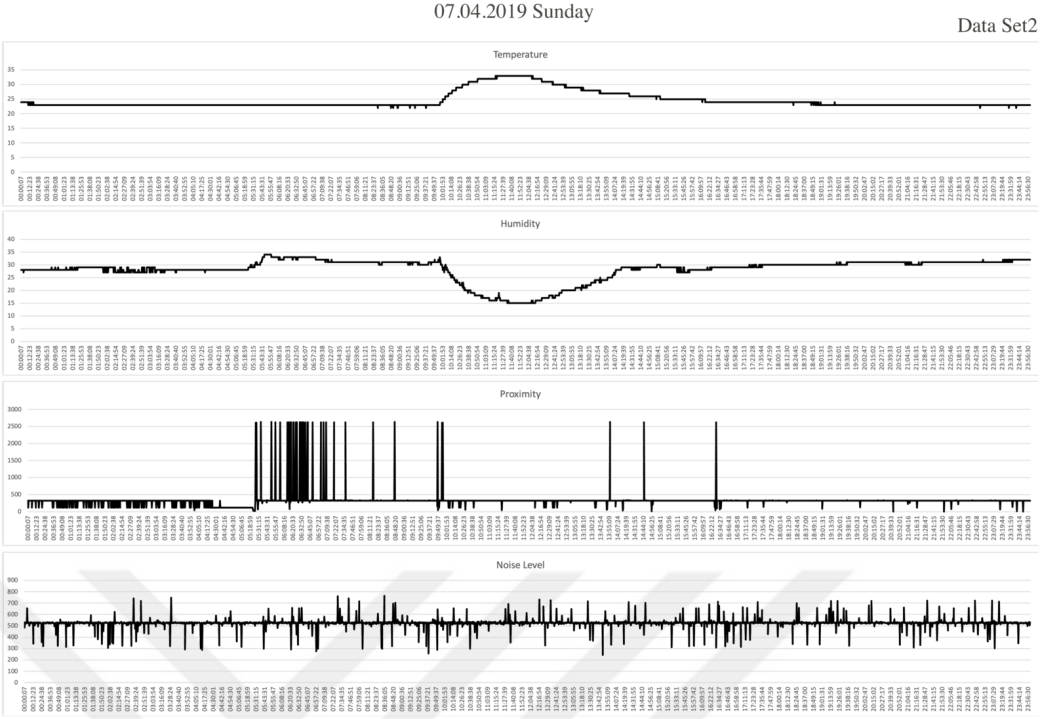


Figure C.11: Sunday—Day 4 of data set 2

are not correlated with the other data. However, the overall noise is lower, and the values are changing between 200 and 700.

Monday

The temperature starts increasing at about 6:00, and when it reaches about 35 °C at around 08:30, it stabilizes until about 11:30. After that time, it starts decreasing to 25 °C at around 14:00. Around 15:30, there seems to be another increase in the values, but this time until 30 °C. It reaches about 30 °C at around 16:30 and starts decreasing until about 20:00. Then, it stabilizes on the value where it began around 23 °C.

The humidity is around 30 when the temperature is stable. It starts changing with the temperature around 06:00 and goes back to the same values around 20:00. When the temperature starts increasing, the humidity starts decreasing and gets to a value of about 20. When the temperature starts falling, the humidity gets a bit lower first and reaches approximately 15, then starts increasing until 35 at around 15:30. It is

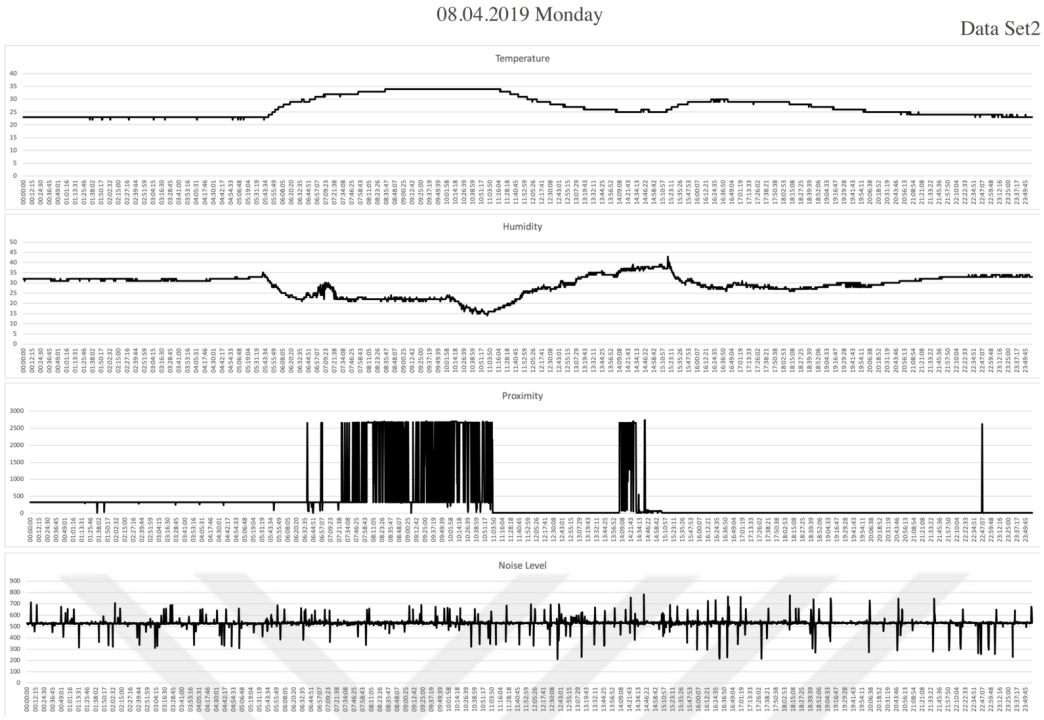


Figure C.12: Monday—Day 5 of data set 2

the time when the temperature stops decreasing. Right after this peak, it starts falling by the time the temperature starts rising again and reaches the value where it began, and stabilizes with temperature.

The distance gets the value 0 at about 1:30 then, gets fixed until the time when temperature and humidity changes. Until the temperature starts going down for the first time around 11:30 and humidity starts going up, the distance is fixed at 0 and has some changes between 14:00 – 15:00. After that time, the temperature starts rising, and the humidity starts falling again. Independently of the other changes in temperature and humidity, after that time, the distance is fixed at 0.

The noise level is again quite unstable during the day, and the changes do not correlate with the other data. The values are changing between 200 and 700.

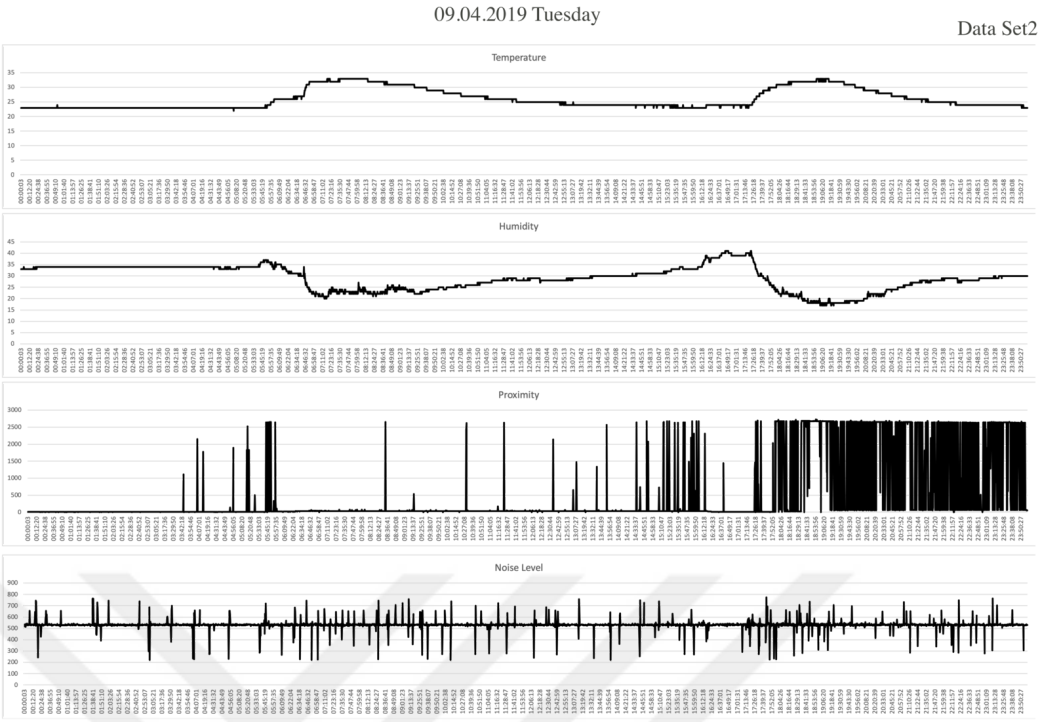


Figure C.13: Tuesday—Day 6 of data set 2

Tuesday

The temperature starts increasing around 6:00 and reaches 30 °C around 7:30. It starts decreasing until 13:00 and stabilizes at the value where it started, around 23 °C. At around 17:30, the temperature starts increasing again; it reaches about 30 °C at 19:00 and starts decreasing. When the temperature reaches the value where it started, it gets fixed.

Like it was expected, the humidity starts changing when the temperature changes. It starts around the value 35 and reaches about 20 when the temperature is maximum. It starts increasing while the temperature is decreasing. When the temperature starts rising again around 17:30, the humidity value is around 40 and starts falling from there. It stabilizes with the temperature around the value 25, which is slightly below where it began.

The proximity data continues from the previous day, from value 0 and gets different values around 4:00. It starts changing when the temperature and humidity start

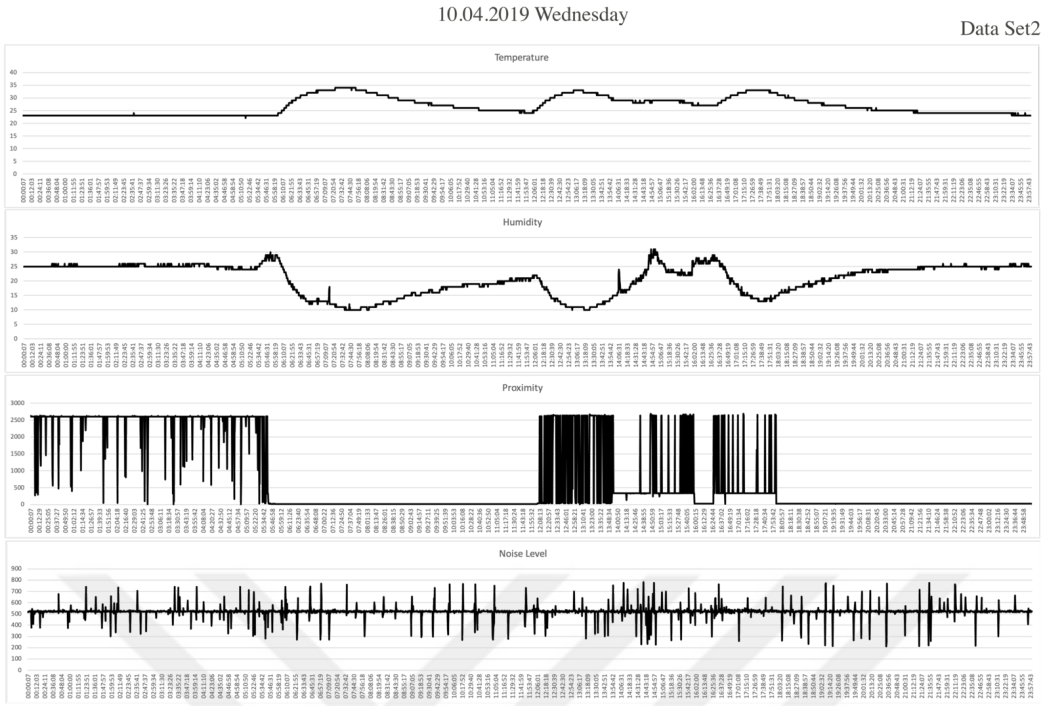


Figure C.14: Wednesday—Day 7 of data set 2

changing. After that time, it barely gets fixed. It continues changing the value until the end of the day. Towards the end of the day, the frequency of the ups and downs increase.

The noise level is again quite unstable during the day. There is no correlated change with the other data. The values are changing between 200 and 700.

Wednesday

There are three hills in the temperature data that day. The first one starts around 06:00 from about 23 °C, reaches the peak, 35 °C around 07:30 and decreases until about 24 °C at noon. A similar cycle starts at that time. It reaches the peak, about 29 °C in one and a half hour, starts decreasing until around 16:30 to 27 °C and starts increasing again. It reaches the peak of this cycle, about 29 °C at around 18:00 and starts decreasing and stabilizes at about 23 °C around 21:00.

Not surprisingly, the humidity follows the temperature and starts changing around

06:00. It increases a bit from 24 to 30 and starts decreasing until 10 when the temperature hits the peak of that cycle. It increases from that point until about 20 when the temperature starts rising again. The humidity value starts decreasing until the temperature hits the peak of that cycle and gets back to 10. From that point, it gets off the trend and starts increasing while the temperature is stable. Between 13:30 and 15:00, the humidity increases and hits above 30. It fluctuates between 15:00–17:30 and starts following the temperature again. It gets lower when the temperature starts increasing. It gets to the lowest of this cycle, around the value 15 when the temperature reaches the peak of that cycle. Then, it rises from that point and stabilizes with the temperature at about 25, where it started around 21:00.

The ups and downs in the previous day continue this day as well until when the temperature and humidity changes. It is fixed at the value around 0 until the start of the second cycle. It fluctuates until the end of the changes in temperature and humidity. It stabilizes at the value 0.

Just like in the other days, the noise level is again quite unstable during the day. There is no correlated change with the other data. The values are changing between 200 and 700.

C.3 Data Set 3

Thursday

There were small differences in temperature data which can be explained by the temperature changes in the environment.

Humidity fluctuates a little during the day, but there is an increase during the evening hours (19:30–21:00).

Proximity increases and decreases momentarily during the day except early in the morning (07:00–10:00) and from the afternoon (13:00) till evening (19:30). The fluctuation begins again when humidity increases.

The noise level is almost stable during the day except when proximity is stable in the

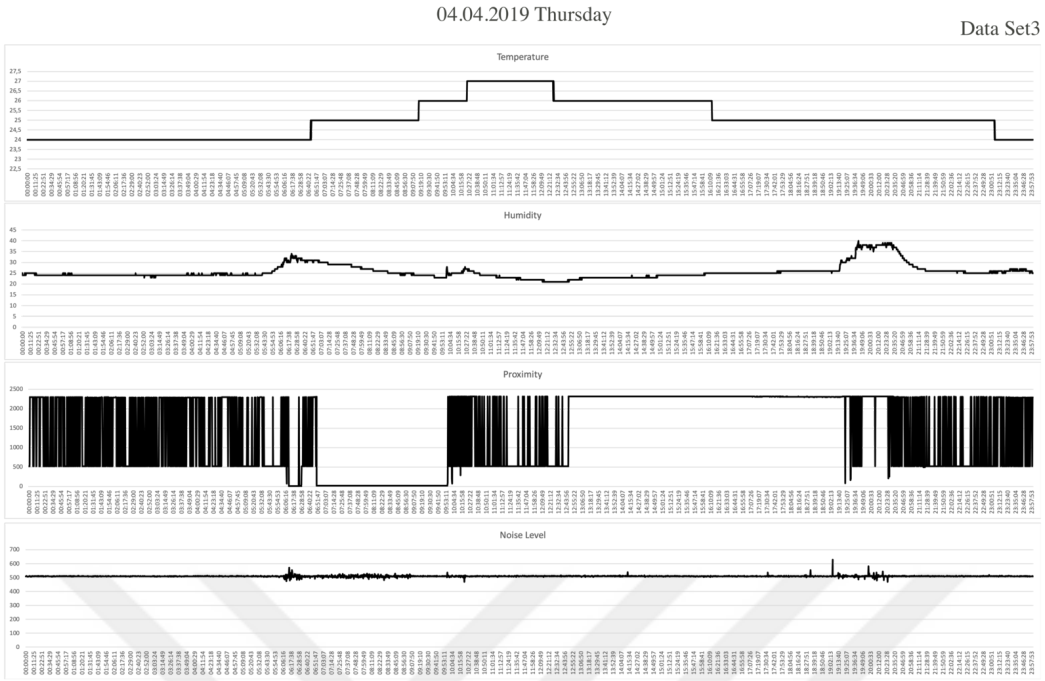


Figure C.15: Thursday—Day 1 of data set 3

morning and when the humidity is increasing.

Friday

For today, there are two peaks for the temperature at about 11:00 and 16:00. In those moments, there is a sudden increase in temperature. It rises from about 24 °C up until 60 °C. After the first jump, it maintains its value for a while and drops back in about an hour, but after the second peak, the temperature goes down in about 40 minutes.

When the temperature starts increasing, the humidity starts decreasing at about 11:00 and again, it goes back to the value before it drops when the temperature goes back to the value before it rises. However, the same trend does not apply in the second peak of the temperature. This time, again in the same hours, the humidity increases with temperature first and then, drops below the value where it started.

The proximity starts fluctuating after 7:00 in the morning and stops at 22:30.

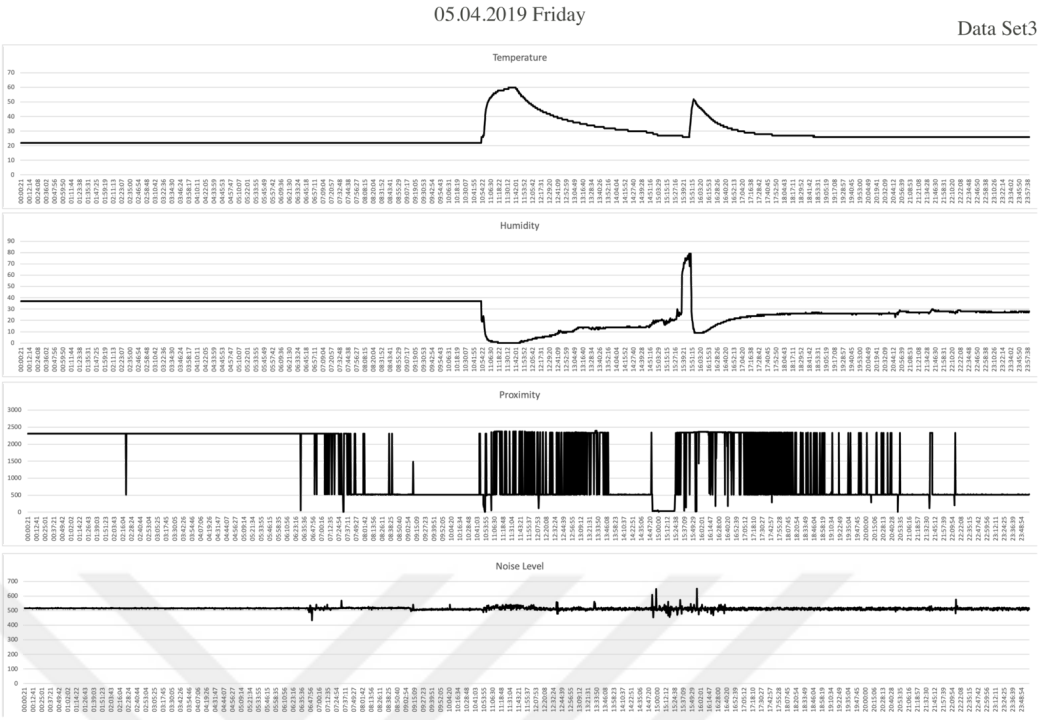


Figure C.16: Friday—Day 2 of data set 3

A slight change is seen in the noise level at the time where proximity starts fluctuating, and a bit more considerable change was seen where temperature and humidity increase at about 16:00.

Saturday

Today, there is not a considerable change in the temperature until noon. At noon, the temperature suddenly increases and then drops and gets to where it was within about an hour.

There are small changes in humidity between about 7:00 and 11:00. Then, there is a sudden increase and right after a decrease in humidity values. The value goes back to the average again when the temperature stabilizes.

In proximity, there are a lot of ups and downs between 07:00–16:00. Other than these, the value points are rather away from being something close.

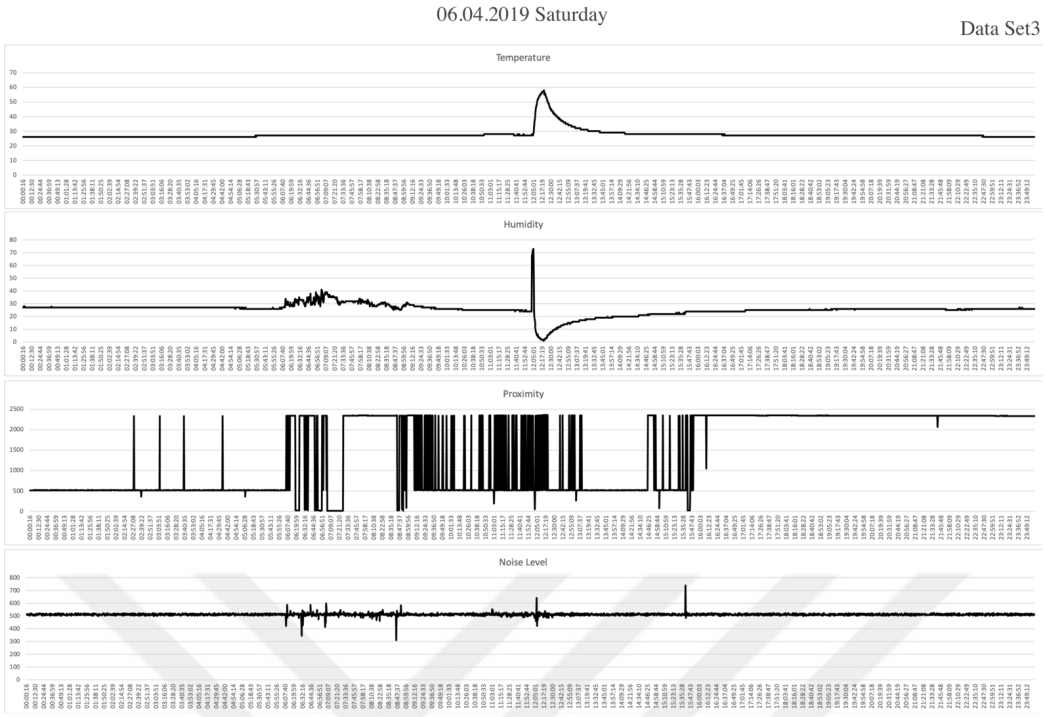


Figure C.17: Saturday—Day 3 of data set 3

The noise level starts fluctuating with proximity. There are a lot of changes, mainly when the humidity level changes.

Sunday

There is a sudden increase in the temperature value at about 06:30. It drops back at about an hour and a half.

In humidity, there is a jump high when the temperature starts changing. Just like in the other days, after a jump high, there is a drop-down in the value. Then it rises back to the value that it started within the same amount of time that temperature goes back. In addition to this, there are rather small changes in the values at about 16:30.

Proximity values are rather low when compared to other days. There are highs and lows in parallel with the changes in humidity. Additionally, there is a fluctuation in the data at about 1:40, which lasts for about 10 minutes.

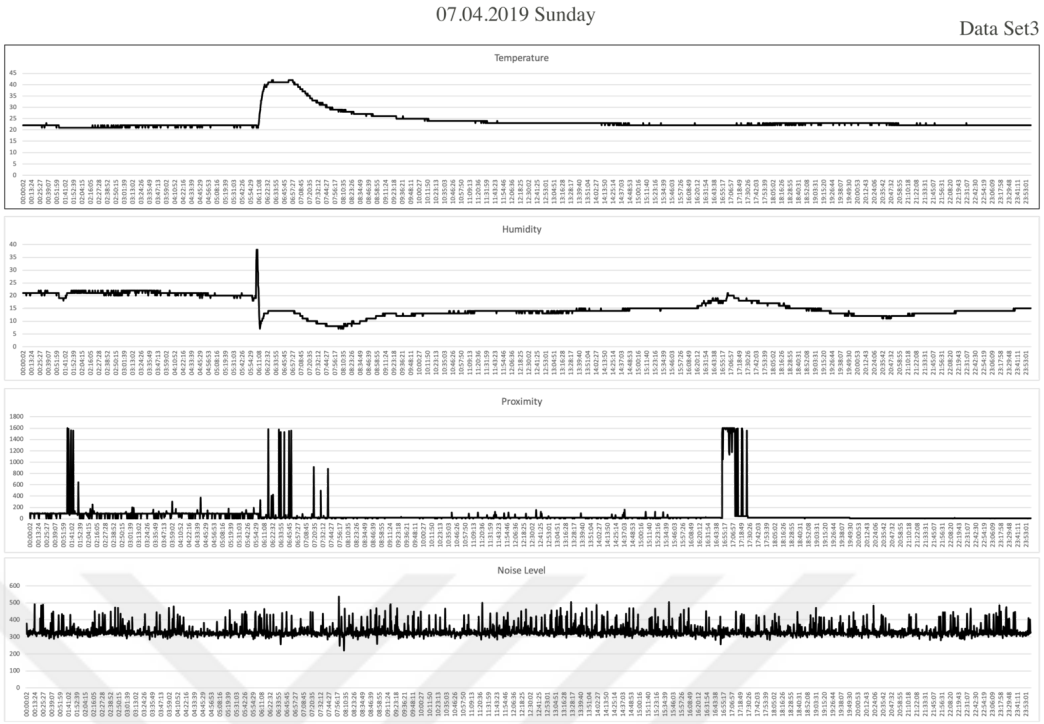


Figure C.18: Sunday—Day 4 of data set 3

For noise data, it is the quietest day of the week. There is not a considerable peak.

Monday

There is a sudden rise in the temperature value at about 5:00 in the morning, and it goes back to the almost same value where it started rising within one and a half hours.

When the temperature starts increasing, there is a small jump high and then a drop. It stabilizes when the temperature stabilizes as well. Moreover, after about 17:00 the values start fluctuating until 22:00.

There is not a clear-cut trend in the proximity data. However, by the time that humidity fluctuates, the proximity is changing a lot. In addition to the changes by the humidity, between 9:00 and 12:30, there are also ups and downs in the data.

There are small changes in the noise level when the temperature starts changing. After that, there are fluctuations when the humidity level changes.

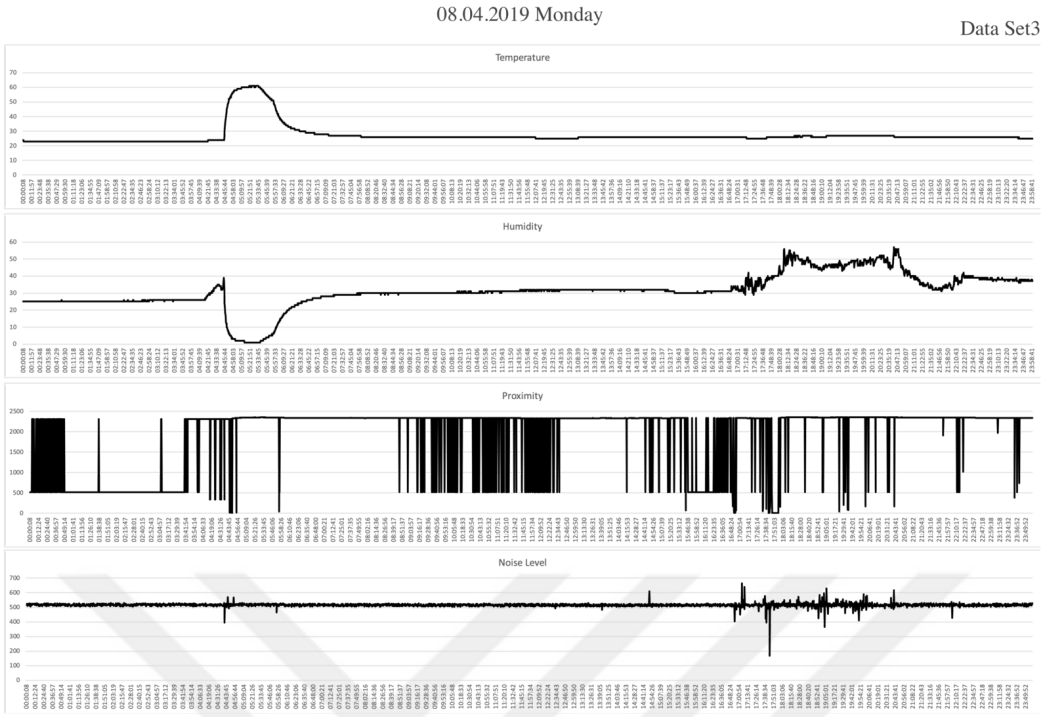


Figure C.19: Monday—Day 5 of data set 3

Tuesday

There is a sudden increase in the temperature data at about 5:30 in the morning. It goes back to where it starts at in about one and a half-hour. There is no change in the temperature other than this one.

Parallel to the temperature, humidity goes up and down and then back to where it started in line with temperature. In addition to this, before 05:00 and between 09:00 and 10:30, there are small changes. Moreover, there is a gradual increase and then decrease in the values between 17:00 and 19:00.

Proximity fluctuates until 4:00 in the morning. It reaches almost 0 when the humidity considerably changes; the first one at 09:30 and the second one at 17:00. Other times it seems to be stable.

Noise level changes a lot between 09:30 and 17:00–17:30. At those times, the proximity is quite low, and there are small changes in the humidity but no change in

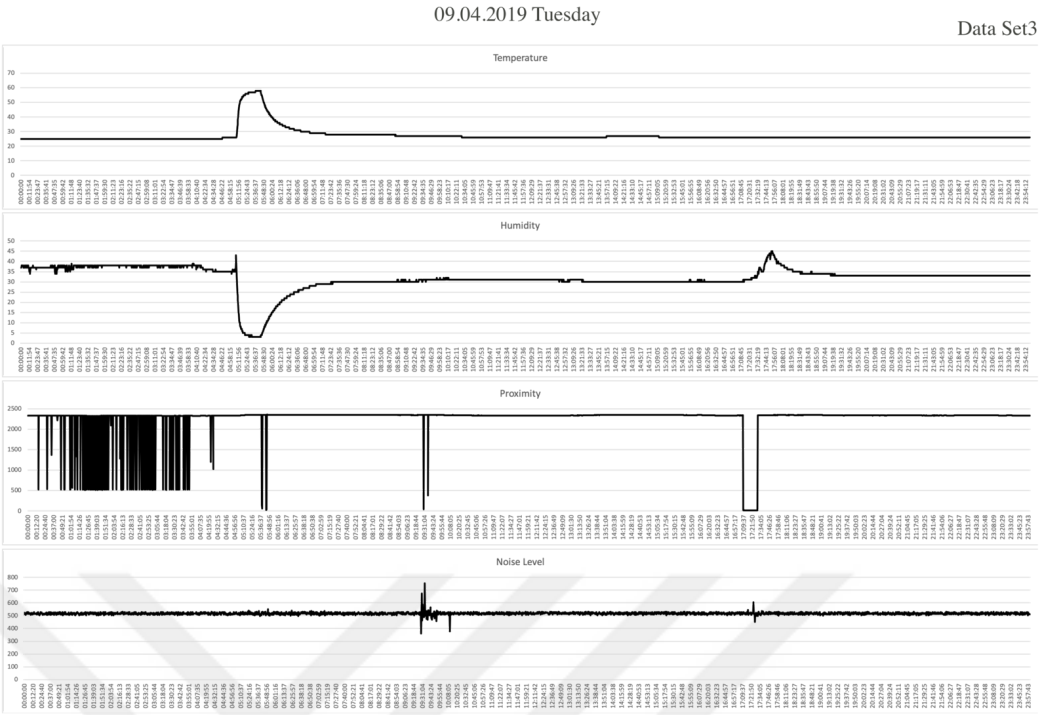


Figure C.20: Tuesday—Day 6 of data set 3

temperature.

Wednesday

In the last day of one-week time, the temperature shows a similar change. It starts increasing at about 5:00 and cools down at 06:30. There is no other change in the data.

Again, at about the same times, the humidity rises and drops suddenly. It gets back to where it started with temperature again about 06:30. Additionally, there are small changes in the values between 10:30 and 13:30 and at about 19:30.

The proximity fluctuates after 5:00 in the morning, but it approximates to 0 when there is a change in the humidity.

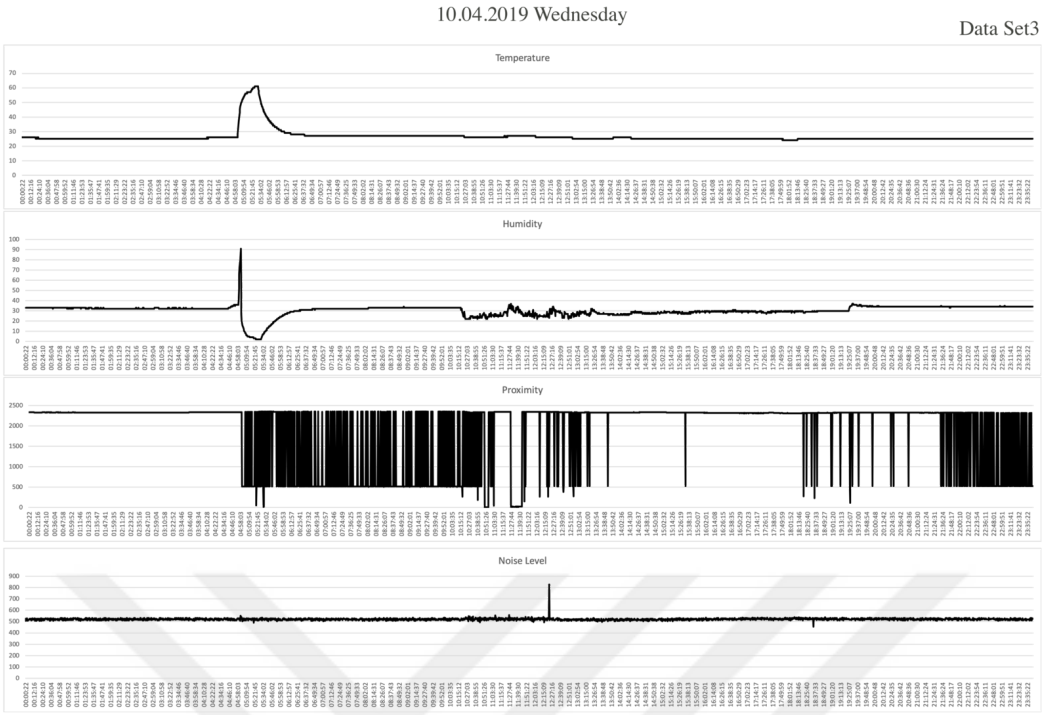


Figure C.21: Wednesday—Day 7 of data set 3

C.4 Data Set 4

Thursday

The temperature and humidity do not change throughout the whole day. The temperature is fixed at 22 °C, and humidity is constant and 37.

Before 7:00, the proximity data is almost fixed. There are increases and decreases in proximity between around 7:00 and 8:00 in the morning. Between those times, the values change between nearly 0 and 1600 mm. Then, until about 19:30, the proximity level is around 300 mm like it was in the morning. After that time, changes occur between almost 0 and 400 for about 10 minutes, but later, the values vary between 600–1600 mm until midnight.

While noise level wave between 20–50 band until around 6:00 in the morning, it starts oscillating in a broader range after that time until 21:00. After 9:00 and until 21:00 it can be said that the variance is lower than before. The same trend continues until

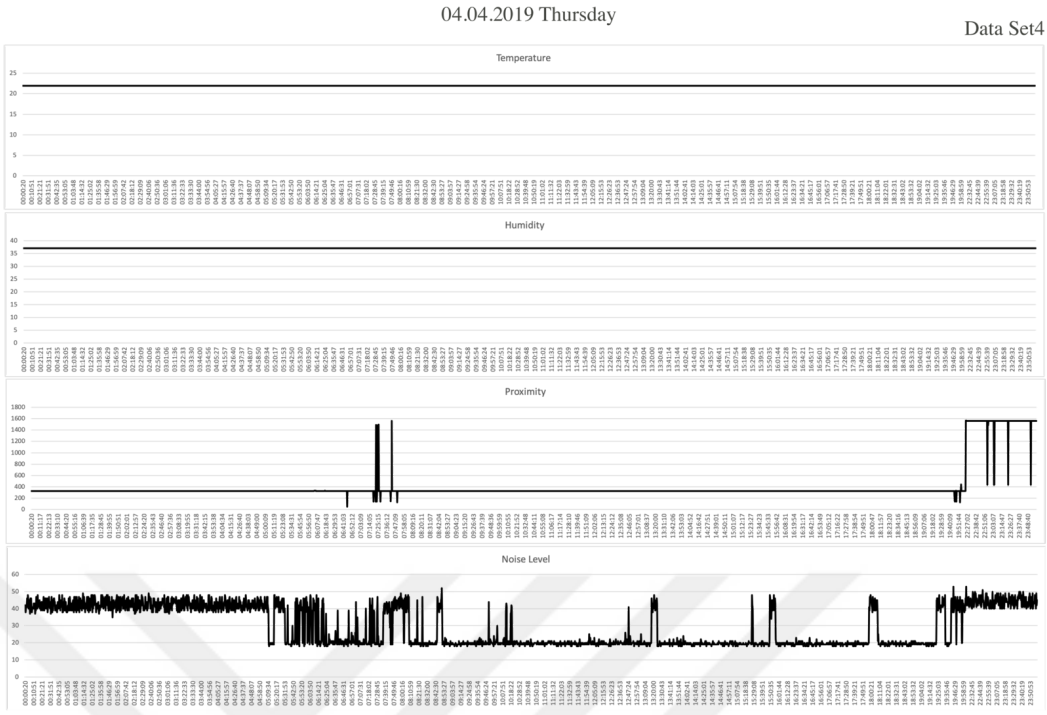


Figure C.22: Thursday—Day 1 of data set 4

6:00 can be seen from 21:00 until midnight.

Friday

The temperature increases slowly during the day. It starts the day with the value 21 °C, but it gradually increases and measured as 24 °C at 18:00. After that time, the increase rises its pace and reaches 43 °C at around 19:30. It is the peak of the whole day. It slightly decreases until 20:00 and maintains the temperature around 35 °C about 15 minutes. Then it increases a little bit more but cannot reach the peak again. At around 20:30, the increase stops, and it starts to decrease. After that, it falls until the end of the day and finishes the day at almost the same value it has at the beginning of the day.

The same comments can be made for humidity as well. It slowly increases during the day until 18:00. Then, it reaches the highest degree in about 15 minutes which is recorded as 69. Then, it starts decreasing. At around 19:30, the decrease gets faster,

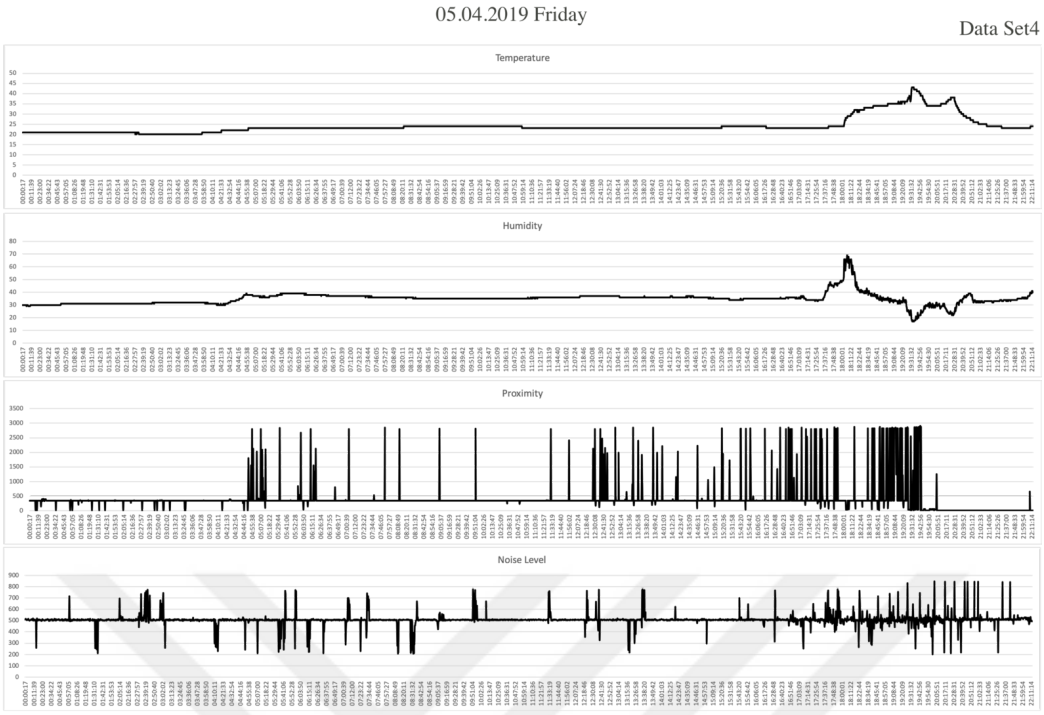


Figure C.23: Friday—Day 2 of data set 4

and the lowest value is recorded as 17. As the temperature starts falling, the humidity increases a bit, maintain the value and increases a bit more. When the increase stops in temperature, the humidity stops fluctuating and gets to the values it has during the day.

The proximity changes during the day but the variance is low and most of the values are close to 350. An increase in the changes of proximity values is observed before the changes start in the temperature and humidity. The most intense difference is found during the temperature is rising. After the peak in the temperature, the proximity values are closer to 0, and the mean of the values is almost 0 after 20:00 until the end of the day.

There are ups and downs in the noise level during the day, but the variance is quite higher when the proximity is around 0. The fluctuations in noise level increase when the intense proximity change is observed. The highest and the lowest values are recorded for the noise level in this period as well.

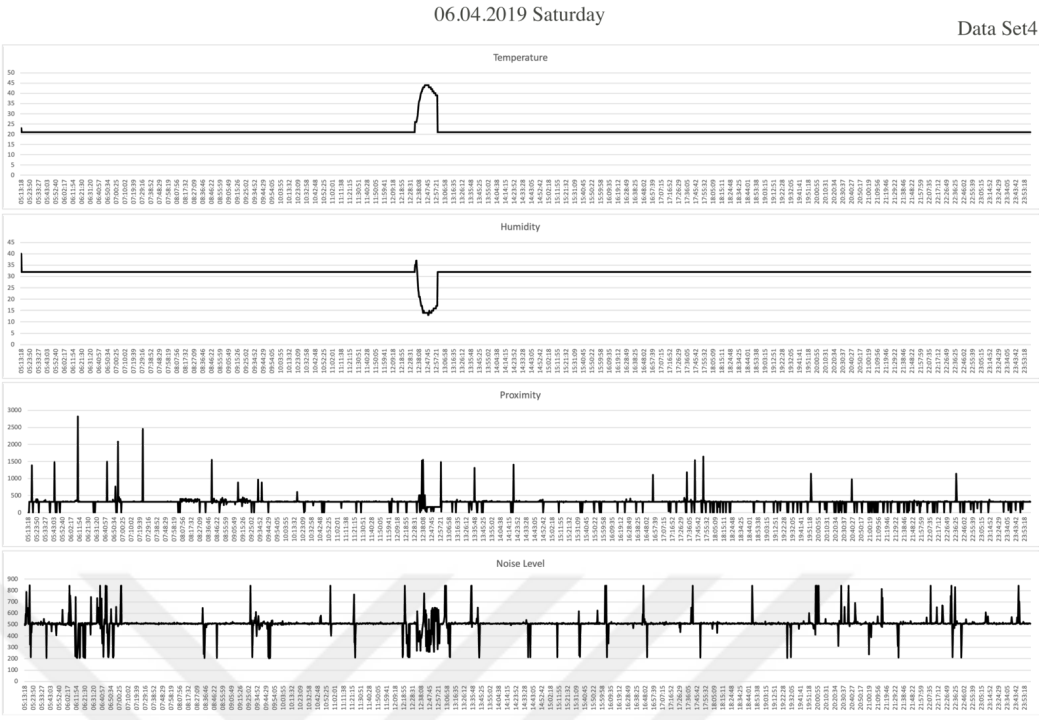


Figure C.24: Saturday—Day 3 of data set 4

Saturday

The temperature is almost constant throughout the day except between around 12:30 and 13:00. It increases from 21 °C to 44 °C in about 10 minutes. Right after that, it starts decreasing, and it goes back to the same degrees in half an hour.

Around the same period, the humidity almost shows the negative of temperature. It makes a jump when the temperature starts increasing and right after that, it decreases until it reaches the value 13 from 37. Just like temperature, it goes back to the value 32 which the humidity shows during the other times of the day.

It is hard to observe a correlation between proximity and other data types. The proximity changes almost always during the day.

There is an increase in the variance of the noise level data during the same period that temperature and humidity start changing, but it is not the only period that noise level values change. Therefore, it is a bit hard to say that there is a correlation between

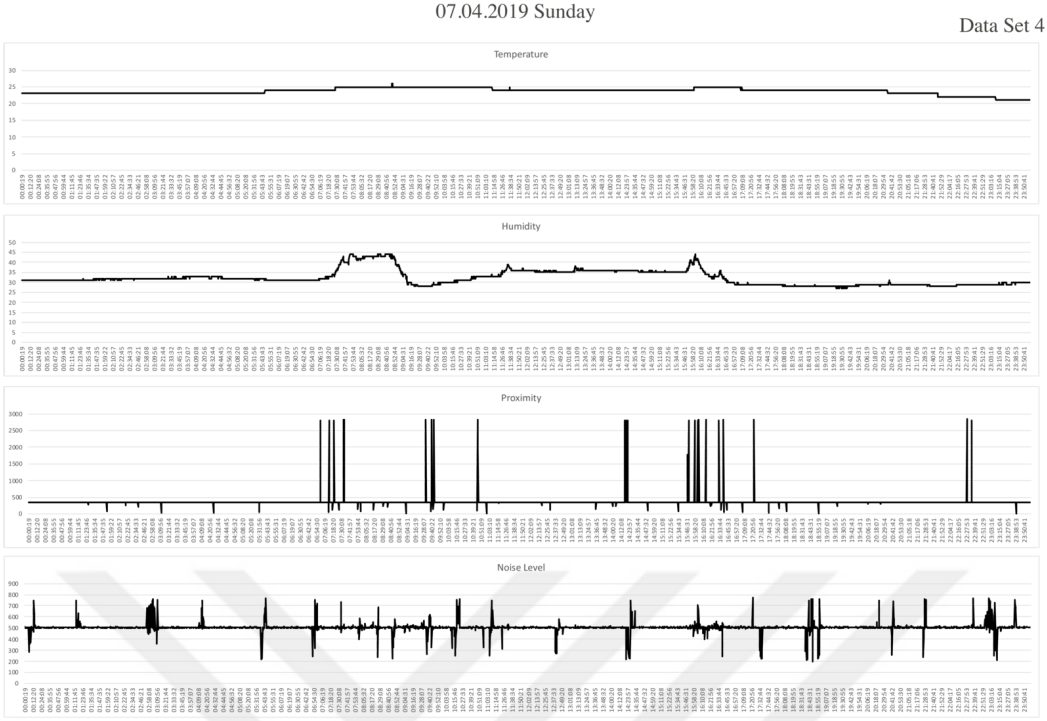


Figure C.25: Sunday—Day 4 of data set 4

noise level and other data types.

Sunday

The temperature increases at around 8:00 from 23 °C to 29 °C. After that jump, it slowly decreases back to 24 °C until around 15:00. After that period, there are three hills in the graph. The first increase rises to 52 °C and then decreases. About 20 minutes later, when it reaches 32 °C, it starts to increase again, creates a smaller hill that reaches up to 40 °C and drops to 30 °C again, in around 20 minutes. It remains stable for about half an hour and increases to 40 °C. Then, it falls slowly to 30 °C and slightly below. Then, it seems to be stabilized towards the end of the day.

When the temperature first increases at around 8:00, there is a small decrease in humidity. After half an hour, the increase stops and an irregular increase in data is observed. Right before the jump in the temperature at around 15:00humidity increases a little bit. When the temperature starts rising, the humidity starts decreasing. While

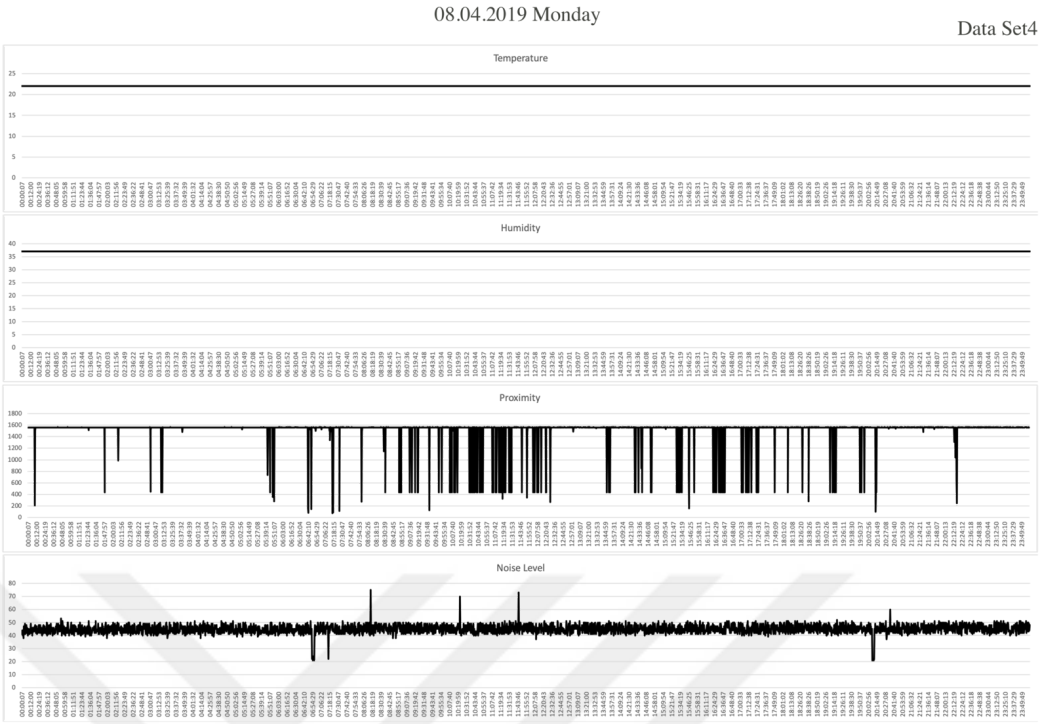


Figure C.26: Monday—Day 5 of data set 4

the temperature is creating the second hill in the graph, the humidity creates a similar hill which gets up to 20s and down to 10s. While the temperature is making the third hill, the humidity creates the second hill. When the temperature starts slowly decreasing and stabilizes, the humidity starts increasing slowly. It makes two jumps to higher values, but the overall trend points to a very slow increase.

The proximity values are almost constant at 0 during the entire day. The only exception is observed during the period that the temperature makes three hills—the variety of data changes during that period.

A very subtle increase in the frequency pointing a higher variance can be reported in noise level in the same period that temperature and humidity changes.

Monday

Today, the temperature is fixed at 22 °C, and the humidity is at 37 the entire day.

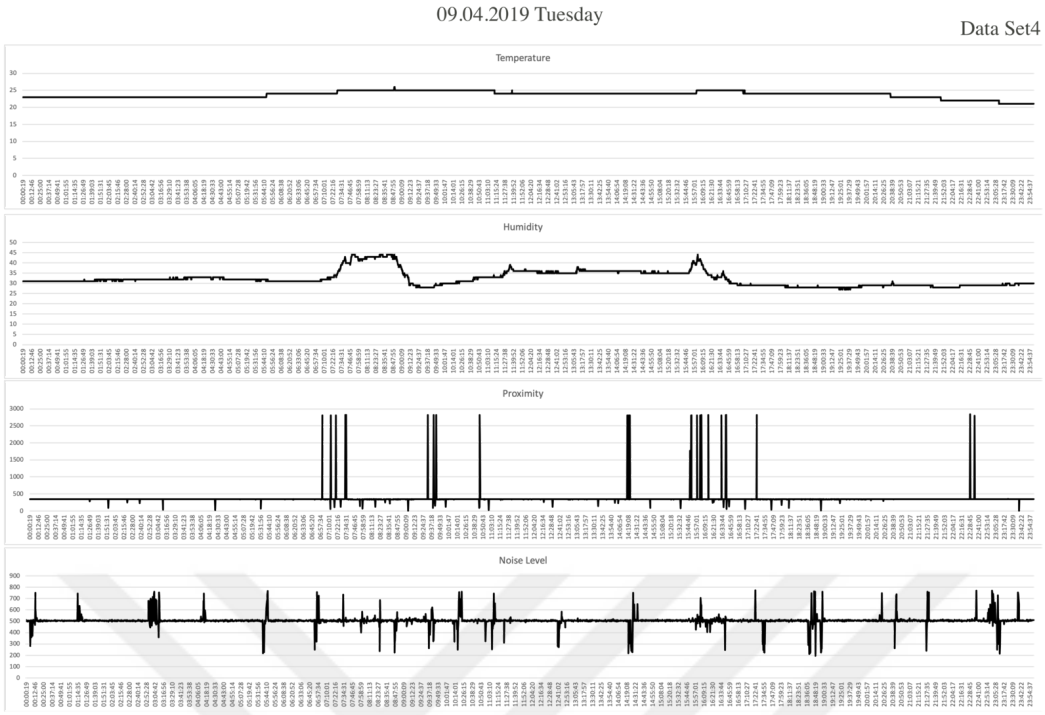


Figure C.27: Tuesday—Day 6 of data set 4

Although there are changes in proximity levels, the minimum value is recorded as 73 early in the morning. It never gets closer to 0, and the values mostly change between 400–1600 mm.

Except for a few slightly quieter and noisier moments, the noise level is very low when compared to the data recorded in other days and changes between 40–50 band.

Tuesday

The temperature changes in longer intervals at very low rates. Humidity is more volatile when compared to the temperature. Between around 7:00 and 9:00, there is an eye-catching increase and decrease in humidity. It gets up to 45 from 30. There are small changes until 15.30 around the value 35. At that time, there occurs a little peak that carries the value to above 40 again. It lasts very short and drops to around 35 again in an hour, and in about 45 minutes, it gets back to 30s again and ends the day around that values.

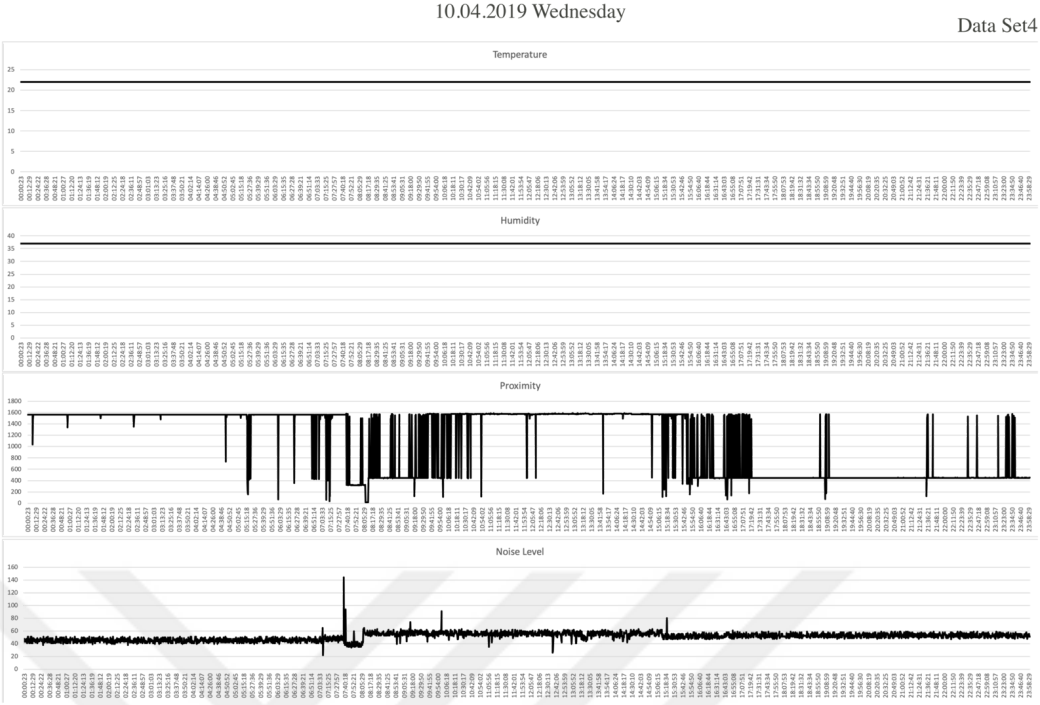


Figure C.28: Wednesday—Day 7 of data set 4

In proximity, there are bumps from time to time, but a still line can be observed which follows the value around 350. When the humidity starts increasing dramatically, the variance in the proximity value increases considerably. Peaks occur from time to time after the humidity decreases, and the frequency is increased during the second increase in humidity.

The noise level seems to be less volatile when compared to the other days but much higher than the previous day. It changes between around 200–800.

Wednesday

Wednesday's data is very similar to Monday's. There is no change in temperature and humidity. The proximity changes during the day, and the change is more intense between 6:00–10:00 and 15:00–17:30. However, there is no correlation with other types. Like on Monday, the noise level is much lower when compared to other days as it changes between 40–60 mostly, but there is a peak at around 7:40, and it gets

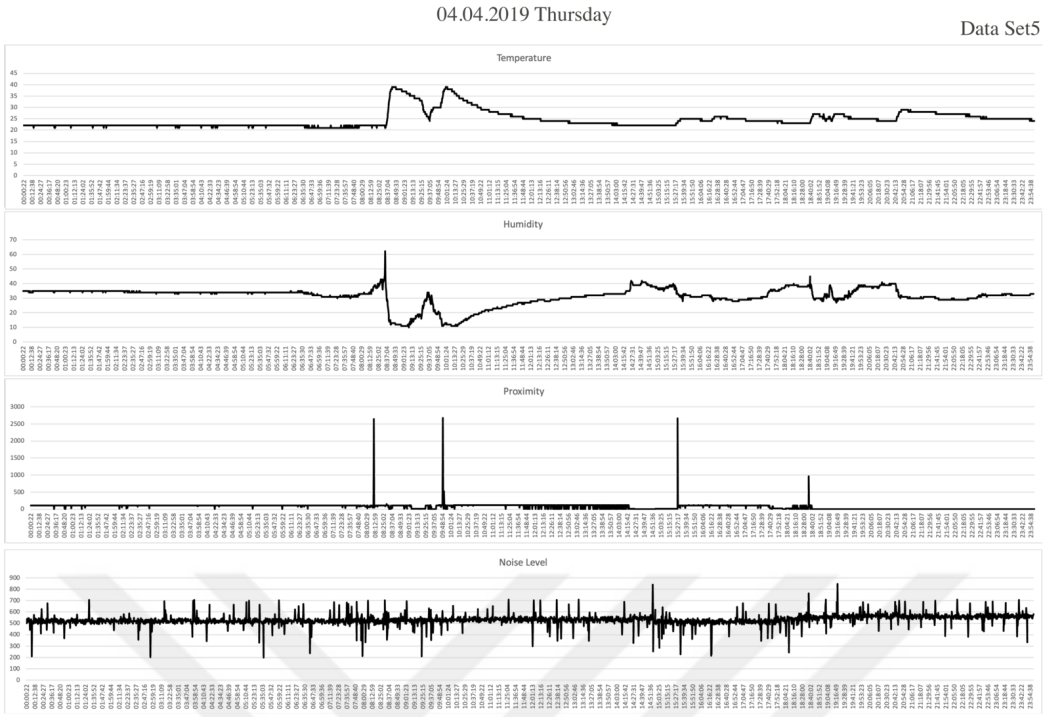


Figure C.29: Thursday—Day 1 of data set 5

to almost 1600. After that momentary peak, the data continues to fluctuate between 50–60.

C.5 Data Set 5

Thursday

The temperature starts the day with the value around 22 °C. It more or less is recorded so until about 8:30. At that time, the temperature starts increasing up to almost 40 °C. When it reaches its top, it starts decreasing and gets to 24 °C in an hour. After that, it again shows an increasing trend—it gets to almost 40 °C at around 10:00. Then it starts decreasing until 14:00, and it is recorded as 23 °C. After that time, until the end of the day, it shows infrequent and small increases and decreases but stays around the same values.

When the temperature starts increasing the humidity starts rising as well. After mak-

ing a peak, the humidity gets to 62 from 34. It decreases dramatically almost to 10 at around 8:30 and gradually increases after that point. When the temperature reaches the lowest after the first increase, the humidity reaches the highest after its first gradual increase. After that point, when the temperature starts increasing again for the second time, the humidity gradually decreases. During the time that temperature increases until 14:30, the humidity increases. Around 14:30 and 18:30, the variance gets higher in smaller time intervals. However, the changes that humidity shows after 15:00 till the end of the day seems higher than that temperature shows, but the differences between the values never reach to the changes that happen previously.

The proximity is changing a lot during the day, but it is mostly around 100 mm except when the changes in humidity occur. During these times, the variance increases considerably from almost 0 to 2500 mm.

The noise level is always changing between 200 and 700. However, during the humidity changes at around 14:30 and 18:30, it gets to the highest noise level of the day, and momentarily it reaches almost 900 around those times.

Friday

Except for some small changes around midnight, the temperature is almost stable at 20 °C until about 14:30. It makes a peak and reaches 34 °C. After 10 minutes, it starts to get down until almost 18:30. It stabilizes again after that time at 22 °C.

The humidity fluctuates a little until the temperature starts rising. At around 14:30 the humidity makes a peak and increases from around 40 to above 90. Right after the peak, it decreases dramatically and drops to almost 15 when the temperature gets its highest value. After that moment the humidity starts increasing until the temperature stabilizes. Around 18:30, the humidity value is measured as 32 and ends the day around so.

Until the dramatic change in temperature and humidity, the proximity is fixed at 0. When the temperature and humidity make peaks the variance, the proximity level starts changing suddenly. The variance in data gets its highest at that moment. Around 15:00, the value gets up to 85 and around and fluctuates until the end of the day.

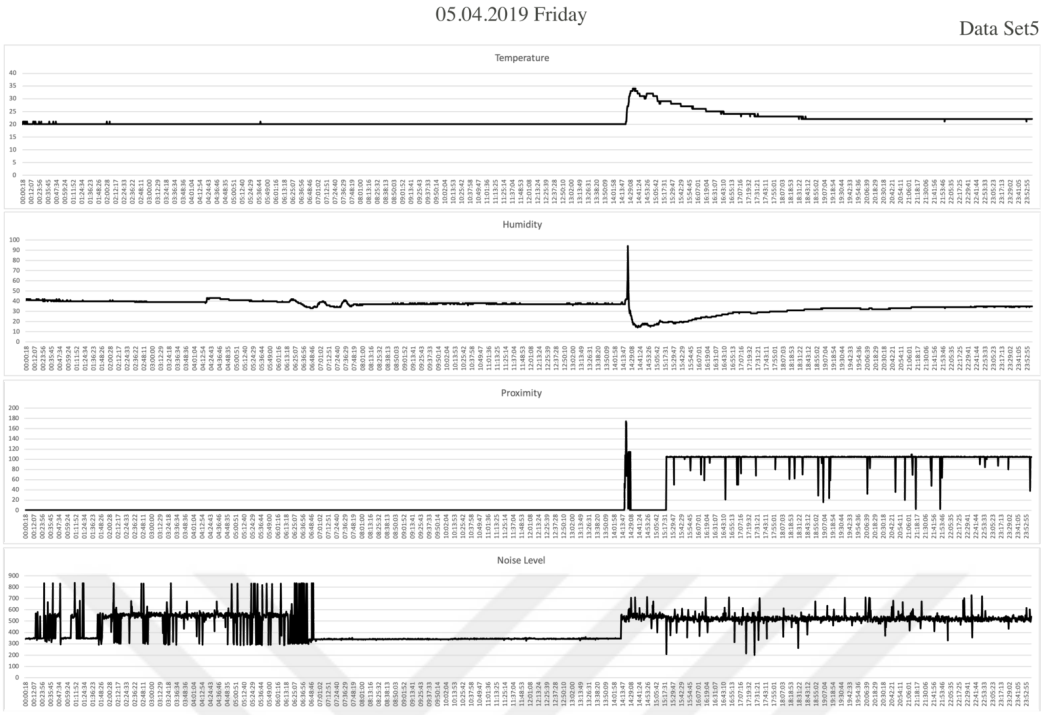


Figure C.30: Friday—Day 2 of data set 5

From the beginning of the day, until around 7:00 in the morning, the noise level changes between 300–800. After 7:00 until around 14:00, there are minimal changes around the value 350. With the increase in other data types, the noise level starts changing again in a broader range. Interestingly, the mean of the recorded data after that point is lower than the values recorded from midnight to early in the morning. Moreover, the lowest value captured this day is in this period as the values are varying between about 200 and 700.

Saturday

This day, the temperature almost stable except for tiny momentary changes. The values are around 21 °C.

The humidity is stable as well. The values are mostly recorded around 27.

Proximity values are recorded around 110 with few changes in data until 19:55. At that time, the values drop dramatically, and for about 15 minutes, it changes between

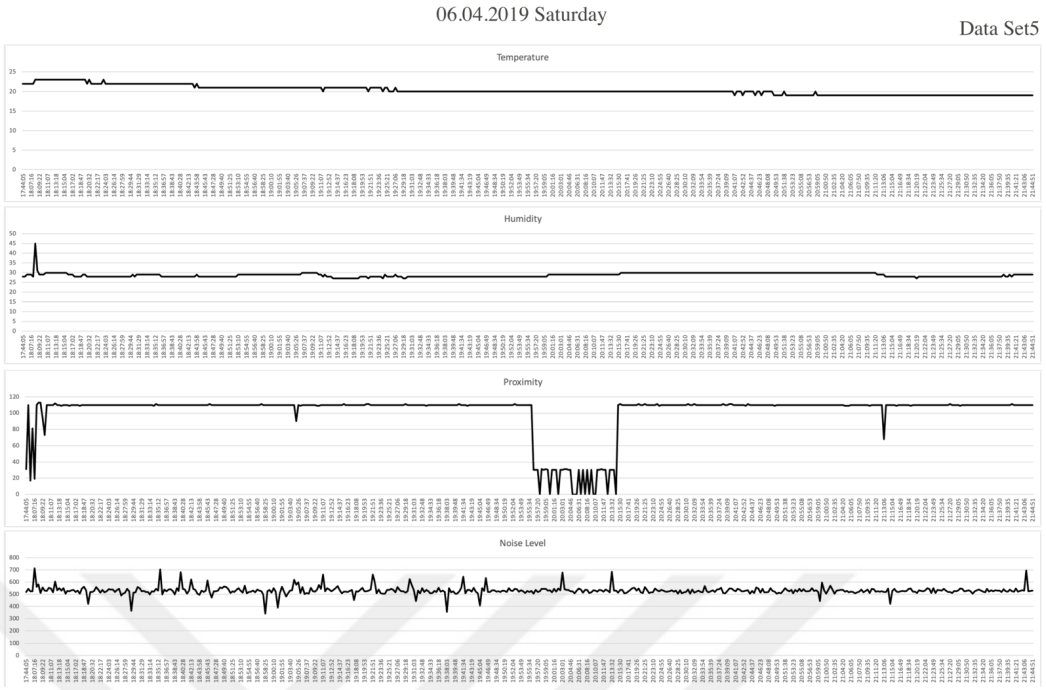


Figure C.31: Saturday—Day 3 of data set 5

around 0 and 30. Towards the end of the day, there is another eye-catching momentary decrease towards the end of the at around 21:15. However, it does not even reach 60 mm.

There is not a considerable or relatable change in noise level data. However, it can be reported as the range is narrower than the other days as it fluctuates between 350 and 700.

Sunday

The changes can be reported as insignificant when compared to the transition from 24 °C to 29 °C at around 8:15. After that time, there is a very slight decrease to 24 °C in the data until 15:00. After that, first, the temperature increases to 29 °C in about 5 minutes and then it makes a peak to 51 °C. In about 20 minutes, it drops down to 30s and makes another jump to 41 °C this time. It drops back again in only 10 minutes, maintains the temperature at 30 °C for half an hour and makes another

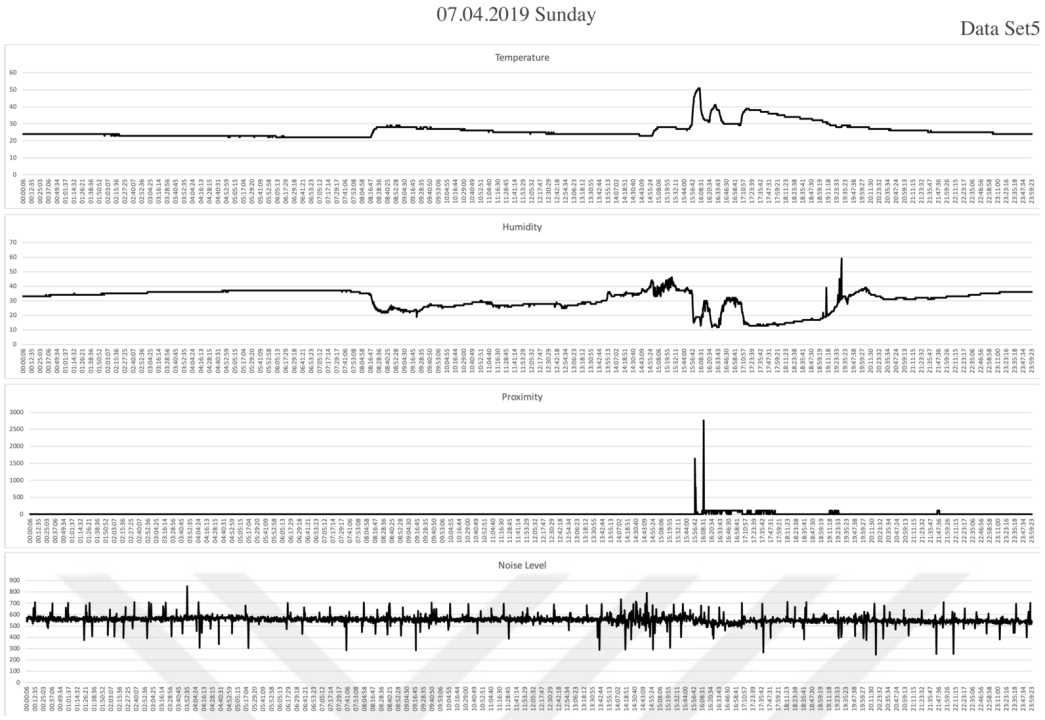


Figure C.32: Sunday—Day 4 of data set 5

jump. When the temperature is recorded as 40 °C at around 17:30, it starts decreasing and stabilizes after around 20:30. The value recorded at the end of the day was the same as the one at the beginning of the day, 24 °C.

Expectably, the humidity starts changing with the temperature at 8:15. It drops from 32 to 21 very slowly shows an increasing trend until 15:00. It intensely changes between 32–45 and when the temperature makes the peak the humidity drops dramatically. It reaches almost 10 at the end of the first hill in the temperature data. Then, respectively, it increases up to 30s, decreases to 10s again within the same periods that temperature makes one big and one small hill. While the temperature maintains the temperature after 16:30 for half an hour, the humidity increases above 30 and drops back again. While the temperature slowly decreases, the humidity increases. After making two jumps, former is from 20 to 40, later is from 43 to 60, it romps back and stabilizes around 30.

The proximity is almost always recorded as 0 for the entire day besides the time that temperature changes. The variance in proximity data gets its highest between 16:00

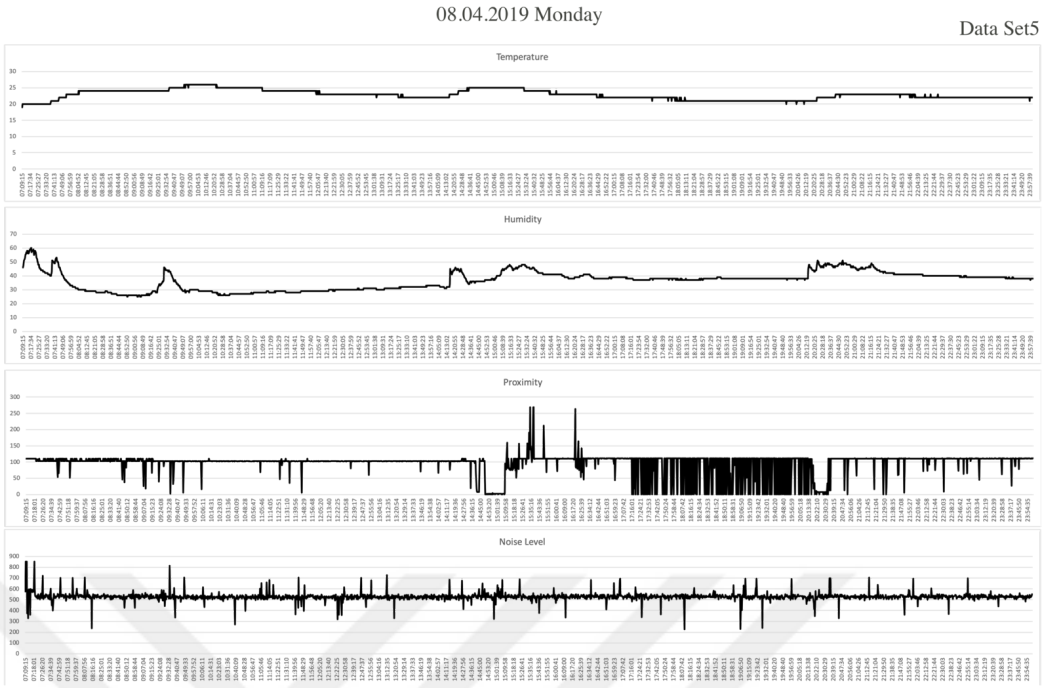


Figure C.33: Monday—Day 5 of data set 5

and 18:00. After small changes, the data seems to be fixed at 0 again.

The noise level continually changes during the day. There is not a relatable change with other data. It seems like there is a small increase in the intensity of the change in noise level just before the peaks in the temperature.

Monday

The temperature changes between 21 °C and 26 °C. The changes happen in long intervals. The highest temperature is observed between 14:30 and 15:30.

The humidity, independently form temperature, around 7:30 it reaches almost 60. Then it decreases to 40 in 10 minutes. It increases again to 50s and starts decreasing after 07:50. It drops to 25 and starts rising again. It reaches 48 around 09:30 and starts falling, and when it arrives at 30s in about 10 minutes, it stabilizes until 14:30. First, it gets almost 35 from 30 in about 10 minutes then decreases to a value which is slightly higher than that was recorded 10 minutes ago. After that, it again draws a

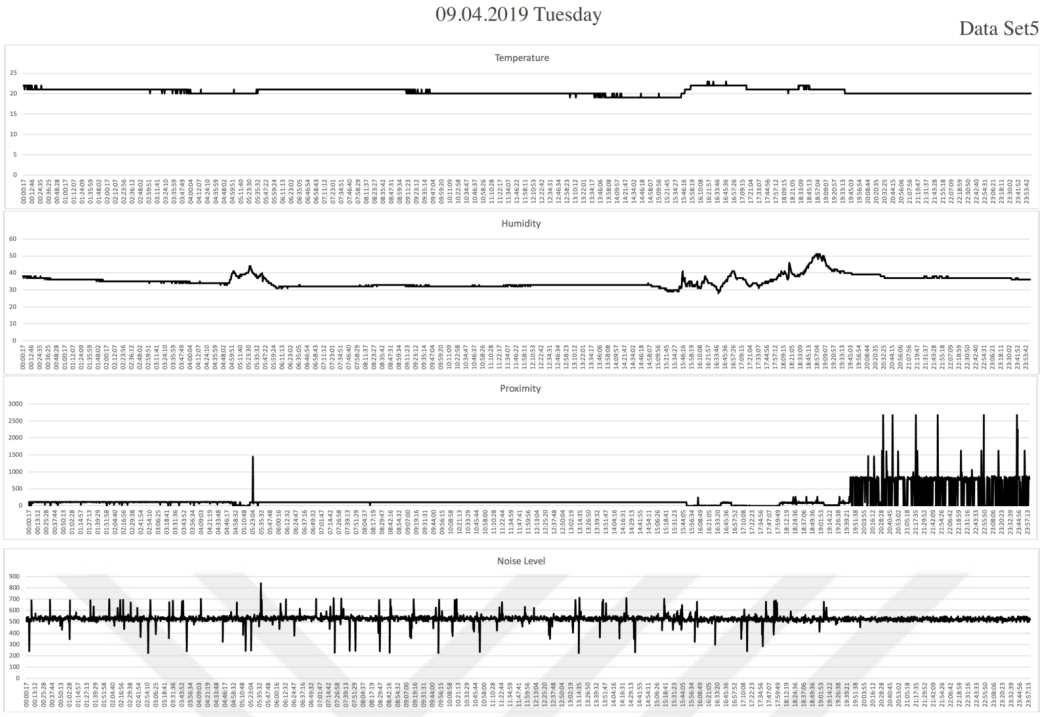


Figure C.34: Tuesday—Day 6 of data set 5

line showing up, and when it reaches to 50 around 15:30, it slowly goes back to 40s. Then it remains almost still at that degree until around 20:00. It increases unstably till 21:30 and stabilizes after that.

Around 14:00, the proximity data gets closer to 0. Although there are ups and downs throughout the day, after the change in humidity that is observed at around 14:00, the proximity values get closer to 0. Moreover, the variance is quite high in this period, and the highest and lowest values are observed in that time range as well.

The noise level is in almost constant change through the day, but it is hard to observe a correlation with other data types.

Tuesday

There are small changes in the temperature values from the beginning of the day till around 16:00. At that time, while the temperature values were changing between 19 °C–21 °C until that time, it increases from 19 °C to 23 °C in almost 15 minutes.

Although, when compared with the increases in the other days, it can be interpreted as rather a small change, it is the only eye-catching change in the entire day. After that increase, it decreases slowly and ends the day at around 20 °C.

The humidity value started the day around 39 and decreased to 32 until around 5:00 in the morning. At that time, the humidity increases to 44 and falls back to almost 31 in about an hour. It can be reported as quite stable after that time until around 15:00. Between 15:00 and 19:00, there are ups and downs in the graph, but the overall trend can be reported as an increase because the value measured as around 30 in 15:00 is measured as 51 in 19:00. After that time, the humidity decreases a bit and end the day at 38.

Until 5:30 in the morning, the proximity values are measured between 0 and 110. However, when the humidity reaches the highest value of its first increase in 5.30, the range increases momentarily, and the value reaches to 1442. After that time the proximity is recorded around 110 mm with small differences until when the humidity rises at around 15:00. After that time, the values are measured as closer to 0 until the humidity reaches its highest. At that time, the range of proximity values increases and reaches 2600 from time to time. The humidity ends the day with this increased variance.

Noise level continually changes throughout the day, but the variance of the values decreases considerably after the variance in proximity increases after around 19:30 and lasts until the end of the day.

This day, in conclusion, is a bit different from the other days as the temperature, humidity and proximity do not act in accordance. However, all the data can be assessed as relevant when it is acknowledged that the sensors also measure the changes in the environment but not only the changes in the object.

Wednesday

The temperature can be interpreted as almost stable in the entire day except for the increase between around 6:30 – 7:00 in the morning. The value increases from 19 °C to 24 °C and starts decreasing right after. At around 9:30, the temperature goes back

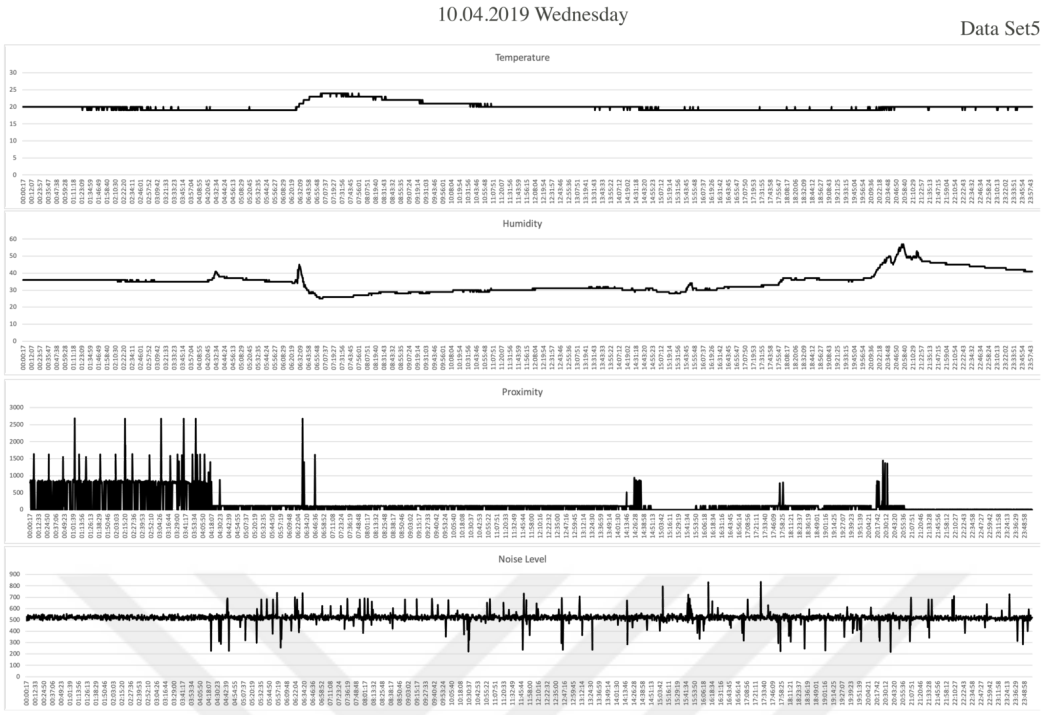


Figure C.35: Wednesday—Day 7 of data set 5

to 20 °C and ends the day so.

While the small increase is happening in the temperature, the humidity makes a peak first and decreases down to 26 from 45 when the temperature reaches its highest. After that, the humidity increases very slowly until around 20:00. Then it increases until 20:30, and after reaching 50, it decreases suddenly to 45. Right after reaching that value, it starts rising again. At around 21:00, it reaches almost 60 and drops a little bit. The humidity maintains its value around 50 for nearly 15 minutes and after making a small increase, starts dropping from 52 and finishes the day with a decreasing trend in the graph.

Proximity and noise level values show a continuance from the previous day. High variance in proximity and low variance in noise level is almost the same until 4:30 in the morning as after 19:30 in the previous day.

Before the increases in temperature and humidity, the proximity level changes in a high range between 2500 and almost 0. Before the rise in temperature and humidity,

the proximity level varies in a smaller scale but makes a peak again at the time of the changes. The variance in the proximity continues in lower values until the second increase in humidity. The range of proximity values increases a bit, and then the values are measured as 0 until the end of the day.

The noise level varies in a minimal range during the high range changes in proximity. However, after the variance of proximity gets smaller, the variance of the noise level increases. After around 4:30 in the morning, the noise level values are changing between 200 and 800. The lowest and highest values are measured before the change in the humidity in the evening.

APPENDIX D

OBJECT PERSONA BOARDS FROM WORKSHOP 2

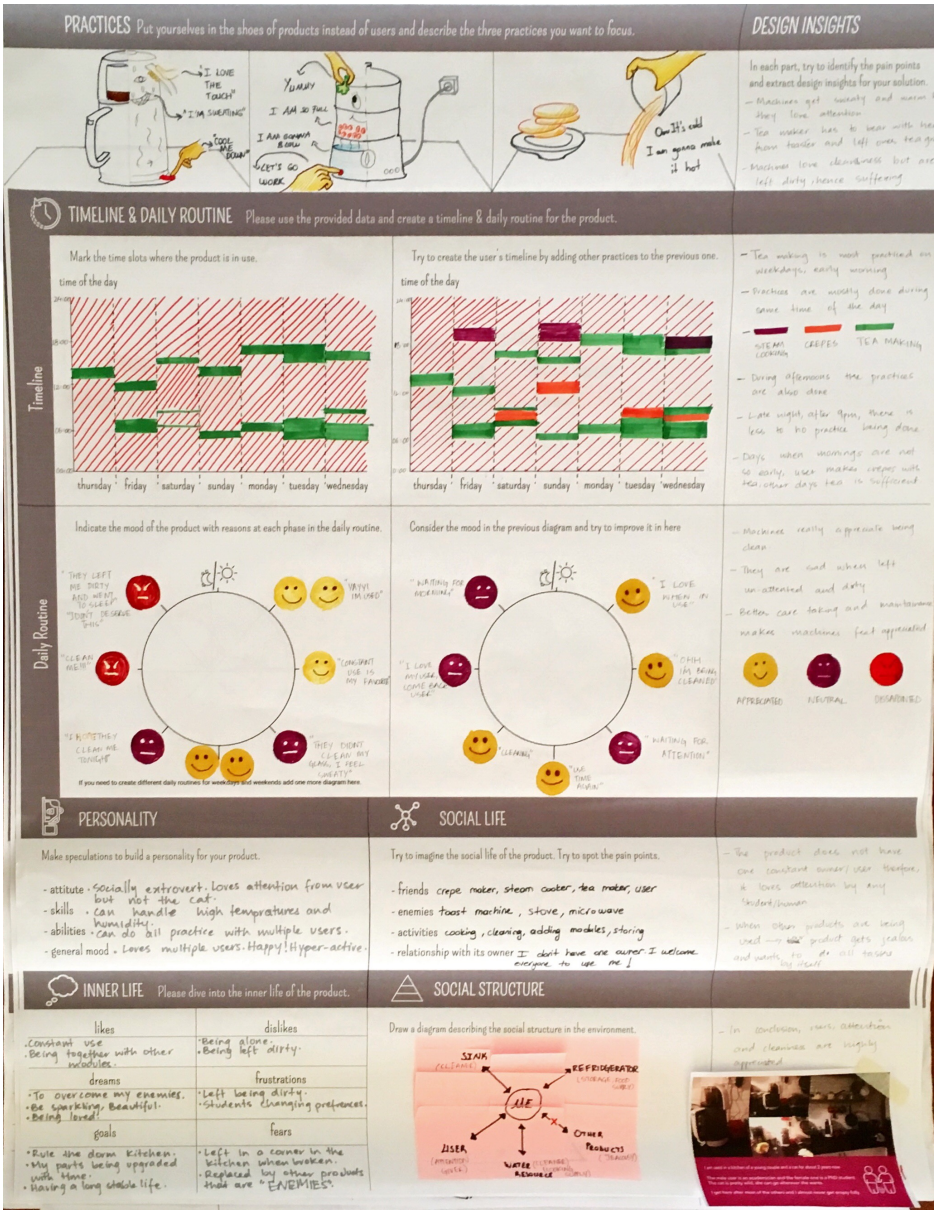


Figure D.1: Object persona board of Team 1 in Workshop 2

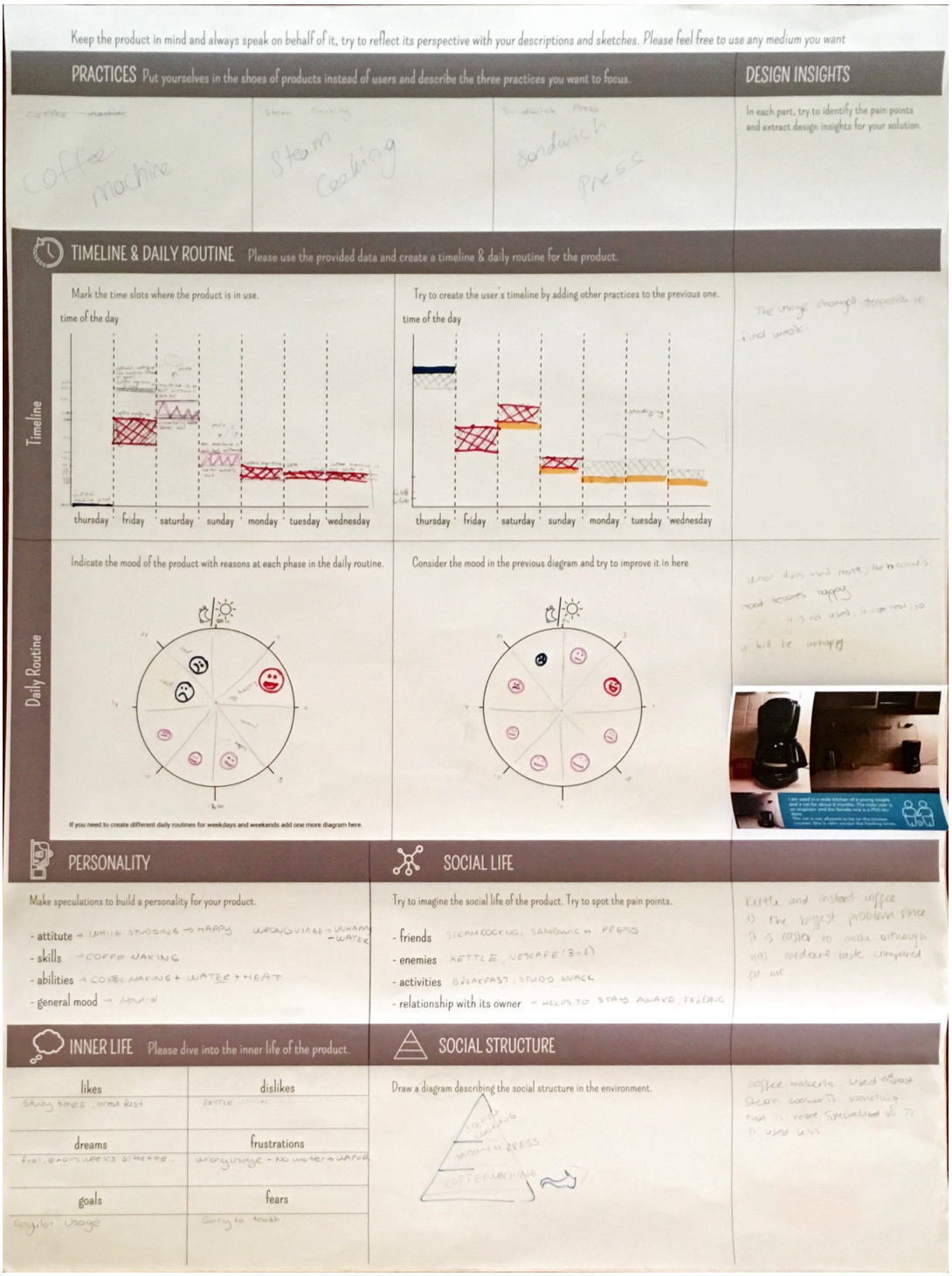


Figure D.2: Object persona board of Team 2 in Workshop 2

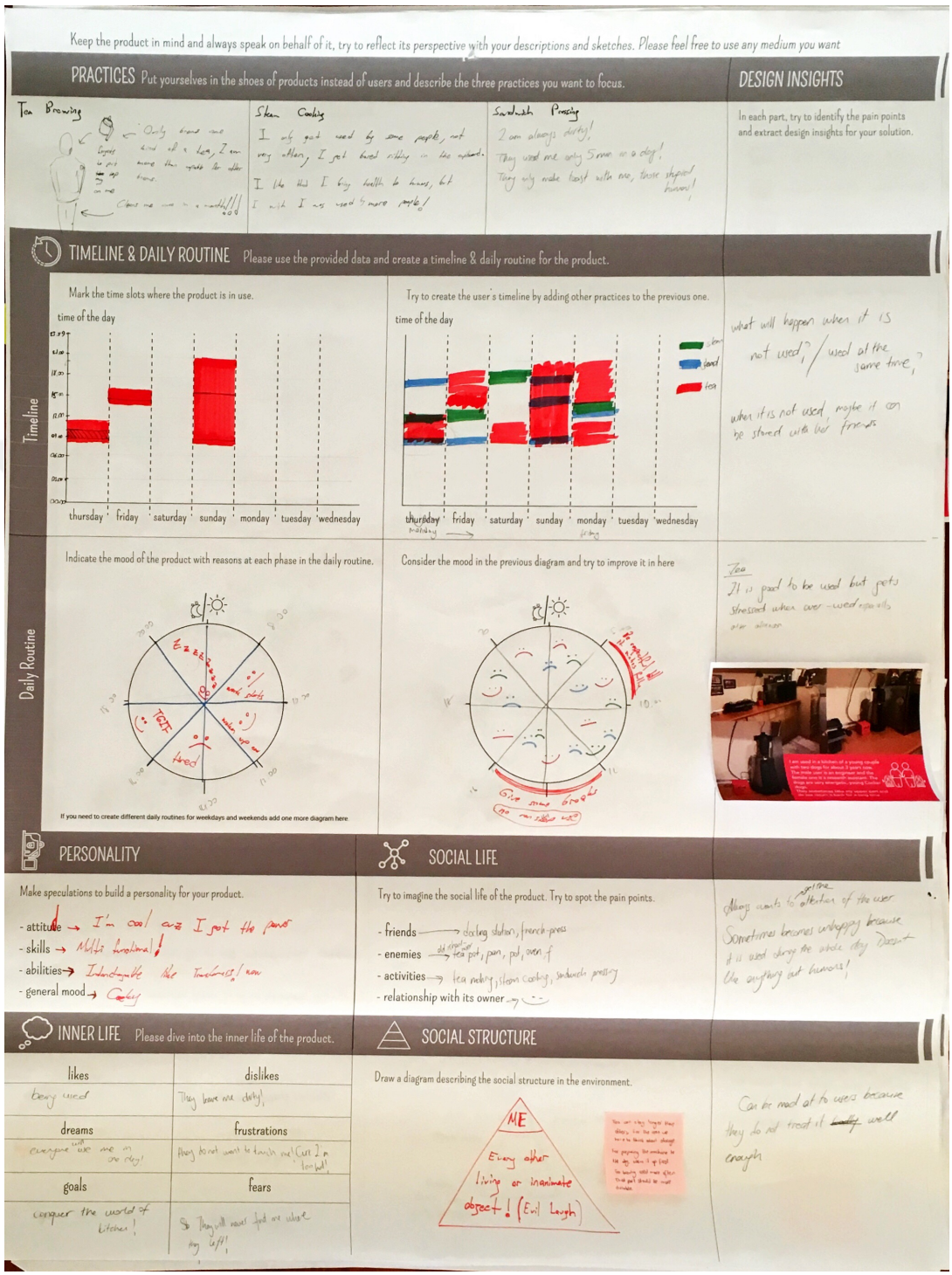


Figure D.3: Object persona board of Team 3 in Workshop 2

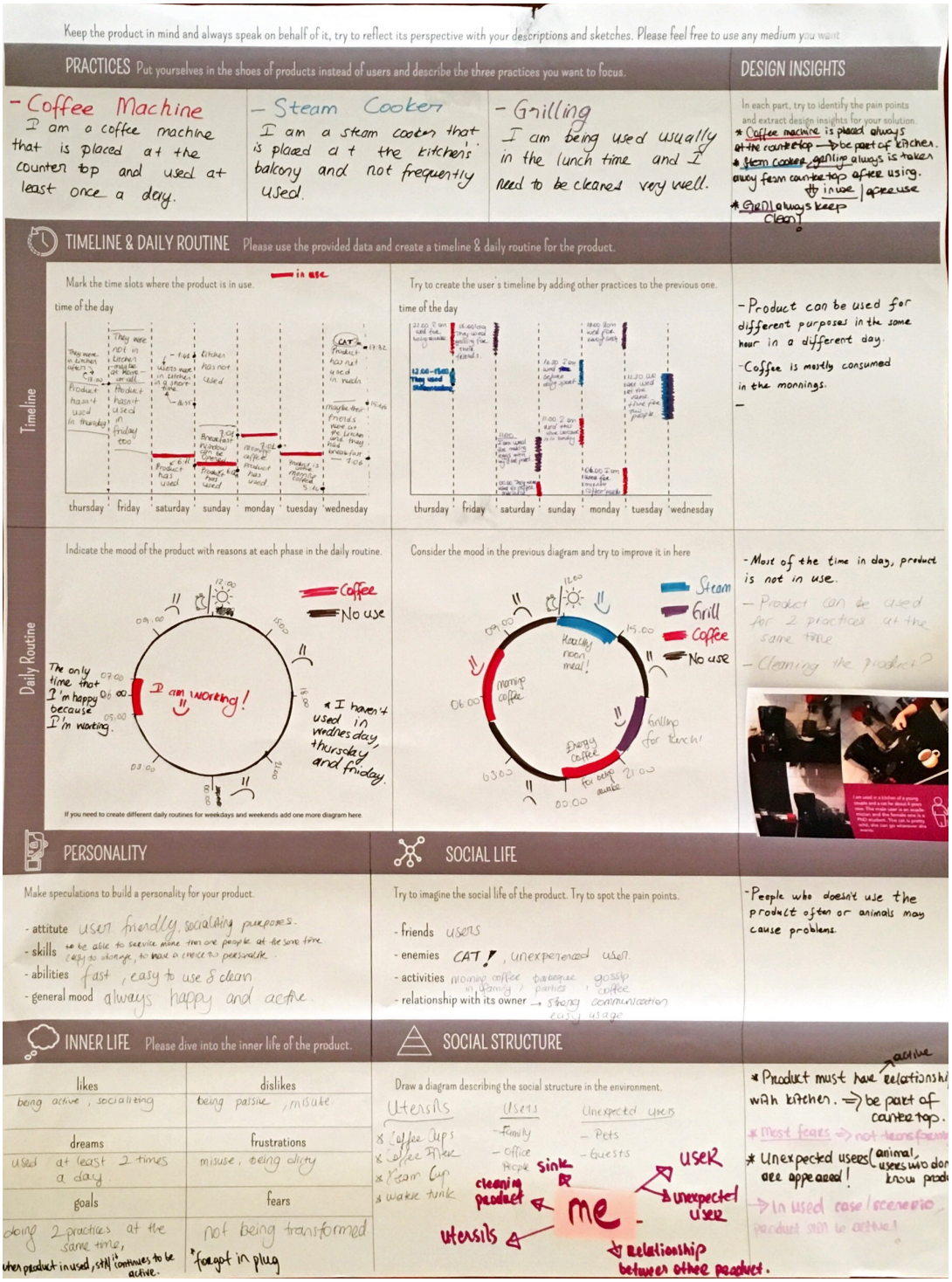


Figure D.4: Object persona board of Team 4 in Workshop 2

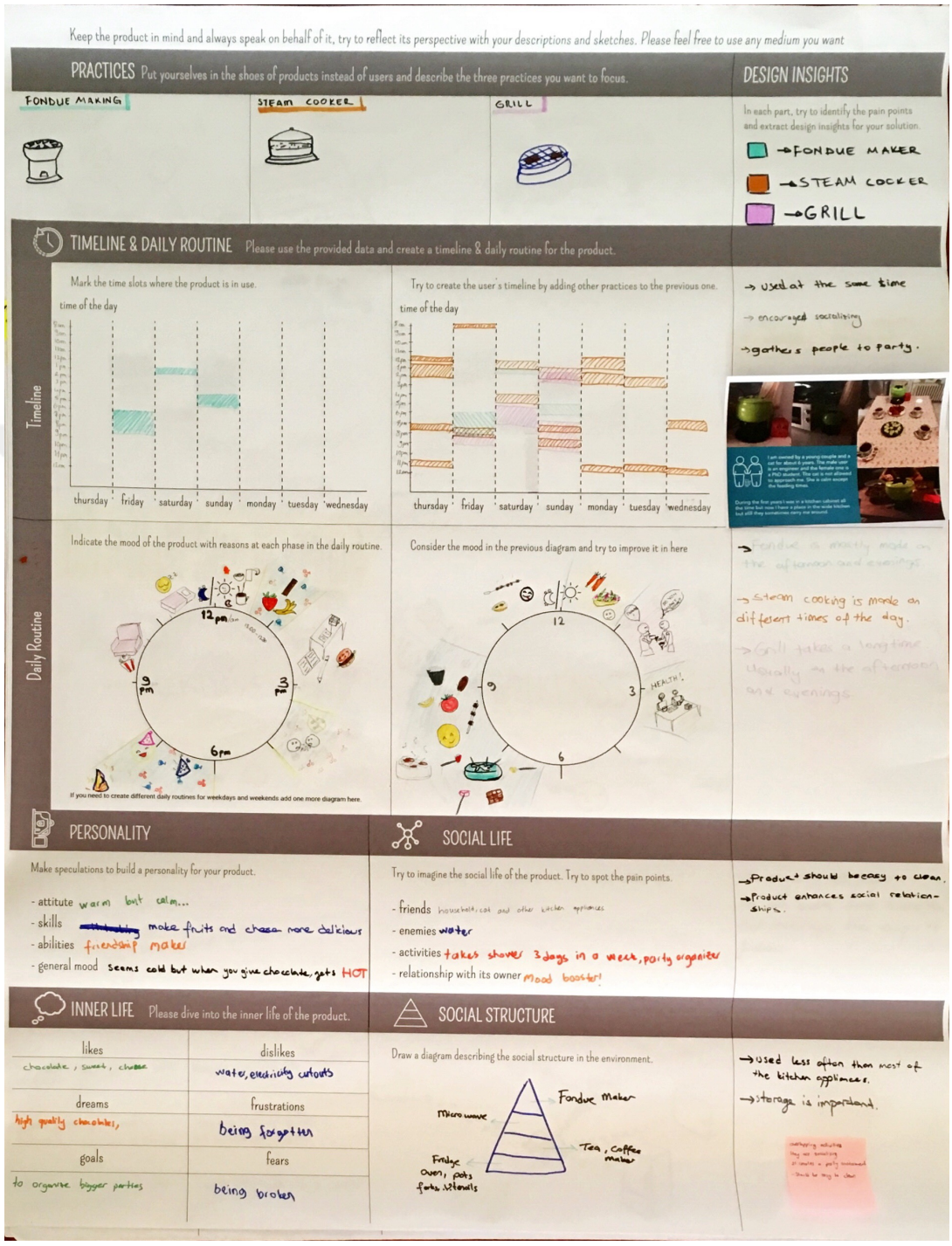


Figure D.5: Object persona board of Team 5 in Workshop 2

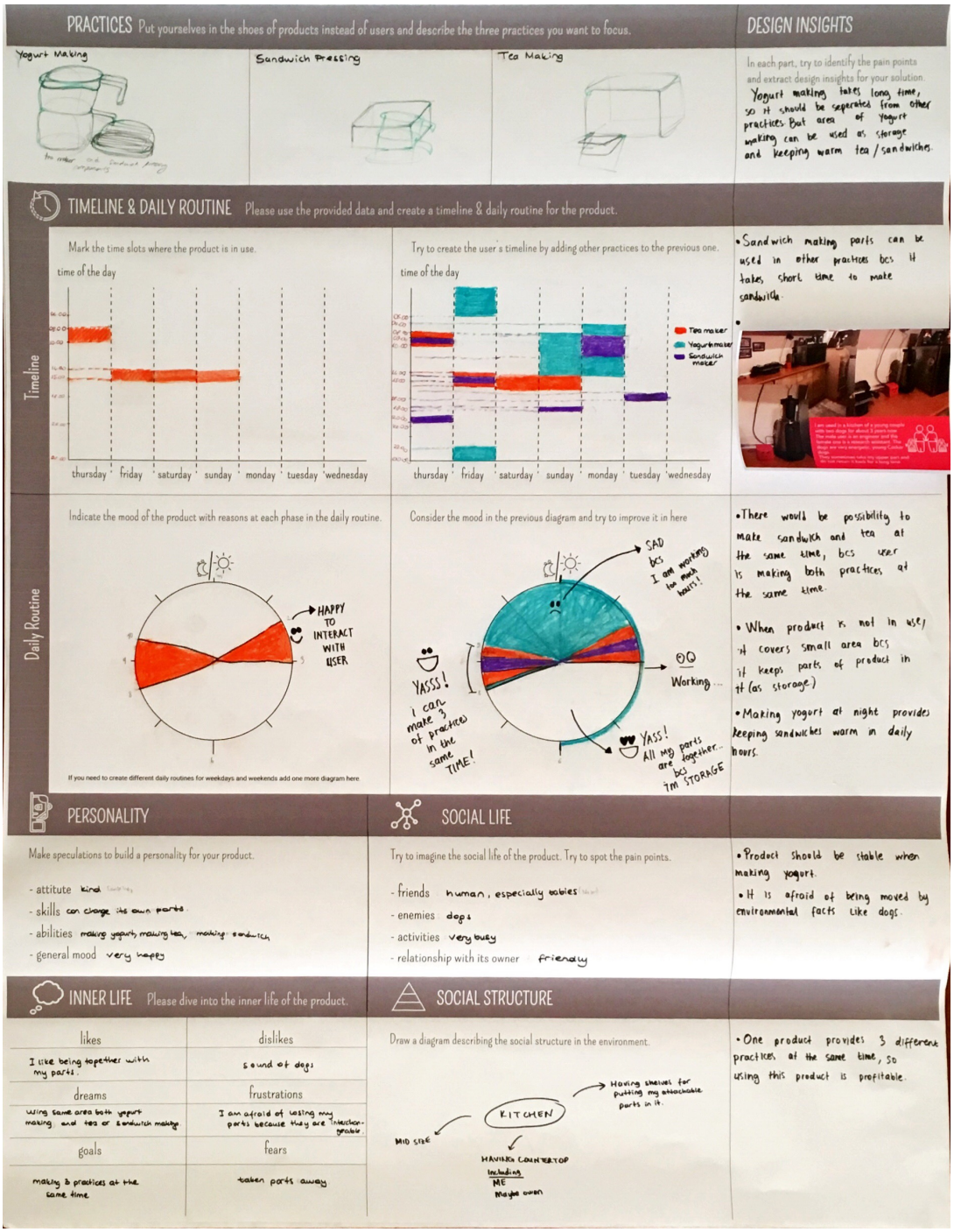


Figure D.6: Object persona board of Team 6 in Workshop 2

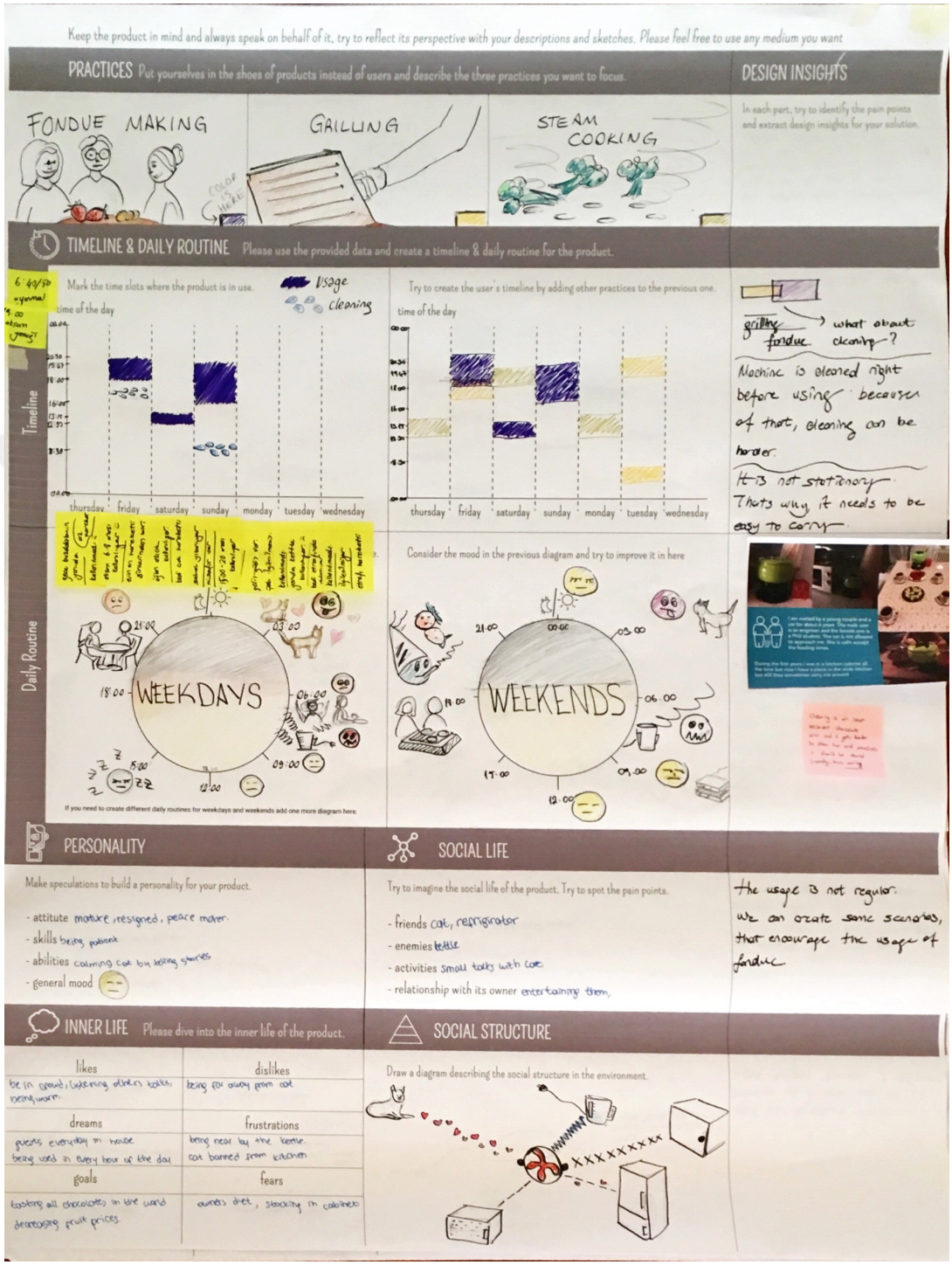


Figure D.7: Object persona board of Team 7 in Workshop 2

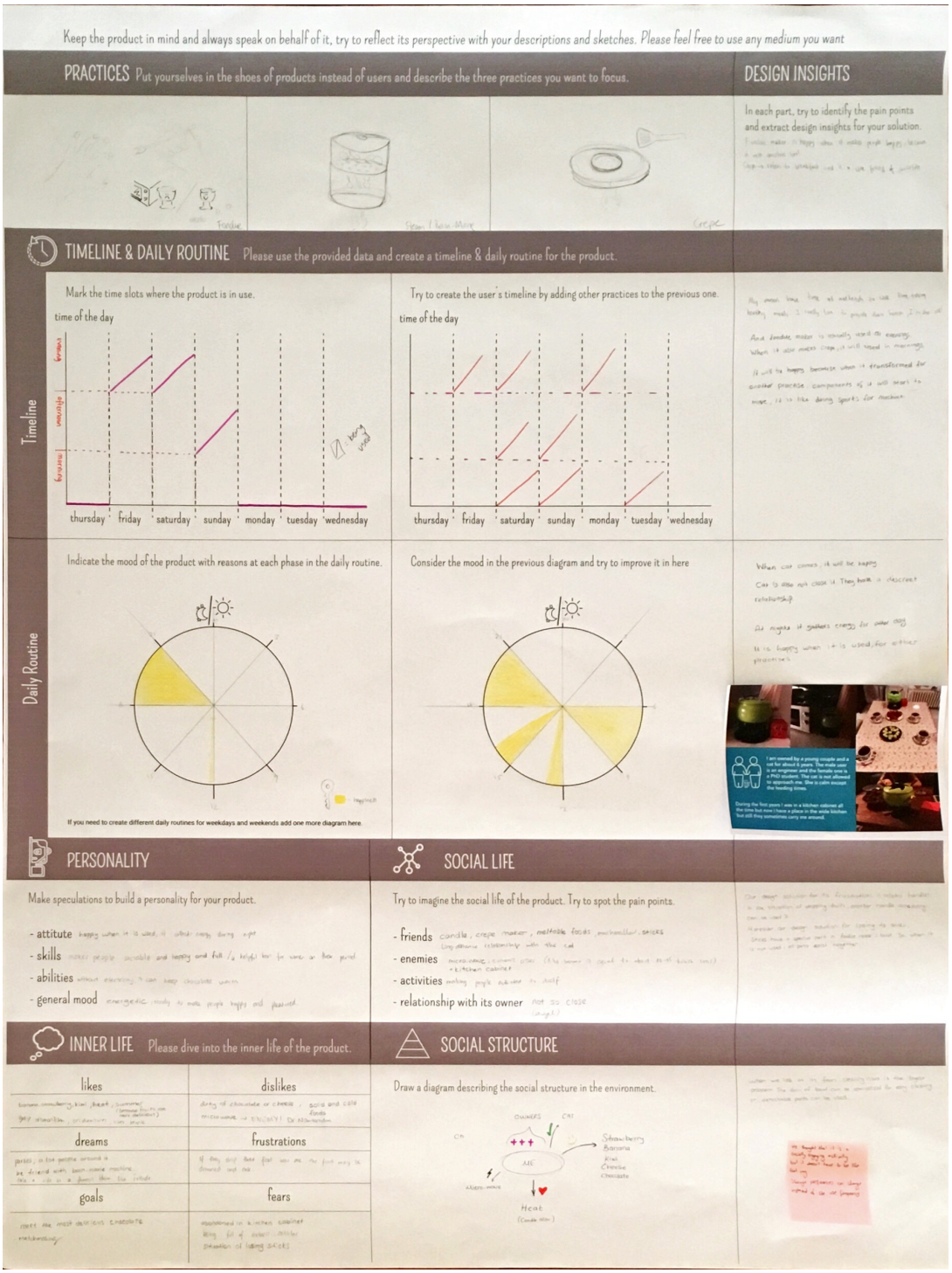


Figure D.8: Object persona board of Team 8 in Workshop 2

APPENDIX E

ENVIRONMENT CARDS FROM WORKSHOP 3

I have been living with my partner and our cat for more than a year.

She is a research assistant in a university and I am a computer engineer in a firm and I am recently writing up my Master's thesis. We try to keep our cat away from the kitchen while we are not around. The kitchen counter is forbidden for her.

We use the machine 2-3 days during weekdays and every weekend. Sometimes, I prefer to preheat it before putting something inside but I usually forget and it takes more time. We make sandwiches on weekdays and make toasts on weekends.

TOASTER













Figure E.1: Environment card for the toaster

KETTLE



I have been living with my partner and our cat for more than a year.

She is a research assistant in a university and I am a computer engineer in a firm and I am recently writing up my Master's thesis. We try to keep our cat away from the kitchen while we are not around. The kitchen counter is forbidden for her.

We use the kettle for tea and preparing meal. We never boil the water on the stove. We usually do not boil tap water inside it. We use it everyday and some days more than once. I was using a plastic kettle before, but in time, its lid expanded and it started leaking water out. That's why I am very happy that its made of metal.











Figure E.2: Environment card for the kettle

COFFEE MAKER



I have been living with my partner and our cat for more than a year.

She is a research assistant in a university and I am a computer engineer in a firm and I am recently writing up my Master's thesis. We try to keep our cat away from the kitchen while we are not around. The kitchen counter is forbidden for her.

We are using the machine at least 3 times a week. During weekdays we make coffee, put in our mugs and take out our coffee. During weekends, usually, we make coffee in the afternoons. If we do not use paper filter, there remains residue in the coffee. Its filter is not good enough. The measures on the reservoir and the carafe are not the same, so it took a while to learn. It is a simple machine and I am happy with the coffee it makes.











Figure E.3: Environment card for the coffee maker

APPENDIX F

INTERACTIVE DATA GRAPH

The source code of interactive data graph can be reached from https://web.archive.org/web/20201020133919/https://sites.google.com/view/nt-phdthesis-code1/. After the code is saved as an html file, the graph visualising the data used in Workshop 3 can be observed in a web browser.

APPENDIX G

OBJECT PERSONA ATTRIBUTES AND NOVELTY SCORES OF WORKSHOP 1 AND 2

Table G.1: Workshop 1, Team 1—Object persona tables for novelty score

Team 1	
A day in life	
Functional activities	Having headaches, working, resting, cleaning
User activities	Gathering in kitchen, drinking coffee
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Losing parts, to be used more
User related f/m	Missing out gossip
Other agents related f/m	—
Friends / Enemies	
F/E related to the practice	User
F/E amongst the agents from environment cards	—
F/E amongst other agents	Young friends

Table G.2: Workshop 1, Team 2—Object persona tables for novelty score

Team 2	
A day in life	
Functional activities	Working, resting
User activities	User studying, cleaning
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Losing a part, not warming coffee quickly
User related f/m	—
Other agents related f/m	Presented in the saloon
Friends / Enemies	
F/E related to the practice	—
F/E amongst the agents from environment cards	Kettle, blender
F/E amongst other agents	Electricity, other coffee machines

Table G.3: Workshop 1, Team 3—Object persona tables for novelty score

Team 3	
A day in life	
Functional activities	Waking up, start working, breakfast and dinner, sleeping, resting
User activities	—
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Being left dirty, more time with the cup
User related f/m	To be left alone
Other agents related f/m	Electricity cut
Friends / Enemies	
F/E related to the practice	Coffee cup, water carafe, humans, coffee jar, water
F/E amongst the agents from environment cards	Stove, kettle
F/E amongst other agents	—

Table G.4: Workshop 1, Team 4—Object persona tables for novelty score

Team 4	
A day in life	
Functional activities	Working, socialising, getting dirty, getting clean
User activities	User came to the kitchen, cat visited me, user left coffee inside me, used the kettle
Other agents' activities	Kettle works
Frustrations / Motivations	
Activity related f/m	Staying clean
User related f/m	Forgetting coffee in it, engaging all the users
Other agents related f/m	I am better than the kettle
Friends / Enemies	
F/E related to the practice	Cup, coffee, the user
F/E amongst the agents from environment cards	—
F/E amongst other agents	Tea, instant coffee

Table G.5: Workshop 1, Team 5—Object persona tables for novelty score

Team 5	
A day in life	
Functional activities	Sleep, wake up, first job
User activities	Everybody is in the kitchen, party, prepare dinner, hang out in the kitchen, drink coffee, make noise, drink tea
Other agents' activities	Kettle working
Frustrations / Motivations	
Activity related f/m	More use, more heat, fast cooling
User related f/m	Forget filter inside, forget it dirty
Other agents related f/m	Breaking kettle
Friends / Enemies	
F/E related to the practice	Coffee cup, coffee jar, likes to be clean, plug
F/E amongst the agents from environment cards	Cat, kettle
F/E amongst other agents	—

Table G.6: Workshop 1, Team 6—Object persona tables for novelty score

Team 6	
A day in life	
Functional activities	Working, sleeping
User activities	Meeting with friends
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Coffee grinder, breaking down, losing parts
User related f/m	Talking with users
Other agents related f/m	—
Friends / Enemies	
F/E related to the practice	Coffee jar, coffee mug
F/E amongst the agents from environment cards	Cat, tea maker
F/E amongst other agents	—

Table G.7: Novelty scores of teams in workshop 1

Teams	Object persona novelty score
Team 1	5.00
Team 2	7.00
Team 3	5.00
Team 4	9.25
Team 5	9.00
Team 6	6.00
Mean	6.87

Table G.8: Workshop 2, Team 1—Object persona tables for novelty score

Team 1	
A day in life	
Functional activities	Product in constant use, cooking, cleaning, adding modules, crepes, steam cooking, tea making
User activities	Storing, left the machine dirty and went to sleep, didn't clean the glass
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Love cleanliness, being together with other modules, having parts being upgraded, have a long stable life
User related f/m	Being left dirty, students' changing preferences, having multiple owners
Other agents related f/m	Rule the dorm kitchen, get replaced by other products, has to bear with heat from toaster, has to bear with left over tea grains
Friends / Enemies	
F/E related to the practice	Love multiple users
F/E amongst the agents from environment cards	Cat, toaster, stove, microwave
F/E amongst other agents	—

Table G.9: Workshop 2, Team 2—Object persona tables for novelty score

Team 2	
A day in life	
Functional activities	Keep the user awake, feed the user, on with water, on without water
User activities	Prepare study snack, prepare breakfast
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Final exams all the time, being thrown away, wrong use, regular user
User related f/m	—
Other agents related f/m	—
Friends / Enemies	
F/E related to the practice	Steam cooking, sandwich press
F/E amongst the agents from environment cards	Kettle
F/E amongst other agents	Instant coffee

Table G.10: Workshop 2, Team 3—Object persona tables for novelty score

Team 3	
A day in life	
Functional activities	Wake up, work, give some break
User activities	Clean the machine once a month
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Being used, sitting idle in the cupboard, being left dirty, burn the user, being forgotten, everyone use me
User related f/m	—
Other agents related f/m	Conquer the kitchen
Friends / Enemies	
F/E related to the practice	Docking station, old school, loser teapot
F/E amongst the agents from environment cards	Oven
F/E amongst other agents	Pan, pot

Table G.11: Workshop 2, Team 4—Object persona tables for novelty score

Team 4	
A day in life	
Functional activities	Morning coffee, barbecue, parties, gossip coffee
User activities	Users are in kitchen, they are not at home, users were in kitchen for a short time, made breakfast, had some guests and made breakfast together
Other agents' activities	The others are not used, windows are open
Frustrations / Motivations	
Activity related f/m	Being able to serve more than one person at a time, easy to store, work fast, easy to use and clean, misuse, being passive, being dirty, not being transformed, doing two practices at the same time, being used at least two times a day, always placed at the countertop
User related f/m	Socialising, forgot the machine in plug
Other agents related f/m	Being part of kitchen
Friends / Enemies	
F/E related to the practice	Users, coffee cups, coffee filter, steam cup, water tank
F/E amongst the agents from environment cards	Cats, sink
F/E amongst other agents	Inexperienced users

Table G.12: Workshop 2, Team 5—Object persona tables for novelty score

Team 5	
A day in life	
Functional activities	Fondue making on weekends, steam cooking at different times of the day, grill in the afternoons and evenings, take shower 3 days in a week, organise party
User activities	—
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Used at the same time, make fruit and cheese more delicious, being forgotten, being broken, high quality chocolate
User related f/m	Gather people to party, encourage socialising, organise bigger parties, friendship maker, mood booster
Other agents related f/m	—
Friends / Enemies	
F/E related to the practice	Chocolate, sweet, cheese, household
F/E amongst the agents from environment cards	Cat, kitchen applience, microwave, tea and coffee maker, fridge, oven
F/E amongst other agents	Water, electricity cut out, pots, forks, utensils

Table G.13: Workshop 2, Team 6—Object persona tables for novelty score

Team 6	
A day in life	
Functional activities	Making yoghurt
User activities	—
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Make three practices at the same time, work too much, keep parts together, happy to interact with user, can change its own parts, losing parts because they are interchangeable, take parts away
User related f/m	—
Other agents related f/m	Shelves, less dog noise
Friends / Enemies	
F/E related to the practice	Human
F/E amongst the agents from environment cards	Dogs
F/E amongst other agents	—

Table G.14: Workshop 2, Team 7—Object persona tables for novelty score

Team 7	
A day in life	
Functional activities	Fondue making
User activities	Cleaning in the morning, right before the use, wake up, dinner, home is vivid, having guest, didn't pay attention to the machine, move around
Other agents' activities	Together with fridge, at is active, kettle is used
Frustrations / Motivations	
Activity related f/m	Being warm, being used every hour of the day, tasting all the chocolate in the world, being stack in cabinet
User related f/m	Entertain user, be in crowd, listen talks, guests every day in the house, owner on a diet
Other agents related f/m	Small talks with cat, being far away from cat, decrease in fruit prices
Friends / Enemies	
F/E related to the practice	—
F/E amongst the agents from environment cards	Cat, refrigerator, kettle, microwave, cupboard
F/E amongst other agents	—

Table G.15: Workshop 2, Team 8—Object persona tables for novelty score

Team 8	
A day in life	
Functional activities	Fondue, used in the evening, collect energy during night
User activities	—
Other agents' activities	—
Frustrations / Motivations	
Activity related f/m	Transformed for other practice – it is like doing sports, without electricity, keep the chocolate warm, dirt of chocolate or cheese
User related f/m	Make people sociable and happy and full, hero of women in their period, hear more gossip
Other agents related f/m	—
Friends / Enemies	
F/E related to the practice	Banana, strawberry, kiwi, heat, summer, microwave
F/E amongst the agents from environment cards	Cat
F/E amongst other agents	Girl dorms

Table G.16: Novelty scores of teams in Workshop 2

Teams	Object persona novelty score
Team 1	9.12
Team 2	5.42
Team 3	7.47
Team 4	8.83
Team 5	5.89
Team 6	5.11
Team 7	9.30
Team 8	5.11
Mean	7.03

CURRICULUM VITAE

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WORK EXPERIENCE

2020–present	Dept. of Computer Science, Aston Univ.	Teaching Fellow
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PUBLICATIONS

Tuna, N. and Çağlar, E. An exploratory study for provocative prototypes: Creating Personas. In *DRS Learn X Design 2019*, Ankara, Turkey, July 2019.

Tuna, N. and Hasdoğan, G. Nesnelerin interneti için kurgusal tasarım. In *Ulusal Tasarım Araştırmaları Konferansı (UTAK '18)*, Ankara, Turkey, September 2018.

Tuna, N. Nesnelerin internetinin diyet takibi uygulamalarına etkisi. In *STS Turkey 2018*, Ankara, Turkey, September 2018.

Tuna, N. and Çağlar, E. Thematic analysis of online comments for design researchers to contribute to autonomous technologies. In *Proceedings of SIDeR '18, 14th Student Interaction Design Research Conference*, Helsinki, Finland, May 2018.

Tuna, N. Mock-up tools for creating user interfaces. In *10th International Conference on Design Principles and Practices*, Rio de Janeiro, Brazil, February 2016.

Tuna, N. and Kaygan, P. Ürünlerin Cinsiyeti ve Tasarım. *Arredamento Mimarlık*, (295): 110–118, 2015.

Tuna, N. and Şener, B. An investigation of diet apps for enhancing people's health and wellbeing. In *Proceedings of the International Conference on Engineering Design (ICED)*, Milan, Italy, July 2015.

Tuna, N. and Kaygan, H. Beyond prevention: Exploring the new technologies of graffiti. In *5T: Design and Resistance*, İzmir, Turkey, May 2014.

WORKSHOPS

Workshop co-facilitator with Emre Çağlar (2019), DRS Learn X Design 2019, Ankara, Turkey. Facilitating the workshop "Blatant Fabrications".

Workshop co-facilitator with Emre Çağlar (2018), Ulusal Tasarım Araştırmaları Konferansı (UTAK), Ankara, Turkey. Facilitating the workshop "Kurgusal Tasarım Kullanarak Kullanım Bilgisi Toplama ve Tasarım Öngörüleri Oluşturma (Gathering Usage Information and Creating Design Insights Using Design Fiction)".