Arrangement Design Studies

the introduction of the digital wall in domestic environments

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Abstract

This research focuses on the emergence of ‘digital walls’ that can project images onto almost all or even the entirety of interior (and perhaps exterior) walls, and what implications this might have for how we arrange our rooms. It demonstrates the arrangement, i.e., the way that domestic products are arranged physically, of rooms changes in the domestic environment in a complex scenario when using large screens. Due to the fast-growing demand for large screens, this product could potentially be available to be used by people in their home environments; however, it does not yet exist in reality at this scale. Constructing large screens can be carried out using different production methods. Here, this concept is called the digital wall, a very thin wall-sized interactive screen. The characteristics of the digital wall will vary to be able to create different scenarios. One such scenario is a space in the home where the surface of the wall is covered with screens, which allows multiple possibilities to experience and interact with digital content.

In this research, the social gathering space of homes, nowadays called the living room, is considered as a highly relevant space for installing the digital wall. In this space, the conceptual framework outlines the basic elements of the research and demonstrates the relationships between people’s interactions with the digital wall and domestic products in the domestic environment. I show two examples from design history to understand how arrangement changes impact the home environment: the transformation of the parlor to the living room, and entry of the television into the living room. These two examples are focused on the place in the home where people gather for socializing. The discussion of these examples led to the elaboration of the relationships between the elements in the conceptual framework.

I explored relevant design research methodologies to bring this future scenario into the present to understand the relationships between people and the digital wall. I applied research through design and the constructive design research approaches to frame the design research methodology. In this thesis, I set up seven series of design studies in two cluster groups: Supportive studies and Main studies. All of the design studies were conducted in the Design Research Lab, the actual space for carrying out the design experiments, prototyping the digital wall, and the setting of the experiments for user participation. The Lab was fully equipped with relevant technology and allowed me to use multiple methods to collect data while people were experiencing the design study sessions. The Lab
was useful as a platform to understand user experiences, barriers for interactions as well as people’s experiences in a simulated space of a domestic environment.

The main contribution of this research is to understand the forms of arrangement changes when people use the digital wall in homes. The research demonstrates two significant implications that are seen in two forms of arrangements: tangible arrangement and imperceptible arrangement. These findings are useful for both designers and users of the elements of domestic contexts and the relations that can be shaped by the presence of a digital wall in home environments. This understanding may provide design guidelines in future scenarios in which the digital wall is used in homes. The findings are also beneficial for designing the domestic environment, improving the arrangement of space, and raising the requirements for designing domestic products.
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In this thesis, I investigate the emergence of ‘digital walls’ that project images onto almost all or even the entirety of interior (and perhaps exterior) walls, and what implications this might have for how we arrange our rooms. In this research, the term arrangement refers to ‘the way that domestic products are arranged (physically) in a space’. This definition is chosen because this dissertation explores how whatever is included in a physical arrangement can lead to certain experiences and create tangible or invisible implications for the user. This thesis aims to make potential implications visible and available for understanding future scenarios in which the digital wall is used in a social gathering space at home, contemporarily called the living room. The living room is chosen as the effective center of socializing in the home. The contribution of this work, then, is in an increased understanding of these tangible and imperceptible arrangements.

This is a Ph-Licentiate thesis in Industrial Design, and the conclusions are geared toward Industrial Design. However, part of Industrial Design is Interaction Design, and designers design the interaction that they intend to support. For instance, in different circumstances, “Industrial Designers, are increasingly using information technology (IT)” (Koskinen et al., 2011, p. 9) in designing a product. This thesis uses a constructive design research approach to explore the arrangement changes in relations between people and the digital wall in domestic environments. This relationship is seen as a mutual interaction between one or several users with the interactive digital wall (Figure 1).

The main focus is an investigation of the relationships between people and the digital wall. Here, the digital wall has been considered as a type of rollable ‘large-
screen user interface’ that can be installed on flat wall surfaces in home spaces. Large screens have become more available and affordable, and researchers have become interested in investigating the different technical and educational aspects of such screens (Czerwinski et al., 2006, 2003; Huang & Menozzi, 2014; Khan et al., 2009). Meanwhile, television screens have been getting bigger and bigger; we have seen large screens in movies for a long time. The digital wall might not be a reality yet, but it is a concept quite likely to become available soon. Currently, the digital wall is at a concept level only; however, the final product will be available with several features as an interactive display to provide audio-video content on a big surface. Since the digital wall does not exist yet; this thesis does not attempt to solve a problem or optimize a situation, because the actual problem does not exist at present. Instead, the problem description is identified as a problematic situation instead of framing research as a solution to particular problems. In this situation, the probable relationship of the interaction between the user and the digital wall is seen as a complex scenario that requires a wide-ranging approach to interpret the possible situations that might arise.

This complexity presents several aspects for interpreting the relationship between user and artifacts. With the specific aspect of complexity, Janlert and Stolterman elaborate that complexity can appear in different situations in which relationships between people and artifacts occur (Janlert & Stolterman, 2017, pp. 74–96). Considering this complexity, this project has two views: first, the complexity shows that this design research should not linear, as it consists of several elements that may be hard to capture with traditional research approaches. Second, in a complex situation, such as the relationship between the user and the digital wall, we require a mechanism to articulate the complexity of the facts and what is taken into account (Janlert & Stolterman, 2017, p. 83). Accepting the complexity in this relationship serves as an awareness of the situation that users

Figure 1: One of the most basic interaction between user(s) and the digital wall.
will encounter in the future, and it has been considered in the design research process here.

Several aspects can enter into this complex situation of interaction; some of these aspects directly correspond to this relationship and the others may not. For instance, the digital wall as an artifact will be presented with complex production methods. These solutions might refer to the way of producing the artifact or any operational system; Janlert and Stolterman called it internal complexity (Janlert & Stolterman, 2017, p. 85). They have also identified other major complexities that are important to consider in a complex possible situation: user complexity, environment complexity, and interaction complexity (p.85). Based on these possible complexities and similarities with my research situation, this thesis acknowledges that relationships with arrangement organization are complex. There is no attempt to simplify the complexity, but it requires a frame to suitably investigate the complex user experiences with the digital wall.

The assumptions about this complex situation in this thesis consist of four main elements: users, the digital wall, domestic products, and domestic environments (Figure 2). The digital wall potentially will be used in many interior and exterior spaces. Based on the initial estimation in this research, most domestic environments have a high potential to install the digital wall. Since the range of domestic environments is varied, I use the expression ‘home’ as a synonym to the notion of the domestic environment. In the home environment, we all use domestic products in everyday life: furniture, frames, curtains, table, shelves, carpet, electronic devices, and things that potentially can be connected to the internet. Here the digital wall is seen as a type of large display, and it will be accommodated together in this research (and the home itself, in the future) with other domestic products that have been used for many years. In the conceptual framework of this condition, a triangular relationship is assumed between ‘user, the digital wall, and domestic products’; this triangle is placed in the domestic environment (Figure 2). This framework demonstrates an abstract understanding of this condition and the relation between elements. It is essential to acknowledge that the items of this framework are not assumed to have equal impacts on each other in this complex relationship.

The conceptual framework serves as a guideline to begin studying the impacts of the digital wall on arrangement changes. The arrangement is the underlying assumption to help reason how the digital wall will change “between the existing and not-yet-existing” (Nelson & Stolterman, 2012, p. 120) situation of our homes. Here, the arrangement is chosen as one of the possible ways that
emerge from the multiple degrees of changes from the existing situation to a future existence with the digital wall. This understanding serves as tangible and imperceptible arrangements that are discussed in Chapter 6 of this dissertation. This thesis attempts to show two examples that can connect to the notion of arrangement in this situation.

In response to this requirement, I use design histories to study previous historical examples of how the introduction of a new technology in the home has resulted in new ideas about how to furnish a room. Here, the mechanism of reading design histories is not synonymous with considering the exact scenario in the past for use in the present. Instead, investigation in design histories enables us to establish our thinking and reflect on our future (Fry et al., 2015, pp. 205–211; Löwgren & Stolterman, 2004, pp. 144, 158). In Chapter 2, I describe two relevant examples: first, I investigate the arrangement changed at the beginning of the 20th century in America. This example shows the relationship of invisible elements such as cultural distinctions, consumption visions, product choices, and industrialization movements that transformed the structure of the parlor to the living room (Halttunen, 1989, pp. 157–189). Television is the second example that shows how this domestic object has influenced our everyday lives in homes (Silverstone, 2003); it has become the pivotal point for arranging the living room. Analyzing examples in design histories provides a rationale for practicing critical thinking about these elements in the historical contexts of arrangements and reflect on the learning to see the present and possible future.

Domestic objects are set in homes with intentions and plans. In this thesis, it is assumed with the entry of the digital wall to the living room, this technology would bring different dimensions into the existing arrangement system; it would also influence people’s life routines, i.e., “co-shape human action and perception” (Verbeek, 2005). For instance, we have seen changes in the past
with the entry of the television in homes. The television has influenced in various ways people’s behavior and their relationships in home spaces (Silverstone, 2003). The relation between people and the digital wall also can be taken into account in interdisciplinary research between architecture and interaction, as Wiberg (2020) articulates, “digital technologies give us the tools to reimagine, repurpose, and ultimately change spaces”. When the digital wall comes to our home, it might bring its type of relationship to the existing structure of current home arrangements.

1.1 Research Approach

I used a design research methodology as well as constructive design research to frame this thesis. In this frame, the research through design (Frayling, 1994) and designerly ways of practicing research enabled me to bring the relevant elements to the research process (Koskinen et al., 2011, p. 23). In Chapter 3, I discuss the value of choosing a design research approach in comparison with the scientific research approach. The arguments indicate the design research approach is capable of gathering infinite information and helps to frame this research with incalculable values (Nelson & Stolterman, 2012, p. 123). The choice of using the design research approach provided possibilities to prototype a future scenario and study the complex relationships between the user and the digital wall.

As I planned the experimental approach for the design studies, two features were considered in the design studies: data collection, and the way of framing the research. The ways of data collection are based upon practice-based research through design (Zimmerman et al., 2010). I used programmatic design research to investigate and develop the research. The programmatic approach provides a system to connect the design research elements to each other from theories to the design experiments (Redström, 2017, pp. 83–111). I collected data and evidence to demonstrate different possibilities within the design space (Redström, 2001). Programmatic design research was applied to glue the research elements together and make the connections between the research pieces.

I used the Design Research Lab, described more fully below, to establish the experiments and simulate possible scenarios of using the digital wall in home spaces. The Lab provides possibilities of using multiple methods to produce an original reflection of participants’ experiences and demonstrate the general patterns of the relationships between the digital wall and participants. In this
section, I explain the stage when the Lab was used and the structure of setting up the experiments and the flexibility of the Lab system that could be adopted in the various structure of design studies (Abdipour et al., 2016). The Design Research Lab was chosen because it offered possibilities of prototyping multimedia, such as audio-video contents, and simulating the appropriate scale of the digital wall on three connected wall-sized screens. The Lab was considered for conducting the design studies, and a powerful platform to produce design knowledge by its ability to host the design experiments.

The methods used in my research provided rich data from each experiment. The purpose of using multiple methods was not capturing all the details of each study session; instead, the usage methods allowed me to reach different types of participants’ behaviors with different feedback. In addition, during the studies, I realized that only using one method was not sufficient for monitoring the entire set of experiments, or some participants were not familiar with how to express their opinions. Therefore, using multiple methods, such as interviews, questionnaires, observations, during the studies were used to build a holistic picture of complex user experiences. Particularly, being able to use video recording as a part of the observation method enabled me to review the study sessions several times in the analysis phases and pay attention to the details from different angles. Using multiple methods not only had benefits for my research but also it was useful for pedagogical purposes (Abdipour, 2019) in the Industrial Design program in my home institution.

1.2 Motivation

There are four motivations in this thesis, each of which are interconnected: growing demands for large screens, practice-based and designerly ways of doing research, the calls of design pedagogy, and design for inclusion.

1- Growing demands for large screens. As noted above, large display user interfaces have become more available and affordable, and researchers have become interested in investigating the different technical and educational aspects of such screens (Czerwinski et al., 2006, 2003; Huang & Menozzi, 2014; Khan et al., 2009). In this research, the digital wall is seen as a type of technology; the research focuses on the interpretation of the relationship between people and technology in domestic environments. In a broader perspective, there is a growing understanding of how technology finds its way into our homes and everyday lives (Alavi et al., 2019; Wiberg, 2020). In this sense, this thesis
was considered to be necessary to further conceptual and empirical studies investigating how technology causes a transformation in people’s life. With these technologies, we arrange our activities and ultimately the ways we use our homes, or how we occupy our homes with activities and objects. It is essential to consider that this research is not focusing on developing new technologies, such as the digital wall; instead, it is one empirical study of how to arrange our future living rooms in the presence of the digital wall.

2- Practice-based and designerly ways of doing research. The second motivation for using the Lab refers to the willingness to use the Lab by the research partners. A research group in material sciences, Fiber Science and Communication Network (FSCN), at Mid Sweden University has started an inquiry to investigate applications, i.e. the digital wall, for paper products that are compatible with contemporary machinery. In their visits and discussions, they realized that the Lab, with its user-centered design approach, has the appropriate potential for prototyping and simulating design experiments. In their research, the paper industry is facing the limitation of demands in paper products with current types of machinery. The research partner estimates that there will be significant demands to use the digital wall—for instance, home spaces will be one of the primary targets for this concept. The Lab was chosen to provide an ambient display environment to conduct design studies and simulate the home environment with the digital wall.

3- The calls of design pedagogy. The Design Research Lab was one of the plans of the Industrial Design Division at Mid Sweden University (MIUN) to develop the subject program. There was a need to update the pedagogical courses for different types of design that were associated with the Industrial Design program: Service Design, Interaction Design, and as Norman suggested “Behavioral studies” in design programs (Donald Norman, 2010). The purpose was to improve the design knowledge of students to practice with different approaches in the design process alongside, as Seago and Dunne articulate, “traditional design practices” such as prototyping and design workshops (Seago & Dunne, 1999). The learning outcomes of using the Design Research Lab should be revealed in the values of teaching and learning at all levels of the Industrial Design program: Bachelor, Masters, and Ph.D. programs.

In addition, the Design Research Lab can potentially be set up for collaborative projects with other disciplines, both in terms of design projects and design research. The Lab serves as a significant foundation to establish design theories and set up constructive and collaborative design experiments (Binder et al.,
Throughout this thesis process, as well as conducting my design studies, the Lab was developed at different levels, i.e., simulating various design scenarios, evaluating different types of design solutions, and rapid prototyping (Abdipour et al., 2016). As the Design Research Lab director, I spent several years facilitating and developing the Lab to involve different groups of users in various design scenarios. The Lab enables design students and researchers to construct their prototypes and evaluate different design solutions (Abdipour, 2019).

4- Design for Inclusion. This rationale consists of two parts: the first part refers to personal motivation. As an artist and design researcher, I am keen to understand in which ways I can apply the knowledge of “practice-based design” into an actual “design research” project (Koskinen et al., 2011, pp. 18–28). For instance, in this research, I engage in the use of design interpretation to describe the design research process when the research project is not problem-oriented. This design research faces a situational problem that the standard research measurement scale is inadequate to clarify the complex scenario (Nelson & Stolterman, 2012, p. 120) and interactions between people and the digital wall.

The second part refers to design responsibility and commitment. Based on an initial estimation by the research partners, it is expected that diverse groups of people will use the digital wall in the future. The digital wall might be an attractive product for some people and organizations. At the same time, it can profoundly influence others’ lives, i.e., people with special needs. Since this display will take up a large space of the wall surfaces in home spaces, it is essential to know the users’ attitudes (Stephanie Wilson et al., 1997) in terms of using the digital wall. Hence, the user-involvement approach has an essential role in contributing to design studies. This refers to design responsibility and reflecting user behaviors and increasing the awareness of the probable implications in relations with the digital wall (Wever et al., 2008). In this thesis, user involvement is an inseparable approach to design research; it has been embedded in the design studies’ structure.

1.3 Research question

This thesis has been framed to explore the possible future relationship between people and the digital wall; however, to frame the investigation and find an area to establish this research, I consider one primary question, one main question, and two sub-questions.
Initial question

- What will change when we use the digital wall in home environments?

This question was constructed based on the frames and presumption of the research partners on the potential of using the digital wall. Although this is a broad question, it focuses on a direction toward making the main question. The initial question attempts to tackle forming a research area for starting the investigations. It offers an overview to identify guidelines for experiencing the digital wall in home environments.

The main research question

- How will the introduction of the digital wall influence the arrangement of the social gathering space in home environments, such as the space we nowadays call the living room?

The main research question attempts to reflect the user experiences of using the digital wall in an accessible condition in the Lab environment. Each element of the main research question triggers the investigation for generating knowledge in the design research process. This question is not expected to demonstrate results by a measurable scale, instead interpreting the holistic situation (Nelson & Stolterman, 2012, pp. 119–126, 137–158).

Sub-questions

1- What is the appropriate design research methodology for conducting design research experiments to investigate the relationships between participants and the digital wall?

2- In what ways do design histories enable us to exemplify the arrangement changes of the living room in the presence of the digital wall?

These two sub-questions present two points of entry for opening up the discussion. For both sub-questions, several possibilities can be considered to articulate the situation, and I will discuss them in two different chapters.
1.4 Series of experimental design studies

In this Ph-Licentiate thesis, seven design studies were conducted to answer the research questions. Conducting the design studies have significant roles in shaping the contribution of this thesis. The design studies are divided into two parts: Supportive studies and Main studies (Figure 3). The design studies are evolved in chronological order from the Supportive studies to the Main studies. The Supportive studies were conducted to frame the explorative studies from different aspects to develop the initial research question. At the same time, the Supportive studies were useful to practice for identifying the potential of the Design Research Lab. In the Supportive studies, multiple methods were used to identify the focus of the overall study. Each Supportive study revealed pieces of understanding, identifying limitations of the experiments and setting up a critical thought process as part of a progressive explorative process.

In the second part of the series of studies, the three Main studies attempt to answer the main research question through experimental design research. In the Main studies, participants engaged with the arrangement of space with domestic products in the presence of the digital wall. Each design study, Supportive and Main study, has an individual structure with a particular task that has been given to the participants. The analyzed data were interpreted to demonstrate the results and insights. The studies were framed to articulate the holistic attitude of scenarios of using the digital wall in a simulated living room space.
1.5 Thesis structure

I have structured this thesis into seven chapters. To guide the readers through this thesis, I explain briefly the topic of each chapter:

Chapter 1 introduces the thesis subject, purposes, motivations, design research approaches, and research questions. Chapter 2 gives an overview of the research scope and explains the main elements of the conceptual framework and the related theories. In this chapter, I elaborate on two examples in design histories and demonstrate the reasons for transformations in the social gathering space at home. Chapter 3 covers the design research approach, which scaffolds the structure of this thesis. In addition, it articulates the Design Research Lab as a platform to conduct design experiments, and the methods used in the design studies. Chapter 4 presents a series of studies. I present this chapter in two parts: the first part explains four Supportive studies in the Lab. The Supportive studies demonstrate the dilemmas and findings about the possible impacts of the digital wall. The second part focuses on the three Main studies: investigating the arrangement changes in the presence of large screens. Chapter 5 presents the findings from the design studies. I present several results that are relevant to this work and the design research communities. In Chapter 6, I reflect on the implications of using the digital wall in a domestic space. This chapter shows two major forms of arrangement changes: Tangible arrangement and Imperceptible arrangement. In Chapter 7 I present design suggestions and suggestions for future work on this research topic.

Limitations

In this research, there were two types of limitations for user participation in the Lab environment. First, the Design Research Lab had limited space with strict safety rules; only a limited number of participants could join the design experiments in each study. Second, I acknowledge that all design studies were conducted in a controlled design stage in the Lab environment. The participants do not experience the actual design scenario in the Lab as would actually be in reality (Koskinen et al., 2011, p. 62). This research accepts the constraints of using the Lab to investigate future digital wall scenarios for each design study. However, in this constructive design research, the aim of presenting the outcomes of studies was not to generalize the findings of the design experiments to every situation.
1.6 Summary of Contributions

The main contributions of this Ph-Licentiate thesis are the series of design studies and form of arrangements, and the design research approach.

Tangible Arrangement

This contribution portrays the visible arrangement changes. These findings demonstrate that using the digital wall can influence how the domestic environment is used. In Chapter 6 I present three forms of tangible arrangements: Given arrangement, Taken arrangement, and Blended arrangement. For instance, the findings from the Main studies 2 and 3 show the number of domestic products needs to be reduced from the space, such as other televisions and bookshelves. In addition, new furniture choices need to be developed to be adapted with the size of screens and body positions of users. Any physical objects that are placed in between participants and the digital wall can interfere with the relationships of users with the digital wall. The arrangement in domestic spaces is undergoing a significant change; some participants asked for a particular space, i.e., a room with curved walls, to accommodate the digital wall, and the space needed in front of it to completely view it.

Imperceptible Arrangement

Some of the findings of experiencing the digital wall were identified as invisible impacts. During the main studies, the domestic products were moved far from the digital wall towards the center of the domestic space. The participants also realized that they needed space to have an appropriate experience with the digital wall; they rearranged their experienced positions to keep some distance from the digital wall. This distance could occupy the home space as an invisible volume in the space. The studies demonstrate there is gravitation in the space where users move toward the center of space. Although these impacts are not visible ones on the participants, it influences participants’ behavior, and consequently, the significant rearrangement of the domestic space will be inevitable.

Contributions in design research methodology

Using the Design Research Lab is beneficial for conducting design studies and constructing a design research methodology. The Lab is equipped with technological tools and facilities; using these systems tempts the design researchers to scaffold their research upon the Lab system. However, using the Lab to construct design research methodology, has both benefits and drawbacks.
I have realized the Design Research Lab has a remarkable potential to conduct and set up a variety of types of design studies and involve a different group of participants (Abdipour, 2019). This methodological contribution can be taken into account as a constructive approach in the Industrial Design field to work with various design studies and user experience in different design scenarios.

**Future research directions**

This thesis suggests some future work to develop the experiences of using the digital wall in domestic spaces. These suggestions were not recognizable at the beginning of this study; instead, they were identified as valuable aspects during the design research process to develop this research. Sustainability is one of the most critical challenges that need to be developed in future research, i.e., to increase “the quality of our living contexts” (Manzini & Cau, 1989). Also, practical development can refer to developing operational systems and user interfaces hand-in-hand with one another to establish appropriate interactions. Moreover, studying ethical issues is a crucial aspect to be improved. During the design studies, participants were concerned about how the digital wall can be used appropriately for all family members. How could they link their own devices to the big screens as the digital wall and protect their privacy? Finally, these studies have been conducted with time limitations for academic purposes. In the next stage, it will be useful to investigate the experiences via long-term participation in an actual domestic space. These suggestions in this domain will be useful to improve the quality of the user experience.
Chapter 2

Elements and Framework

Overview
This chapter presents the essential elements and grounding to identify the arrangement changes caused by using a digital wall in the home environment. First, I present the notion of the arrangement in this thesis concerning the social gathering space in the domestic environment. In this thesis, a social gathering space, i.e., the living room, is seen as a gathering spot and one of the possible areas in the home where to install the digital wall. Then, I introduce the conceptual framework and the relation of elements with each other. These elements consist of *people, the digital wall, and domestic products in domestic environments*. The discussion demonstrates the current and prior arrangements in the social gathering space in a domestic environment.

In addition, I demonstrate two examples of arrangement changes in home environments that have come about in the past: the transformation of the parlor to the living room and the entrance of the television into the living room. These two examples are focused on the place in the home where people gather for socializing. The discussion of these examples leads to the elaboration of the relationships between the elements in the conceptual framework. From the pieces of evidence emerge the variety of values that are crucial to understanding the influences of the arrangement changes in the domestic environment.

In the following, I describe the concept of the digital wall as a type of large display user interface. The explanation shows the characteristics of the digital wall that can be applied to future scenarios using this concept. One major issue in the research about large displays is seen with the appropriate user interfaces for the interaction. Finally, I illustrate the analysis of the literature investigation
that corresponds to the conceptual framework. This contribution provides useful suggestions to frame the design research methodology and design experiments in the next chapters.

2.1 Arrangement

Despite its common usage, the term ‘arrangement’ is used in different disciplines to mean several things. There are a number of different definitions of arrangement that are used as “the way that things or people are organized for a particular purpose or activity”. Similarly, an arrangement can be expressed as “a plan for how something will happen”, and “a group of objects that have been put in a particular order or position”. Here, the term arrangement relates to things in the domestic environment. According to Kent (1993, Chapter 1), the arrangement can be exemplified as a sign system that affects all the human senses. The term ‘arrangement’ reflects a broad range of definitions from general meanings to a specific use. It has also been mentioned in different fields: music, landscape design, interior design, art, architecture. In this thesis, ‘arrangement’ is used to refer to the area of the domestic environment and interior spaces.

The Definition of the Arrangement

The term arrangement, as used in this dissertation, refers to the understanding of the relationships between people and objects in domestic spaces. In this thesis, the notion of arrangement is defined as ‘The way that domestic products are arranged (physically) in a space’. This definition is chosen because the dissertation explores how whatever is included in a physical arrangement can lead to certain experiences and create tangible or invisible implications. It also provides possibilities to pay attention to details, minor and general changes in the design when participants experience digital walls in the Lab environment.

Design arrangement emerged from architecture design and interior design contexts, where some of the pioneers elaborated the ideas of designing homes, such as Le Corbusier, Elsie de Wolfe, and Ludwig Mies Van Der Rohe. Despite the acknowledgment of the former’s works, building on Tafuri, John Thackara argues “the buildings are no longer an object; it is the only place in which the elementary assemblage of single cells assumes physical forms” (Thackara, 1988). This means that designing homes brings more than individual aspects of talented designers. In the same manner, the arrangement at home refers to the wide range of examples in design, seeing the multiple aspects can be a double-
edged sword. In this thesis, the term ‘arrangement’ can be useful for considering different opinions, at the same time, it can be problematic to find the relevant context in linkage with the particular research subject.

We all have experience with arranging our home environments. Each arrangement has its purpose; it may consist of some movements of objects, a table, carpet, sofa, or it may refer to significant change through designing a home environment. In a domestic environment, elements are arranged to create harmony to increase satisfaction, “each object contributes to the room, resulting in a feeling of unity” (Henton, 1972; Nissen et al., 1994; Stepat-De Van, 1971). As Norman discusses, we arrange our domestic environment “the better to serve our needs” (D. A. Norman, 2004, p. 224). Mostly, the results of arrangement performances are seen as tangible changes; however, some concerns are not visible. These concerns also influence arrangement changes, such as people’s habits, cultural background, and the implications of a particular location. In this thesis, the arrangement is seen as a powerful judgmental aspect. Here, the term arrangement not only considers the scale of changes but also takes into account translating the invisible reasons that come from users’ behavior by interacting in the environment.

This notion of arrangement implies a broader range of relations between objects in space. It also refers to people’s behavior as Verbeek (2005) scrutinizes the relations between technological mediation to co-shape human actions, habits, and family life. In the description about responsibilities between people and things, “technology embodies ideas and morals of its creators, in their attempt to make technology part of people’s lives. But, not only do designers co-shape particular use-acts, the mediating role of technology extends beyond the individual situation, to society” (Verbeek, 2005). Following the arguments about the impacts of technology, Wiberg states “we inhabit built environments where digital technologies not only occupy space but also actively work for us in the production of new social places” (Wiberg, 2020).

The notion of arrangement may have some overlapping definitions with terms such as layout in architecture. To clarify, by considering my architecture and interior design background, the relation of notions of this vocabulary are chosen cautiously. For instance, there are related notions in architecture: program building, space planning, and spatial layout and guidelines for “interactive furniture layout” (Merrell et al., 2011). These notions, still, are part of our related but different areas, and it has to do with the built environment and with our physical environment. Also, notions have been developed concerning
the physical environment. Here, I also have engaged with part of the digital environment, and I have been interested in not just relying on different traditions to read a part of digital space. However, I wanted to come with notions like the imperceptible arrangement, for instance, that is generated based on my empirical studies. The established notions in architecture are seen in traditions and functions; these notions are useful because they provide an understanding of what has been accomplished so far.

Other related research

In the world of relations between technology and people, Sherry Turkle (2017) expresses in her book, ‘Alone Together: Why We Expect More from Technology and Less from Each Other’, that “we make our technologies, and they, in turn, shape us” (p. 19). Turkle does not advocate advanced technology, but by using assessment of technology, she reflects in human values and relationships “how technology reshapes identity because identity is at the center of adolescent life” (p. 169). In other theoretical work, for instance, Henry Lefebvre (1991) on the production of space, builds his arguments to bridge the gap between the realms of theory and practice. In Interaction Design, Benyon & Mival (2008) make distinctions between Designing for relationships and Designing for function; they construct their arguments on the ideas of Bickmore and Picard that “relationships provide emotional support. Emotional integration and stability are key aspects of relationships” (Bickmore & Picard, 2005). The exemplified theories demonstrate wide-ranging approaches to the relations between people and technologies. In this thesis, while multiple dimensions potentially can be reflected in the design exploration, I decided only some of them are aligned with the scope of this research.

Social gathering space

In this thesis, one of the possible areas of using the digital wall at home is in a space for social gathering, such as the space we nowadays call the living room. The living room has been considered as a social gathering space; however, the structure of the home has been changed in different periods of constructing the home environment. Each spot in the home is devoted to certain purposes: “the geography of the home is a place that people experience political, cultural and social activities” (Blunt & Dowling, 2006). For instance, the culture of local and regions in a country might help to understand a better perception of domestic environments (Bronner, 1989). The domestic environment is seen broadly in the architecture context; reviewing the history of building the home is beneficial for describing the meaning of domestic environments.
The notion and function of the domestic social gathering space have undergone changes related to both function and style. Sometimes one style in the past emerges in another period like the Victorian era (1837–1901) of the arrangement of the domestic spaces that are influenced by the 18th-century (Quennell, 1980). According to Quennell, there is an essential link between “the art of talking and the art of living there has always been a vital link”. In the Victorian period, “as civilizations developed, manner and etiquette socially accepted behaviors for all human interaction….and talking emphasize when dining in public” (Downey, 2013, p. 63). At the same time, Downey elaborates that the dining room was arranged with specific rules among “the complex decorative objects and the organization of objects”. The arrangement of the dining rooms, as a social gathering space, is presented as a complex orchestration that is selected obsessively to be used during the socializing time in home environments. The changing of the title of the social gathering space over the centuries implies the varied dimensions for space and arrangement to establish appropriate setups for a complex relationship in a space which is currently called the living room.

**Conceptual framework**

In this thesis, the conceptual framework is one aspect that demonstrates how the elements are engaged with each other and create one possible future scenario (Figure 4). Many aspects can be applied to show the situation, and each view can give a different understanding of this situation of using the digital wall.

![Figure 4: The abstract view of the elements of the conceptual framework.](image-url)
The conceptual framework provides a way to study the elements separately or together in a particular direction. This framework does illustrate a probable relationship between the major elements to provide the possibility of searching for and bringing together the relevant theories and examples. This framework is also helpful to build an understanding of how the arrangement changes when people experience the digital wall in domestic environments.

The framework consists of four elements: the user, domestic product, the digital wall that are connected to each other and are based on the domestic environment. These elements of the framework have been identified in literature with different synonyms and term definitions that correspond with the idea of the conceptual framework.

*User:* Synonym terms for ‘user’ can be replaced by ‘People’, or ‘Participants’ (Kujala, 2003; P. Wright et al., 2005).

*Domestic products:* This term includes synonymous terms like ‘Home Objects’, ‘Household objects’, and ‘Home products’; in Norman’s world view, this is called ‘Everyday things’ (Don Norman, 2013).

*The digital wall:* This word does not exist in the literature; the term has been created to use in this thesis. However, the digital wall has been identified with similar concepts in the literature: ‘Large display, ‘Ambient display’ (Andrews et al., 2010; Czerwinski et al., 2003).

*Domestic environment:* It has been considered as a social gathering space, and it can be replaced by ‘Living room’, ‘Parlor’, and ‘Dining room’ (Halttunen, 1989; Greig & Riello, 2007; Nissen et al., 1994; Silverstone, 2003)

These elements of the framework are tied together; however, in different combinations. The elements have been looked at from two directions: The first part implies understanding the arrangement in the group combination of ‘user–domestic products–domestic environment’. The purpose of making this group is to show the values that can influence the arrangement changes in home environments. The second part presents the studies of the digital wall. This part demonstrates the similar concepts to the digital wall and characteristics of large display user interfaces that have been studied in the literature. The classification was progressively developed in the literature review process. These two parts are aimed to demonstrate the basis of the present studies and elucidate the perception of the arrangement in this thesis.
Two examples of arrangement changes

The arrangement is associated with multiple elements in domestic environments. I describe two examples to clarify the arrangement changes in the social gathering space in two historical periods:

- The transformation of the parlor to the living room
- Arrangement with the television

These two examples were chosen to draw the frame of investigation for the main research question. Although various examples and aspects might be relevant, these two examples are helpful to elaborate on the principal elements in the main research question. First, I investigate reasons for a designated name in a home space that contemporarily is called a living room. The evidence shows the root of this naming and multiple factors causing transformation from the parlor to the living room. Television, as the second example, is seen as a technology that entered into the living room and caused changes in different directions in everyday life and arrangement changes of the living room. These two examples are focused on the place in the home where people gather for socializing. In aligning with the arguments in the literature, about the values of reading design history, (Fry et al., 2015, pp. 205–211; Löwgren & Stolterman, 2004, pp. 144, 158) the elaboration of the past is aimed to show the arrangement alterations and reflect on our future.

2.2 Transformation of the parlor to the living room

The first example focuses on the transformation from the parlor to the living room. In the trajectory journey to the past, Halttunen’s work was identified as an example to describe the shifting from the parlor to the living room (Halttunen, 1989, pp. 157–189). Her work was published as a book chapter in the book: ‘CONSUMING VISIONS—Accumulation and Display of Goods in America, 1880–1920’ (Halttunen, 1989). In this book chapter, the author reflects on the holistic aspect of American culture and movements to frame domestic spaces and rethinking the character of the home in that particular period. Halttunen’s writing presents an important piece of evidence to show the transformation of the parlor to the living room as a new social gathering space. She elaborates the motivations of revolution from the parlor to the living room: inclusive views such as people’s behavior, cultural privileges, product choices, and aspirations to design a living room. The narratives of her writing are demonstrated as
inspirational discourses and reflection of the situation of the probable use of the
digital wall in the home environment.

Parlor
Unlike the living room, the parlor is a closed space for daily life and is an
arrangement of high-class crafts, such as domestic products and furniture to
display to a few groups of people and visitors of the home. The

arrangement of the parlor is influenced profoundly by the style of Gothic art
and design and followed by the social principles of the Victorian era (Halttunen,
1989, p. 160). In the parlor, the aspired-to home arrangement significantly
expresses the social class and personality of the homeowners, because the parlor
is “the face of the house” (G. Wright, 1983). In these situations, social values
govern the style of the parlor arrangement as a private space to be used on
particular occasions.

Figure 5: The role of walls to show information and character of the owner of the home
to the visitors, circa 18th century. The image takes a quote from "Anon. Frederick
Elegantly Furnishing a Large House Etching and engraving with hand coloring, 1786.
Lewis Walpole Library Yale University" (from Greig & Riello, 2007).
As well as the importance of furniture and domestic products, walls have an essential role in exposing the character of the owner. The walls are used as a vertical element with the purpose of separating the parlor from other parts of the home, and it provides a base to expose the decorative items: colors, frames, wallpapers, paintings, and mirrors. In this sense, the walls are used as a surface to show the decorative items together with a variety of objects that are needed to be excellently organized (Halttunen, 1989, p. 160). To illustrate the character of the parlor, objects, and decorative items on the walls endlessly present actual information to the visitors in the parlor space (Figure 5).

**Living room**

At the beginning of the 20th century, the idea of the living room replaced the parlor as a new place for family gathering. In work undertaken by Elsie De Wolfe (1913), the term living room is assigned to “a room for Live in suited for all human needs”. Her reasoning implies that the openness aspect offers different ways of arranging; various activities that provide for casualness, friendliness, and at the same time for family living. De Wolfe advised that the living room would serve a variety of functions and should fulfill the needs of daily life (Halttunen, 1989, pp. 174–177). The main impacts of the living room are recognized as eliminating the incommensurate parlor decoration and shift to a new arrangement for physical activities in everyday life.

The main argument of Halttunen emerges from the transition from the parlor to the living room by the culture of the personality in America. In her view, the living room is presented as a new organization of the middle-class domestic space and a new understanding of the meaning of domestic things. In this regard, several elements of the mechanism are shown: the influence of beliefs, e.g. Christianity, domestic layout, the connection of interior space with exterior style, and specialization of the space. In relation to arrangements, Halttunen (1989) was not assumed to take a position from a design aspect; she also elaborates both models of parlor and living room in the alignment of the theme of social and trait values that can influence the arrangement of a social gathering space.
Analysis of arrangement in two spaces

Halttunen’s writing is used as a source of inspiration and conveying two models of spaces, the parlor and living room. Here, I demonstrate three essential elements of the conceptual framework that are interconnected and have mutual impacts on each other in the arrangement of the spaces: domestic products, people, and activities in the space.

**Domestic products:** In the parlor space, high quality produced domestic products are used to expose the character of the owner, but these days, not so many writers celebrate that style. Building on Wharton and Codman, Halttunen criticizes this idea as opposed to “architectural sincerity”; they believe the domestic products in the parlor are costly and shameful (Halttunen, 1989, pp. 172–177). Following Halttunen’s explanation, the living room’s domestic products are functionalized as a form of language to offer a new vision and proper arrangement where space has expressed the personality, function, and meaning in design.

**People:** The parlor’s arrangement system creates a barrier for moving smoothly within the space due to the lack of space between the objects; people feel immovable in positions to interact with elements in the space. In the parlor space, people maintain themselves in particular body positions in a pre-arranged set of furniture. On the contrary, the living room provides a space for joy and people both in daily life and festivities. (Halttunen, 1989). The structure of arrangement in the living room offers space for the reunification of family members, and the people of the home are capable of changing the elements to experience comfort and restfulness.

**Activities:** The arrangement in the parlor is organized for non-daily activities and a small group of visitors to the home. The constant prestige of the space is prioritized for the narrow range of activities (Halttunen, 1989). Activities in the living room provide a variety of situations and groups such as a small space, and middle-class suburban houses with a diversity of functions for daily activities (De Wolfe, 1913). By comparing the activities in two models, the parlor and living room, the arrangement system of the parlor is restricted to only open for particular occasions. In contrast, the living room manifests the arrangement system as a social gathering and social activity zone for family members and guests.
Reflection

Comparing the arrangement changes from the parlor to the living room at the beginning of the 20th century reveals remarkable thoughts:

1- Multiple types of arrangements are manifested as physical changes or mapping the domestic products, but other invisible facts influence changes such as, traits, culture, and organizing ceremonies. It is hard to identify a particular pattern of the changes and generalize one arrangement with another.

2- Each historical area and individual idea is engaged to generate different arrangement plans. For instance, Halttunen emphasizes the personal decorating and the culture of personality that affect American interior decoration (Halttunen, 1989, p. 158). While, in Europe, e.g., in Sweden, Ellen Key with her influential essay about ‘Beauty in the Home’, expresses the notions of aesthetics, taste, harmony, and beauty of the home pragmatically (Creagh et al., 2008, pp. 33–55). Ellen Key illuminates the characteristics of ‘home’ in both personal and social scales; she believes keeping both of these two values is essential for designing a home (p. 36). These variations of arrangement changes from different cultures are interwoven, and they overlap with each other in transition from one period to another.

3- The localization of the social gathering space has been changed in different periods. To embody the other aspects, some historians focus on the localization of each section at home in different historical periods. For instance, the authors explain the reasons for socializing in different divisions in homes, such as in the dining room or the kitchen (Downey, 2013; Göransdotter, 1997). In the eighteenth century, the Georgian style dining room was one of the main socializing areas in the domestic environment (Greig & Riello, 2007). The localization of social gathering space may depend on several reasons: the size of the home, the plan of the space, the style of inhabitants. In the same manner, the arrangement at home refers to the wide range of examples in design histories; considering the multiple aspects in this thesis, I do not discuss the label of the space. However, I respectfully consider the place for gathering at home can have varied names.

4- Considering the Halttunen work, until the beginning of the 20th century, the features of domestic products are not changed in the social gathering space—the dining room, the parlor, living room. It is observable that relationships between people and domestic products have clearly been defined. For instance, furniture
is a designed object for seating purposes, perhaps the fabric or color of the furniture structure changes, but, still, it is furniture. The furniture is needed to be arranged appropriately in a domestic environment, and consequently, furniture serves as the place for seating.

Other related research

Investigation of the previous examples is crucial to consider their values and impacts up to the present time. It is a significant practice in the design research process and enables us to establish our thinking and reflection on our future (Fry et al., 2015, p. 211). At the same time, it is essential to know the current aspects of related work. For instance, ‘smart homes’ would one of the critical areas in which to investigate the home. Particularly, smart homes are relevant to digital connections and internet-equipped products. However, in this thesis, I focus on studying the arrangement changes. In addition, smart homes are a broad topic, and it requires larger discussion forums than this limited thesis work. I acknowledge that it is unavoidable not to face the group of smart digital techniques in this research process. Therefore, by considering the conceptual framework, I devote a brief explanation of the current work in the field.

Smart homes connect to multiple devices and construct systems to control and manage homes, such as the heating system and lighting. Smart homes represent the technological structure that has been fitted to our home by using IT knowledge and an internet connection (Harper, 2006, p. 17). Harper considers that smart homes relate to “diverse fields: sociology, ethnography, feminist analysis, human-computer interaction (HCI), computer-supported cooperative work (CSCW), artificial intelligence, buildings research, and health care” (p. 6). Smart homes have significant implications and serve a variety of services and possibilities that can provide value to people’s lives. For instance, Wakkary & Tanenbaum (2009) prioritize that adopting the home with “digital artifacts or interactive technology for the home is one part of the puzzle of sustainability in interaction design”.

Smart homes have a broad context with multiple research orientations like information technologies. I accept the broad range of knowledge and the practices associated with digital technologies in relation to smart homes. I recognize the current tendencies, but I maintain the focus of the scope of this research and investigation to answer the main research question of this thesis.
2.3 Television and arrangement

This section demonstrates the second example of the arrangement changes through the conceptual framework. I am focusing on the aspects of using the television with consideration to the arrangement idea in this thesis. In this regard, two pieces of evidence are shown that are interconnected with each other; it describes the effects on the arrangement changes in homes: first, considering the relationships between people and television. This aspect focuses on social elements, behavior, and the function of television in homes. Second, the placement of the television is identified as the center of attention in living room spaces. This positioning led the other activities to be organized around these household objects. In addition, I present the definitions of television and the meaning of home. Moreover, as current research shows, ‘the second screen’ is shown as an influential user interface in the interaction with television (Neate et al., 2017). Beyond these effects, this section aims to identify the loci of television in the arrangement of home environments.

In this section, I am using the arguments of Roger Silverstone in his influential book, Television and Everyday Life (Silverstone, 2003) as a primary resource for building the discussions. The topic of television research is broad with wide-ranging approaches in related fields. I have chosen the work of Silverstone because the elements and discussions in his book, to some extent, have similarities to the elements of the conceptual framework in this thesis. Television in the living room is a useful example, as a domestic product with particular features, influences the arrangement changes of home environments. Here, it is essential to know that the digital wall and the television might have some similarities, i.e., both of them have screens to display the audio-video contents, but the digital wall is not alike a big television.

What is television?

Silverstone has introduced the television as a medium and a technology (Silverstone, 2003, p. 20). He continues this definition: “Television as medium extend our world of information…, both local and global, domestic and national…”. He also pushes television’s characterization into different directions: “Television is watched at home. Ignored at home. Discussed at home. Watched in private and with members of family or friends. But it is part of our domestic culture in other ways too, or at least of certain versions of domestic life” (p. 24). He advocates that television as technology has several social layers, and television will not be understood without considering this complex relationship.
The relationship between television as a domestic product and people throughout their daily lives is complex. On the one hand, people are engaged socially with the television and with its content. In this case, television as a medium influences people’s behaviors (Fiske, 2004, p. 50). On the other hand, television as a domestic product has been placed in the home and plays an important role in the organization of the place. The latter item impacts a variety of different types of household forms and arrangements (Gauntlett & Hill, 2002, p. 21).

Based on the arguments of Silverstone, television is a technology; it becomes observable that technology has been blended into everyday life (Silverstone, 2003, pp. 21–24). In this regard, McCarthy and Wright (2004) show that people’s close relationships with technology: the placement of technology not only is appreciated but also, we live with technology. This means that television as technology has become part of our everyday routines (Gauntlett & Hill, 2002, p. 21). This acknowledgment gives a special character to television as a technology that takes hold of the position in the home space.

The importance of considering technology in the home arrangement is exemplified in the work of ‘Artful System in the Home’ (Taylor & Swan, 2005). The Artful system suggests: “Technologies in this sense should be designed as resources for people to organize their own everyday arrangements”. Television, as an influential technology, has a significant role in designing the home environment.

Other related research

Television may correspond to a broad range of research areas such as technological impacts and social influences in everyday life. For instance, Anna McCarthy in her book Ambient Television (2001), shows a widespread investigation of the influence of television in the public environment. She explores the significant effects of television in American society, culture, and politics out of home spaces. In particular, her work tackles understanding of the effects of using technology through visual culture and the effects of the publicness of television. More arguments against the content of television have been discussed by Jerry Mander, a former advertising executive. In his book, Four Arguments for the Elimination of Television (1978), he distinguished the powerful impacts of television with other media such as the press and PC. Mander argues that television predetermines the boundaries of its content, and the content of television have remarkable impacts on everyday life. Although these arguments are important for understanding the various impacts of television, I decided to stay with the main scope of this research to investigate
the arrangement changes at home. In this thesis, I acknowledge the broad effects of television as a technology; television is seen as a specific example to demonstrate the arrangement changes in the living room.

**The meaning of Home**

A home is a physical place in which people experience multiple activities. A home usually has several divisions with particular purposes such as the living room, bedroom, kitchen, and dining room. Widely varying definitions of home have emerged; for instance, Baillie and Benyon (2008) state that “the home is a complex environment, designed for general use but shaped by individual needs and desires. It is a place often shared by several people with different demands and requirements. It is a place embedded with technologies utilized at various times by people in diverse ways. Until recently most home technologies have been primarily functional; aimed at easing domestic chores such as cooking, washing and cleaning”. Despite its usage, home is used in different disciplines to mean different things.

In this sense, home is a place to realize behaviors and experience new things. Silverstone articulates, “the importance of the home derives from the fact that it provides a space for action and interaction in which one can develop, maintain and change one’s identity...” (2003, p. 31). In the same manner, Jennifer Mason (1989) demonstrates the social aspect with the wide-ranging approach of home. In her study, the home is defined as a place for the intersection of the public and private. At the same time, home is recognized as material, three-dimensional, and a mundane reality. From the contribution of these two views of home, its physical space, and social aspects emerges a complex structure of the home where people experience life and perform different activities.

The implication of the kinds of activities people engage in has a vital role in devoting a specific zone for daily routines. The living room, as a place for gathering, has become the hub of the home in which people experience media and television (Silverstone, 2003). In this space, “the television is often the focus of collective attention in the living room” (Gauntlett & Hill, 2002). One of the ideas behind using television in the living room assumes a “one-to-one relationship between the mass communicator and the individual viewer” (Fiske, 2004, p. 52). Fiske advocates that television is seen as a medium for communication. These pieces of evidence draw attention to that the role of communication is fundamental in the organization of the domestic environment at large and the living room with its television in particular.
These understandings about the television in the living room as a social space are essential to shaping the arrangement’s attitude. For instance, “while the amount of talking and attention toward other family members generally decreased during television viewing, the amount of touching increased” (Brody et al., 1980). Brody further articulates that this finding may reflect the understanding of the family members to continue the personal contact, and conversation is reduced. Meanwhile, Silverstone (2003) expresses the social situation as “television is a family member in a metaphorical sense” (p. 40). These two views are powerful reflections to frame of thinking about the impacts of television in people’s daily lives. In this sense, television is not seen only as a domestic product for presenting the mass media; it is also a medium in social and cultural forms that can impact the structure of the arrangement in the living room.

Television has become a gravity point that attracts the significant attention of people in the living room. When people want to organize the arrangement of the living room, the television is considered an essential domestic product (Figure 6). Accordingly, the arrangement is influenced by the placement of the physical objects: sofa, frames on the wall, carpet, table. In one of the iconic pictures
of using television, Figure 6 shows the arrangement of the space follows the placement of the television in the space. The figure demonstrates the positions of people to find an appropriate way of experiencing the television. It is significant to see that television has become a dominant element in the arrangement of the living room.

Current thinking and experience television with the second screen

The arrangement of the living room was influenced by interaction with television via new methods of user interfaces. The second screen has been recognized as a high potential user interface with “internet-equipped, interactive devices into our living room” (Neate et al., 2017). The investigation shows that the growth of the second screen has affected the values and preferences of watching television over the past years (Sherryl Wilson, 2016). In this complex experiencing via the second screen, the significant implications are observable in people’s activities, the meaning and pleasure of watching, and the transition of experiencing television (Neate et al., 2017)

‘Second screens’ refer to a type of touch screen device, smartphone, or any tablet computer, that is used to watch and/or interact with content (Neate et al., 2017). The second screen provides multitasking experiences for people while they are watching television. In regards to new ways of using television, Sherryl Wilson (2016) illustrates that unlike the 1950s with the family gathering for watching television, by using the second screen, people are doing their things like tweeting about the TV show or surfing. Dan Hasson reflects a similar opinion; he calls the experience with the second screen: “somewhat of a mystery” about this new communication and activities (Hassoun, 2014). Sherryl Wilson (2016) concludes using the technologies, i.e., second screens, have transformed the “traditional living room into a digital media hub in which families still gather in front of the TV set”

Reflection

Based on the investigation above, television differently impacts the arrangement in the living room:

- Television has become the center of the living room with a family member around the device. Accordingly, television dominates the placement of domestic products with the organization of the living room.
- Communication is a significant value in experiencing television; it
creates various relations in the used time of television. In this sense, two types of communication have emerged: propel with people, people with television, and the combination of these two.

- The second screen scatters the attention of the users like “attention is sporadic and unpredictable” (Neate et al., 2017).
- People perform multitasking by experiencing television. For instance, Wood and Taylor show that “audiences apparently converge to produce new hybrid interactive consumption practices: ‘viewers’ combine ‘using’ and ‘viewing’ to make the new ‘connected consumers’” (Wood & Taylor, 2008).
- The second screen increases the accessibility of experiencing television; it can be used to assist the viewers, for instance, accessing subtitles for the hard of hearing without affecting other viewers (Vinayagamoorthy et al., 2012).
- The second screen is seen as reducing people’s involvement with the television program (Brumby et al., 2014). In this situation, viewers can catch up with the television’s contents at other times as well.

The identified insights of experiencing television demonstrate underlying values to consider the arrangement changes in the living room. Now, it is time to revisit the notion of the arrangement definition in this thesis, ‘The way that domestic products are arranged (physically) in a space’. Based on this arrangement definition, the values of changes with television are seen in two categories that are interconnected.

The first category demonstrates that people’s behavior has an essential role in the arrangement changes. Communication has been identified as an important value of socializing that impacts the arrangement of the living room. The second refers to the situation of domestic products in the living room. Television is the center of attention. This means that domestic products need to be prepared to help provide the appropriate experience of using the television. For instance, furniture placement is arranged to provide appropriate television experiences at various times.

These findings are useful to apply in the research process and especially in design studies when participants experience the content in the Lab. This investigation provides a frame for understanding the arrangement changes in the living room in the presence of the digital wall.
2.4 Digital Wall

The digital wall is the second element of the conceptual framework. In this section, I define the digital wall and introduce similar concepts and the related works that have demonstrated the possibilities of this concept. The investigation further develops the various ideas of a large display. Meanwhile, usability issues have been identified as the main challenges of developing relationships between people and the digital wall. This section has two goals: first, identifying the characteristics of the digital wall, and second, illustrating a picture that can help to understand the connections of the digital wall with the conceptual framework.

Definition of the digital wall

In this thesis, the term ‘the digital wall’ is introduced as “a type of digital E-paper, with high-resolution quality of a display, and possibilities with various options of user interfaces that can be installed on a flattened wall surface in home spaces”. Here, the terms large displays and large screens represent similar examples of the digital wall. Many possibilities can be considered for large displays as “Wall-sized displays are often seamless display surfaces created using multiple tiled projectors. These systems tend to use touch or pen input” (Robertson et al., 2005). A unique method was designed to make a digital wall that could be potentially produced as a coating on paper (Andres, 2017). I am using the term digital wall because it points to the possibilities of presenting digital content on the wall-sized screens. The digital wall is in the conceptual stage of development. In this dissertation, the digital wall is a particular object of study; I am using it as a vehicle to investigate the relationships between people and the elements of the conceptual framework.

The digital wall is seen as a type of large display, with multiple characteristics of user interactions. The examples of large displays emerge from wide-ranging approaches and complex computational systems. The high-tech versions of the large displays have become prevalent with multiple possibilities for interactions since the end of the 20th century (Czerwinski et al., 2003; Robertson et al., 2005). To support the idea of the advantage of using large displays, DS Tan et al. (2006) show that the very large-sized displays help to increase people’s performances in terms of rotation of visual contents. The large displays are compelling artifacts that present information on big screens.
Figure 7: Above: Large-scale trial of making the concept of the digital wall. Coating Electrodes Iggesund coated nanographite on paperboard. The second large-scale coating trial at Iggesund Paperboard (Holmen Group) in Iggesund, Sweden, 2017. Photo by Britta Andres. Used by permission.

Figure 8: Below: One way of making the concept of the digital wall. Coating Electrodes HH coats nanographite onto greaseproof paper with a small pilot coater. The first coating trial. Photo by Kroenert GmbH & Co KG, Hamburg, Germany, 2014. Used by permission.
A unique method was investigated to manufacture the digital wall with the potential to produce by contemporary machinery. One of the digital wall application’s main goals is the increased use of paper industry facilities to produce more cost-effective digital paper rolls on a mass-production scale. The initial estimation, by the research partner of this research, is the production of one million square kilometers of the large display user interfaces. Current estimates state that this concept has a high potential to be installed in interior spaces of domestic environments.

**Historical interest in using wall-sized screens**

The historical evidence shows that humans have been using big visual elements on wall-sized surfaces, in different environments for a long time, even before the advent of industrialism, modernism, computers, and technologies of digital displays. In fact, using wall-sized screens has been seen in various historical periods from many years ago; the pieces of evidence demonstrate that it provides significant performances. Cave paintings are outstanding examples from prehistoric times that cover interior ceilings and walls; the works are estimated around 15,000–20,000 years old (Cavendish, 2015). There are still myths and theories about creating those images in the caves; however, the evidence suggests portrayals of hunting scenes, daily activities, or even special ceremonies and raptures (Mallgrave, 2013, p. 190). The paintings on the ceiling and walls cave reflect remarkably the community’s activities (Figure 9).

A couple of thousands of years after creating cave paintings, the use of big screens prevailed in other parts of the world: A room from the tomb at Aswan, in Egypt, demonstrates wall-sized figures and the text. A bas-relief on the stone in Takht-Jamshid, Persepolis represents a symbol of Nowruz time in Ancient Persia. The paintings of the Sistine Chapel—for instance, the Sistine Ceiling and Last Judgement by Michelangelo, are large frescos on the wall and ceilings with a story in each separate section. The paintings on the wall and ceilings of the interior space in Södra Råda Old Church, Gullspång, Sweden.

In some of these historical places, the purpose of creating these masterpieces is under investigation; however, it seems visible in these examples that people in those periods have identified the powerful impacts of using big displays in their communities or as a way for communication with people.
Figure 9: Above: The first examples of a wall-sized display of information? Cave paintings, Lascaux, France, around (c. 17,000–c. 15,000 BCE). Photo by Bayes, A. (2012) Lascaux Cave, France. CC-BY 2.0.

Figure 10: Below: One example of a very large display. Image by Schmidt et al., 2013.
In the last 50 years, artists and digital artists have considered the powerful impacts of large displays and ambient lights and space. James Turrell is one of the prominent artists who reflects the use of ambient light in the space (Govan & Kim, 2013). In his artwork, Turrell explores lighting, its limits, and human perception (Beveridge, 2000). In recent years, one group of Japanese digital artists, TeamLab has been exhibiting large displays in multiple spaces where people can experience the ambient displays in three dimensions of the space. Design researchers have also attempted to echo the “voices of conversation about the relationship between materiality, technology and design” such as the project of Dynamic optical properties of the Ice hotel X architecture (Robles & Wiberg, 2011). In these works, artists, designers, and researchers have a humble vision to connect the perception of humans with the infinite source of beauty in nature. Their efforts might be interpreted as part of a kind of a manifesto to break down the barriers between science and art.

**Large-screen user interfaces**

The literature presents various types of large-screen ideas. For example, ‘Ambient Display’ is introduced as a system to explain the physical elements of architecture and people’s behavior. “Envisioned as being all around us” is one of the cognitive science theories relates to ‘Ambient displays’ (Wisneski et al., 1998). They are suited for the home environment and everyday life. It describes the possibility that people have a “need to feel connected to others, especially loved ones, and ambient displays can aid in this connection” (Wisneski et al., 1998). Wisneski et al. attempt to articulate the characteristics of Ambient display: it focuses on people’s access to an interaction with the computer, underlying human issues with the computational interaction, and the impact of displays on the attention and perception of users.

Another example of large displays is Roomware. This concept is based on the context of computer-supported cooperative work (CSCW). The goal of Roomware is “to make progress towards the integration of architectural spaces and information spaces”. (Streitz et al., 1998). In Roomware, the authors introduce the i-LAND environment and attempt to demonstrate the relationships between the physical space of the building as an object with a “virtual information environment”. Streitz et al. consider Roomware to design the integration of the physical environment with information spaces (Streitz et al., 1998). The authors emphasize that intuitive interaction solutions are crucial for displaying the content on the large surface’s screens.
The major contribution of the Roomware project is the holistic system and integrated design of architectural spaces and information spaces. In this system, three components are in the core of the integrated design: Human, Group, and Organization (Streitz et al., 1998). These three central items have relations with four sub-domains to different degrees:

- Cognitive space: contents, tasks, cognitive possesses
- Information space: communication, information technology
- Physical space: rooms, architecture, facility management
- Social space: work practices, organizational structure

The Roomware project provides understanding about “the mechanism for assigning physical objects as representatives of information objects in the virtual world” (Streitz et al., 1998).

Selected examples of large displays describe a basis for problem-solving and thinking for future scenarios. For instance, the ‘Intelligent Room’ was created to “demonstrate the command post for planning disaster relief” (Coen, 1998). In this concept, Intelligent Room is a research platform to prototype environments to experiment with interactions with people. Aligned with this user-centered aspect, the ‘Spatial Environment’ with the advanced technology of large display, is examined to identify the effects on the real space (Andrews et al., 2010). According to Andrews et al., Spatial Environment articulates that “objects in space are visible and persistent, it is important to consider not just physical or virtual artifacts, but the space they occupy as well”.

In terms of the integration between architecture and interaction, Wiberg explains “A new spatial engagement will in turn also lead us into innovative thinking around sustainable solutions for the spaces we’re engaging. This, due to the fact that we do not only engage places in our interactions with others, but equally the other way around, we engage ourselves in the places we occupy.” (Wiberg, 2010). These perspectives attempt to show different types of occupation in the space by tangible elements or computational objects. In these examples, since the occupation is real, people need to consider the ways to integrate into the system of space to create natural ways of interaction.

Large displays have widespread advantages. As well as human-computer interaction, large displays have been used in the design process with multiple systems and interaction ways. In one of the well-known works by Ishii and Ullmer, they introduce three projects: projects including the metaDESK, transBOARD, and ambientROOM systems to illustrate our key concepts (Ishii
& Ullmer, 1997). These projects were not supposed to solve a particular problem in human-computer interaction; instead, they proposed a new view of interface and raised a set of new research questions. In another example in the design field, Redström, Skog, and Hallnäs articulated the problems about placement and design of ambient displays (Redström et al., 2000).

In addition, in the work of Khan et al. (2009), several advantages of large-scale displays are introduced for use in design education. They especially point out the prototyping of design subjects on the large display throughout the design process. Furthermore, in terms of the participation of users in the design evaluation process, using a large display serves possibilities to prototype design scenarios and simulate multiple environments (Abdipour, 2019). The study of Mary Czerwinski et al. demonstrated the importance of performances of information on very large display surfaces (Czerwinski et al., 2006; Schmidt et al., 2013). In all examples, researchers presented complex scenarios of using large displays and the relationship of users with an artifact from different perspectives. The discussions were used to open up the possibilities of using the large display significantly.

**Usability issues and user interfaces**

In the development of the large display, usability is an underlying element for setting appropriate interaction between users and artifact. Czerwinski et al. (2003) observe several usability issues for the large size displays: task management problems and configuration problems.

Task management is associated with several open windows on the large displays, “as a result, users engage in more complex multitasking behaviors and require better task management mechanisms” (Robertson et al., 2005). Robertson et al. also discuss task management problems for organizing the windows on different spots of the large displays. Fallman et al. (2005) present the design of a collaborative interface in an industrial environment and shared interactive displays. The configuration problems refer to the user interfaces with large displays, where the large displays become excessively complex and difficult to work with (Robertson et al., 2005).

User interfaces serve a particular way of interaction, i.e., a haptic system for efficient interaction (Moussette, 2012), a multi-touch solution to use the large display in the environment and mediate interaction (Westing et al., 2011); screen widgets are appropriate for quick access to a region of the screens that are difficult to or impossible to reach (Zhou et al., 2010); pointer solutions can be
“inferred tracking device, more direct interaction with the large display can be achieved to reducing the cognitive load of the user and improving their mobility” (Cheng & Pulo, 2003); and mobile devices, as “alternative display environments and more natural interaction modalities” to support a large display-wall (Kister et al., 2017). The numerous interfaces offer different solutions; each of the user interfaces separately cannot solve the complete configuration problems.

User interfaces need to be considered for several users on how they interact with large displays. A solution for usability issues by Nancel et al. (2015) implies a ‘Preferable mobile device for the multi-user scenarios’. They investigate the ‘pointing techniques for location-independent interaction on ultra-walls’. For instance, the mobile device is connected to the wall-sized screen to perform different tasks via user preferences to more easily select the one that best fits their needs. By contrast to the separate user interface, a mobile device can offer multiple types of performances.

A preferable mobile device serves several users the interaction with large displays. Kister et al. suggest that “mobile is utilized as a personal toolbox that allows independent parallel work on the same context without disturbing other collaborating users” (Kister et al., 2017). Although each user interface has limited accessibility, the mobile device can provide a substantial way for the interaction to connect with the big screens; moreover, multi-users can track their interaction simultaneously.

Summary of large displays
The digital wall has not yet been seen in mass production for use in home environments. The digital wall has similarities to the complex idea of large display user interfaces. In this section, a few examples of the idea of a large display were introduced to demonstrate the probable characteristics of the digital wall. Despite the growth of large displays, usability is seen as the most prominent hurdle of using large displays. Predominantly, user interfaces require holistic methods for the interaction between users and screens. Each user interface has potential and limitations, and the research suggests a method to support the various performance on displays; multi-users can reach the context of the screens simultaneously.
2.5 Complexity in the conceptual framework

Reflection

These two examples and others from the literature reflect a broad picture of the conceptual framework (Figure 12). The initial figures of the conceptual framework demonstrate the abstract relationships between the elements. This figure magnifies the connections between the elements and values that were extracted from the literature and examples. This figure demonstrates several fragments; each of the relationships of elements emerges from underlying values to different degrees. Understandably, it is hard to bring all the pieces that have been discussed in the literature. The exposed values have no particular order in this analysis; some values were highlighted because they have been discussed as influences in multiple references. Moreover, it is essential to consider that the illustrated items do not express a special measurement scale of impacts. These pieces are seen as useful guidance on the trajectory of the research process.

There are several possible ways to reflect the arguments of the literature in this thesis. Using different sources can be overwhelming, Nelson and Stolterman clarify this situation as “challenges to make sense out of all diversity of data and information” (2012, p. 119). The reflection of the references is acknowledged to interpret the mutual relationships between the elements of the conceptual framework (Figure 11).

For this purpose, there are three available pair combinations in the conceptual framework:

• User–Domestic products
• User–Digital wall
• Domestic products–Digital wall

The domestic environment is considered as the basis for each of these pair combinations. I reflect on the analysis of each pair relationship by interpreting the connection of values in each relationship.
This group provides an in-depth understanding of the relationships between people and domestic products. Several values were discussed in two examples and literature: People’s behavior, daily routines, placement of things and objects in spaces, and different activities at home. The first one focuses on Halttunen’s work, which shows the engagement of people with domestic products in home spaces (Halttunen, 1989). She demonstrates the values of changes in the transformation from the parlor to the living room. The corresponding findings of her work emphasized people’s activities that impact the arrangement of the spaces. The discussions not only indicate the physical forms of the arrangement but bring forward the hidden impacts on people’s decision making to rearrange their home spaces.

Communication is seen as a significant value with multiple degrees. People communicate with each other, one by one or several together; at the same time, domestic products are involved in this communication process. For instance, to reach the appropriate communication level, people move furniture in the environment, change the decorations, consider the distance between objects for...
maneuvering in the space. These findings are aimed to help the organization to provide better communication links between ‘people with people’ or ‘people with physical forms’ in the environments. This recognition has governed the arrangement patterns in the social gathering space.

Television in the living room is another example of this group combination. The impacts of watching television can be divided into two periods: before and after using the second screen as a user interface. For understanding the first period, I used arguments of Silverstone about changing people’s lives by using television (Silverstone, 2003). He particularly describes that television has impacted the communication of people in the living room. Unlike traditional domestic products with mainly physical features, the television occupies different dimensions of people’s lives and influences non-physical aspects like behavior and daily routines (Brody et al., 1980). In the second period, using the second screen opened a possibility to experience multiple interactions and activities at the same time. After bringing the television into the living room, consequently the arrangement changed: some domestic products were redesigned, changed, and removed from the living room to provide an appropriate space for experiencing the television. Meanwhile, the television dominates the living room; it is represented as not only a technological domestic product; but also, as a co-resident

*User–Digital wall*

This group combination focuses on usability issues. Mainly, the projects in the literature indicate a large display with multi-tasking, complex interaction, and activities. Several user interfaces have been introduced to support communication and activities. The combination of working between physical space and large displays illustrates the endless possibilities of complex interactions. Moreover, attention and performance values show that large displays occupy physical space for interacting and reaching the content on different spots on the screen. There is a lack of evidence to show the implication of using large displays at home. However, it can be understood the values like communication, user interfaces, multitasking, and performance will have significant implications on the arrangement in domestic environments.

*Domestic products–Digital wall*

This relationship is influenced by the internet connection and linking the IT technology system (Taylor & Swan, 2005). The domestic products can be classified into two groups: 1. products without an internet connection or less possibility of the connection, like pieces of furniture, paintings, shelves. 2.
products that connect to the internet like products with IT technology. Since the
digital wall does not yet exist, it is ambiguous to identify the ways of connection
in this group combination. However, learning from the television examples
in the living room, these two elements would connect through the internet
to different degrees. The major implications can be considered in the design
studies of this thesis.

Some other research
Several aspects can be considered to study the arrangement changes in the
relations to the elements of the conceptual framework. For instance, Edward
T. Hall in his influential book describes that culture is the hidden dimension
of human space (Hall, 1966). To explain this hidden dimension, he coined the
term Proxemics: “for the interrelated observations and theories of man’s use of
space as a specialized elaboration of culture” (Hall, 1966, p. 1). His interpretation
of the Proxemics is useful to analyze people’s experiences of spaces and guides
people’s behavior. Hall also expresses the difficulty in translating various levels
of interdisciplinary culture. He expresses: “Cultural indeterminacy is a function
of the many different levels on which cultural events occur and the fact that it is
virtually impossible for an observer to examine simultaneously with equal degrees
of precision something occurring on two or more widely separated analytic or
behavioral levels” (Hall, 1966, p. 102). In alignment with the Proxemics idea
of Hall, McArthur (2016, Chapter One) discusses the rethinking of physical
space and digital technology and how space and people operate together From
a technological perspective, Proxemics is seen as “relationships by relationships
by continuously tracking the location and orientation of people, the devices they
carry (for example, tablets and smartphones), and other surrounding devices.”
(Boring et al., 2014). I acknowledge that these are interesting thoughts and
aspects that may help to build arguments around the conceptual framework, but
it is important to consider that Industrial Design is the main scope of this thesis.

Summary
This chapter describes the underlying elements and two examples through the
conceptual framework, and it introduces the main related elements in this thesis.
In the absence of the digital wall in the real world, the examples reflect the
knowledge that is considered essential values for probable future scenarios, as
Nelson and Stolterman argue that “every design must fit between the existing
and not-yet-existing” (Nelson & Stolterman, 2012, p. 120). Understanding these
examples are advantageous for this design process; to study the arrangement
changes in the domestic environment in the presence of the digital wall. Results
from two examples, the transformation from the Parlor to the living room and television in the living room, demonstrate the essential tangible and invisible elements which are necessary to consider in the arrangement design studies. Accepting complexity in this research allows me to structure and frame the design research methodology, where things are nonlinear, and instead more complex.

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End Notes


Chapter 3
Research Approach and Methods

In Chapter 2, I presented the groundings and elements of the conceptual framework of this research. The examples of the past were explained to provide an understanding of the landscape of arrangement changes in complex situations. This understanding has demonstrated the characteristics and values in association with the conceptual framework. In this chapter, I present the research approach and methods and the frame of knowledge production based on user experience with digital walls. The discussion is focused on the design research approaches, programmatic design research, constructive design research, and research through design. The Design Research Lab was utilized as the space and the platform to conduct the design experiments, prototype the digital wall, and use multiple methods for acquiring data. This chapter presents the underlying design research discussions to make the design research program for this thesis.

The primary purposes of this chapter are twofold and are interconnected:

- Endeavoring to frame the design research methodology for knowledge production in this research
- Using designerly ways of research to study a holistic understanding of the form of arrangement changes with digital walls

3.1 Constructive Design Research Approach

In this chapter, I explain the purposes behind the choice of a specific approach with design research methodology and its essential differences from the traditional scientific research approach. The explorative design studies and
practice-based showed the wide-ranging of user experiences with the digital wall. I discuss the motivation of using the Design Research Lab and a different section of the Lab environment: the ‘user study stage’ and ‘controlling room’. The Lab was equipped with multiple technologies with the potential to apply to the experiments. The methods used in the design studies varied, but careful observations were the dominant method for data acquisition during the design experiments. The Design Research Lab has been identified as a useful foundation to frame this design research and to set up a wide range of design experiments.

In this respect, seven design studies were constructed with two types of design experiments: four Supportive studies and three Main studies. While these seven design experiments are a related series of studies, each design study has an individual setup with particular purposes and a different number of participants. All studies were conducted in the Design Research Lab, where I prototyped the digital wall for the user experience sessions. The results of the design studies are not generalized to indicate the people’s relationships with digital walls at home; instead, findings describe a pattern of arrangement changes in the introduction level of exploration between participants and the digital wall.

**Methodological perspectives**

Scientific research and design research reflect two different viewpoints in the research process. In this regard, Nelson and Stolterman articulate the different measurement aspects on two fronts: scientific research can measure the most ‘objective’ pieces of evidence, while interpretation is a subjective process as a part of the design process that has the same purpose as evidence and proof in science (2012, p. 120). They elaborate on the fundamental differences between the two aspects, in which scientific approach fact serves truth and interpretation serves to mean. Aligned with this perspective is, “the scientific method is a pattern of problem-solving behavior employed in finding out the nature of what exists, whereas the design method is a pattern of behavior employed in inventing things...which do not yet exist. Science is analytic; design is constructive” (Gregory, 1966). These two aspects, scientific and designerly, address two diverse landscapes in the investigation and the research process.

The purpose of discerning these two aspects, scientific-designerly, is not to disregard one aspect for the other research methodologies. It is about becoming aware that each of these aspects serves different possibilities and ways of knowing in research (Cross, 2001). Concerning this thesis, how would it be possible to identify the arrangement changes with multiple elements by using
the rational scientific approach? Arrangement changes are not an objective value to be measured with the traditional measurement scales, i.e., centimeter, deciliter, kilogram, or temperature differences. In using the digital wall in the future, the measurement scales are inadequate to reflect the patterns of arrangement changes in a complex situation. Because arrangement changes are seen as incalculable values.

In addition, the arrangement changes do not refer to a linear approach that focuses on a particular problem, it is a complex situation that needs to be articulated by considering multiple approaches. This does not mean that design research encounters with a messy and disordered structure. Instead, it has been argued that “design is intentional; design interpretations are also intentional with the direction…the meaning of the outcome of the design process is examined through the lens of connective and compositional interpretation” (Nelson & Stolterman, 2012, p. 122). This understanding is compatible with results from the arrangement examples in the previous chapter, ‘the transformation of the parlor to the living room’ and ‘television’. The review of the examples demonstrates that the existing evidence includes a wide-ranging set of appraisals from different approaches. In this complex situation, Nelson & Stolterman advise applying “aspect of true rational judgment or choice” (2012, p. 123). They advocate that:

We can assess and measure a situation, but any overall understanding can only be reached through design interpretations…

As designers, we create meaning in a situation as a whole, including the systemic or emergent qualities that arise the integrative relationships and connections of the elements composing that whole… We distinguish between different acts of interpretation with different purpose and outcomes…. This is an imaginative process disciplinary by intention and desire, while being grounded in real-world considerations… It is in this sense that design interpretation becomes compositional and creational” (pp. 123–124).

Following the discussion above, Simon draws our attention to the essence of the methodologies where “the natural science is concerned with how things are... design, on the other hand, is concerned with how things ought to be” (Simon, 1996). Now, a methodological conflict might emerge. At the same time, using disciplined methods is common in a different form of research. Considering all of these views lead to an essential question in this thesis, how the design research methodology needs to be framed?
Design research and scientific research have a fundamentally different approach. In addition, these approaches use two different interpretations of data. This does not mean the scientific research approach is not used in design research. “There is always room for traditional measurement in the process of interpretation, but they have limited applications” (Nelson & Stolterman, 2012, p. 126). Nelson and Stolterman conclude; however, “when only one or two measurements are used, the result is a pale and simplistic shadow of the full potential of design’s effect in life” (p. 126). This is the core understanding for making research methodology in my thesis, that design research does not unify with scientific research to rationalize the contribution, nor does it discard using multiple methods.

3.2 The Lab—A platform to produce design contribution

The Design Research Lab is practice-driven with a productive user-centered approach for investigating and evaluating the relationships of people and the digital wall. The Lab is seen as a collaborative environment where several methods can be used, and study sessions open up the conversation and ways of thinking in the process of design research. The earliest use of the Lab methodology dates back to the natural sciences, but it has been used in design through psychology (Koskinen et al., 2011, p. 51). However, over the last two decades, the Lab has been employed in varied disciplines in design. For instance, the Lab is used to set up design research proposals, prototyping a design concept with research practices (Binder et al., 2011). Meanwhile, there are other aspects that the Lab is used in critical design in research for investigating people’s everyday life (Mazé, 2007; Ward & Wilkie, 2009). Although each application has a particular agenda for using the concept of Lab, in this essay, the Design Research Lab is associated with a practice-based way of doing design research.

One of the leading research lab environments known is Media Lab at MIT in Cambridge, Massachusetts that was founded in 1985 and focused on technology and illustrated new concepts by prototyping them (Koskinen et al., 2011, p. 25). There are famous experiments that have been conducted in the Media Lab such as influential research of Hiroshi Ishii’s interactive metaDESK “constrained by the physics of the physical environment, supporting multiple pathways of single- and multi-user interaction”, and “ambientROOM for communicating information at the periphery of human perception” (Ishii & Ullmer, 1997). In my
research work, examples like ‘MIT Media Lab’ and ‘XLAB’ as programmatic
design experiments (Brandt et al., 2011) were inspirational to frame my design
experiments. Primarily, I focused on working with design materials, user
participants, prototyping, and going beyond the experiment performances and
interpreting the findings.

In this thesis, I explore the ways a research lab can be used for conducting
design research experiments to investigate the key relationships between
participants and the digital wall. The aim is knowledge production to present
the arrangement changes of using a not-yet-existing artifact, the digital wall, in
a social gathering space like a living room. The lab has been acknowledged as
a platform to set up the experiments and design studies as a way to understand,
people’s experiences, implications, and probable future scenarios (Binder et al.,
2011; Brereton, 2009). In design experiments, I work with several materials
to prototype the experiment’s scenario, including physical materials, digital
contents and information, and IT technologies.

Design Research Program

There are several ways to understand the relationships of people with the
digital wall; it depends on the types of knowledge that are achieved, and it
requires an explicit framework and research program. Different programs
can frame design research. Koskinen et al. discuss making design research
programs in constructive design research, i.e., in the Field, Showroom, and Lab
(Koskinen et al., 2011, pp. 51–100). Each of these provides an understanding
of how constructive design research can work, such as how to collect data the
appropriate methods and to prototype design scenarios. Although in this thesis
I work with the Lab to frame my research, the Lab might overlap in structure or
methods with other methods. Therefore, I acknowledge the commonalities and
maintain my focus on the Lab.

In the early part of this chapter, I discuss that design research works with
holistic approaches and various materials. I draw the distinctions between the
scientific and designerly ways of doing research; besides, they are constructed
with different programs. In the work of XLAB, Eva Brandt et al. (2011, p. 37)
describe the fundamental program differences:
“Perhaps the most important difference between the design program and other constructs such as a hypothesis, is that while the hypothesis ideally should be quite precise and “testable”, a design program needs to be suggestive and open for the unexpected. Whereas the hypothesis ideally is addressed through one experiment, the design program needs to open up a space where innovation and future development is possible, thus typically requiring us to perform a series of experiments to illustrate the diversity it affords”.

They elaborate on this: “design experiments not only need to expose the logic of the program—they must also illustrate it by means of exhibiting logic in relation to each other” (Brandt et al., 2011, p. 37). Design research programs provide the strategy that the series of design experiments can produce knowledge and connected the constructive design research elements to each other (Koskinen et al., 2011, p. 48).

In this thesis, I set out an experimental approach for design studies. Two features have been considered in the design studies: data collection and the way of framing the research. The ways of data collection are based upon practice-based research through design (Frayling, 1994). Also, I used a programmatic design research approach to structure the investigation in design research development to be able to investigate and develop the research. Collection of data and evidence that demonstrate different possibilities within design space (Redström, 2001, 2017) and programmatic approach string the design research elements to each other. The Design Research Lab provides possibilities for using multiple methods to produce an original reflection of participants’ experiences and demonstrate the general patterns of the relationships between the digital wall and participants.

**Values of using the Lab**

Using the Design Research Lab is beneficial for experimental design studies. Design researchers (Koskinen et al., 2011, pp. 54–61) enumerate some advantages of using the Lab in design research:

- Focus on one particular thing at a time
- Provide an observation system that might be difficult to identify in an ordinary study setup
- Use multiple methods to capture the details accurately
- Enable the researchers to iterate design studies
Even though using the Lab can have several advantages, it also has limitations. For instance, participants do not experience the actual design scenario in the Lab as it is in reality (Koskinen et al., 2011, pp. 62–63). By considering the pros and cons, the Design Research Lab provides a platform with possibilities of applying varied methods for acquiring data. In my design experiments, using the Design Research Lab allowed me to do careful observation and study the details, prototype nonlinear design research scenarios and assumptions producing reliable results through user study sessions.

The Design Research Lab was considered as a platform to produce design contributions. As I explained earlier in the Introduction chapter, there were seen four motivations in this research: ‘The calls of design pedagogy, Practice-based and designerly ways of doing research, Growing demands in large screens, and Design for inclusion’. These motivations drew frames for this research, and the Lab enabled me to focus on this research’s scope.

3.3 Facilitating inquiry learning

In the Design Research Lab, applying different tools and combination methods provide a useful structure for learning and collecting data from different design studies:

Deep design study about emotional responses of users, an Agile approach to rapid prototyping in design subjects, and Simulation of environments on wall-sized screens. The wide-range possibilities of the Lab enabled me to go well beyond the scope of the traditional user study sessions. In this section, I present the assembled mechanism of the Lab and the usage methods in the series of design studies. I carried out seven design experiments, and each design study has a particular purpose and structure that are described in detail in the next chapter of this thesis. In the following, I illustrate the environment of the Lab and the possibilities to perform the design research activities.
Figure 12: Above: Top view of the Design Research Lab. The illustration displays two main areas of the Lab: the control room and the user stage. Three video projectors are used to direct digital contents on three walls in the Lab. Below: A perspective view of the Lab. It presents the layout of the Lab environment, placement of the cameras to record the study sessions, video projectors, and monitors of the control room. In some design studies, the thick curtain is used to separate the user stage and control room from each other if it is required. Design and Illustration by Morteza Abdipour.
Physical space of the Lab

The Design Research Lab is physically located in the Division of Industrial Design at Mid Sweden University in Sundsvall, Sweden, where I facilitated the Lab system and conducted my design experiments. To enter the Lab, accessibility had been considered for participants and people with different levels of abilities and disabilities (Abdipour et al., 2016). The Lab consists of two parts: a. one user stage and b. one control room with several measurement tools (Figure 12).

a. The user stage is in a cubic room to perform the design studies. In this space, three video projectors direct the digital prototype and content on three walls of the cubic space. Virtual content could be a combination of images, videos, animation, or other visual data. In addition, audio and smell stimuli could be applied. In the user space, designers might bring physical mock-ups or models to complement virtual reality (Abdipour, 2019).

b. From the control room the study leader can control the visual contents on the different walls of the user stage, audio presentation, as well as video camera capture of the study and user’s performances (Abdipour et al., 2016).

In the Lab, there is a possibility to draw a thick curtain to separate the user stage and control room in some studies that the user needs to experience the design scenarios independently. In cases of applying emotional responses in design studies, the physiological measurement tools are portable, and they are placed between the user stage and control room. Therefore, during the physiological studies, the curtains must always be open.

The Lab is a suggestion with holistic aspects to conduct various forms of design studies. In my experimental studies, I used a combination of methods and techniques (Löwgren & Stolterman, 2004, pp. 63–70). In the data inquiry process, namely, four methods were used; in the Design Research Lab, I adopted the following methods for each study session.

Questionnaire: The purpose of using the questionnaire was to identify the feedback of participants in a particular task. The qualitative answers in the questionnaire reflect the participants’ perspectives, priorities, preferences, satisfaction, or dissatisfaction. Analyzing the questionnaire is classified in two directions: the actual responses to the questions and collecting unstructured opinions in free conversation with the participants.
Figure 13: The Design Research Lab. *Row A:* Prototyping digital contents on the large screens of the user stage, setting up the design studies, and constructing the frame for user participants to experience the actual size of the large display in the Lab. *Row B:* The control room is facilitated by multiple monitors to observe the design experiments, media recording, and controlling the digital contents on the large screens. *Row C:* A speaker to play sounds, and microphone to register the ambient sounds and user’s feedback. *Row D:* Physiological instruments to register emotional responses. Photo and setting up the Lab by Morteza Abdipour.
Speak out: It is a complement to the questionnaire method, and the purpose is to gather the unanswered opinions of participants that have not been considered in the questionnaire. This method can also be used for prompting participants, such as in a semi-structured interview. Analyzing this part was based on the vocabulary and user’s expressions and comparing with the video recordings and photographs during the design experiments.

Observation: The observation method was conducted to register the participant’s reactions during the study sessions. Participants were notified that their behavior was recorded for the research’s purposes. The observation was registered in two ways: 1. Film recording, each study was recorded by two cameras, one camera facing towards the front of them, and the other was placed in the back of the user stage in the Lab. The recorded data allowed me, after the experiments, to review and playback the session from different camera directions. 2. Noting, during the study sessions I note the essential points or opinions of the participants. After conducting the studies, the photographs were analyzed to determine the details of the user’s behavior or interaction during the sessions. The captured images, screenshots of movies, and photographs provided the wide-ranging data that provided multiple layers of tangible and non-verbal feedback such as changing body positions to experience the digital wall. In addition, in corresponding the observation materials, I used sketching, and annotation methods to analyze the captured images to bring out the connections between the items in the pictures. I realized that these two methods, sketching on the images and annotations, assisted me significantly to provide more details of what participants experienced in the study sessions than the images would have done alone.

Psychophysiological measurement tools: This method was used in the first two Supportive studies at the beginning of this research. It was constructed to probe the behavioral changes and registered the emotional responses of the participants (Abdipour et al., 2016). Three measurement tools were set up to register the emotional responses of users: Electrocardiography (ECG) (Cacioppo et al., 2007), Electroencephalography (EEG) (Pizzagalli, 2007), and Galvanic Skin Response (GSR) (Dawson et al., 2007). The acquired data needed to integrate with the time period before the analyzing phase. I used OBSERVER XT as software to integrate and analyze the data. To set up this type of psychophysiological study session, I obtained the appropriate license and experience to operate the integrated hardware and software systems and follow the principles of performing behavioral studies. Although, in this method, the acquired data show the unconscious reaction of participants and details of emotional responses, and analyzing data requires significant time and effort.
The methods used in my research provide rich data from each experiment. The purpose of using multiple methods was not to capture all the details of each session. Instead, the usage methods allowed me to reach various types of participants’ behaviors with different purposes. Sometimes, only one used method was not sufficient to monitor the entire experiments, or some participants were not familiar with how to express their opinions. Therefore, using combination methods in my research was useful to build a complete picture of data from design studies.

Particularly, using film recording in the observation method enabled me to review the session several times in the analyzing phases and pay attention to the details from different angles. However, not all methods worked appropriately in my research; for instance, I used psychophysiological measurement only for supportive studies 1 and 2. Further use of these tools was not continued, since arranging ECG and EEG required specific clinical setups with particular body positions for the users; this could influence the rest of the design purposes. Using multiple methods not only had benefits for my research, but it was also useful for the pedagogy purposes of the Industrial Design program (Abdipour, 2019). In addition, using a combination of methods had benefits for drafting a guideline of the possibilities for data collecting in the Lab.

### 3.4 Experimental design studies

In my research, design studies were considered for identifying the impacts of the digital wall on people’s behavior. In this research, I conducted seven design experiments that were classified into two parts: Supportive studies and Main studies. Four Supportive studies were conducted to frame the explorative studies with different aspects to develop the research question. At the same time, Supportive studies were useful to practice for identifying the potentials of the Design Research Lab. Three Main studies strive to answer the main research question and demonstrate the arrangement changes in different scenarios that people experienced digital wall in a simulated domestic environment. Each study session had an individual structure with a particular task that had been given to the participants. The data form the basis for the results and insights of each study and the consequences of all experiments.
Supportive studies

In the Supportive studies, different methods are used to identify the focus of the study. It reveals a better understanding of research expectations, limitations, and critical thinking in a progressive explorative process. Table 1 demonstrates the summary of the four Supportive studies, the method used, and the findings of each experiment. Each of the seven studies has been given a full description in the next chapter of this thesis, design studies.

Table 1: Four Supportive studies, methods, and learning.

<table>
<thead>
<tr>
<th>Type of Studies</th>
<th>Purpose of the Design study (In the Design Research Lab)</th>
<th>Methods</th>
<th>Learning and improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study 1</td>
<td>Observing the unconscious reactions of participants while they experience the digital wall. (At the same time, I was applying the psychophysiological setups: acquiring data, integrating data, and analyzing data). Number of participants: 5</td>
<td>- Observation - Questionnaire - ECG, EEG &amp; GSR</td>
<td>- Select contents and themes for experiencing in the next study. - Reduce the amount of digital content. - GSR was the appropriate measurement tool. Remove ECG and EEG.</td>
</tr>
<tr>
<td>Study 2</td>
<td>Compare emotional responses of participants, with and without ADHD, while they were experiencing the digital wall in the Lab. Number of participants: 7</td>
<td>- Observation - Questionnaire - GSR</td>
<td>GSR shows people with ADHD were significantly stressed during the experiments.</td>
</tr>
<tr>
<td>Study 3</td>
<td>Investigate the arrangement of a cooking performance and a kitchen space in presence of the digital wall. Number of participants: 1</td>
<td>-Observation -Questionnaire -Speak out</td>
<td>A kitchen might be considered as a social gathering space. However, the physical elements of a kitchen and activity and regular cooking performance are not compatible with experiencing the digital wall.</td>
</tr>
<tr>
<td>Study 4</td>
<td>investigate the position of a group that experiences the digital wall. Number of participants: One group session with four participants.</td>
<td>- Observation - Speak out</td>
<td>- Demand for multiple user interfaces. - Demand for furniture support in sitting and standing positions.</td>
</tr>
</tbody>
</table>
Supportive studies were designed to answer the general question of ‘how our home environment will change if we use the digital wall at home?’ For instance, Supportive studies 1 and 2 were assumed to show the procedure of using psychobiological measurement tools as a proven method that can reveal the subconscious behavior of the participants. The lessons from these studies indicate, although the process of the whole experiments from the beginning until the end was difficult and time-consuming, it defines the limitation and capabilities of the Lab.

The second part of the Supportive study consists of two experiments: Supportive study 3 focuses on the observation of participants in a simulated kitchen environment with cooking performance. The study indicates that kitchen space has a high potential for installing a digital wall, but the activities in a kitchen are complex. Therefore, designing a kitchen space with a digital wall requires the consideration of several variables. This Supportive study shows the kitchen is a complicated environment for using the concept of a digital wall; yet, it raised ‘socializing’ in the kitchen as an essential activity. This understanding leads to preserving the focus of studies on the living room that might have more potential to install a digital wall because it is suitable for socializing. Supportive study 4 is an exploration of group experiences with the digital wall. It indicates the interests and difficulties of a group of participants in the home environment. It reveals a pattern about preferable body positions between sitting and standing positions.

**Main studies**

Three main studies attempt to answer the main research question through experimental design research. Conducting the supportive studies provided knowledge and experiences to focus on creating the *main research question*:

> “How will the introduction of the digital wall influence the arrangement of the social gathering space in home environments, such as space we nowadays call the living room?”

The main studies were framed to articulate the holistic attitude of a probable scenario of using the digital wall in a living room. In the primary studies, participants have engaged with the arrangement of space with domestic products in the presence of the digital wall (see Table 2).
Table 2: Three Main studies, methods, and results.

<table>
<thead>
<tr>
<th>Type of Studies</th>
<th>Purpose of the Design study (In the Design Research Lab)</th>
<th>Methods</th>
<th>Learning and improvements</th>
</tr>
</thead>
</table>
| Main studies    | Study 1- Movement analysis, sitting and standing position in the simulated environment of a living room space. Number of participants: 1 | - Observation  
- Semi-structured questionnaire  
- Speak out | - Standing position does not appropriate support for experiencing the digital wall.  
After the halfway point of the session, the participant chose a sitting position.  
- User interfaces need to be designed for use in different positions.  
- Sitting position focuses the participant’s attention on one single screen while in standing position, the participant has a position. |
|                 | Study 2- Comparisons of participants’ activities in two sessions: Prearrangement and Rearrangement of domestic products in a simulated social gathering space. Number of participants: 2 | - Observation  
- Semi-structured questionnaire  
- Speak out | - Pre-arrangement of domestic products cause huge barriers to experiencing the digital wall.  
- Contemporary furniture design is lacking flexibilities.  
- The number of domestic products must be reduced.  
- The Rearrangement session provided appropriate eye contacts between participants. |
|                 | Study 3- Comparisons of participants’ activities in two sessions: Prearrangement and Rearrangement of domestic products in a simulated social gathering space. Number of participants: 4 | - Observation  
- Semi-structured questionnaire  
- Speak out | - Pre-arranged domestic products (with ordinary objects) cause barriers to experiencing the digital wall.  
- Current furniture design is lacking flexibility.  
- The number of domestic products must reduce.  
- Re-arrangement of Domestic products provide better space to experience the digital wall. |
The main studies generate rich data with many details. The description of the procedure and analysis of each study are elaborated in the next chapter. For analyzing the findings, the essence of the experiments needs to be presented together with other parts of this design research. To assure reliability, I reviewed the acquired data from several methods and compared the results with each other.

Both groups of studies, Supportive and Main studies, explore design experiments in this thesis. The research questions could be constructed in many ways; here in the series of studies, I considered the framework and preconditions of this research. The experiments stopped at the end of Main study 3 because the results demonstrated sufficient evidence of probable impacts of the digital wall on the arrangements of domestic spaces.

**Ethical reviews**

Users participated involved in all design studies in this thesis. Different types of data users’ behavior were acquired. During the experiments, participants were asked three times for their consent to use the materials of the experiment in this thesis. First, on the invitation day, when I asked them to join the design studies. Second, in the introduction of the tasks in the experiment day before starting the study sessions. Third, at the end of the experiments, I asked if I could publish their feedback as text and visual materials. In addition, I followed the research ethics guidelines of the Vetenskapsrådet by the Swedish Research Council (Good Research Practice, 2017) and the declaration of Helsinki (World Medical Association, 2013). Moreover, the experiments were reviewed by the ethical research group at the Umeå University Library.

**Conclusion**

This research has been conducted to understand the possible future of relationships between users and the digital wall in the domestic environment. Based on the preconditions and motivations of this research, I chose to use the Design Research Lab to construct the design research methodology. The Lab was equipped with technological tools and facilities; using these systems allowed me to scaffold my research upon the Lab system. However, using the Lab has both benefits and drawbacks in the design research process.

The Lab provides valuable design input in the learning process, such as the possibility of setting up a complex scenario with multiple design research themes. I could conduct different design studies in the Lab; construct prototypes
of seven design scenarios; the Lab had the appropriate flexibility to adopt different studies. In addition, the hypothesis is evolved in the Lab by practicing and iterating the studies. Moreover, using multiple methods for data acquisition enabled me to capture valuable data that were crucial for understanding the relationships between participants and the digital wall.

In this research, using the Lab is seen as a useful foundation for conducting design experiments; however, this system might have some obstacles. First, setting up an experiment consumes a significant amount of time; each experiment requires several hours, sometimes days, for preparation. Second, the design researchers need to be aware that the Lab environment provides opportunities, and at the same time, it has some limitations. The Lab scenarios control the context of the experiments; the situation is different from reality. Finally, the Lab is an expensive arrangement for running a design session; it requires to consider a sufficient budget for building the experiments in the Lab.

The Design Lab is not the only way to use in explorative design research, but it serves as a frame to establish design research studies with a methodological program. In this thesis, the Design Research Lab pushes design researchers to discover unconventional models. For instance, the Re-arrangement part of studies 6 and 7 was inspirational when participants began to share their opinions about how experiments can improve the experience of the digital wall. The interpretation of the experiments demonstrates the meaningful results, understanding through observation, and even unstructured conversation in the Lab. Concisely, the Design Research Lab can be inspirational and an opportunity to improve in the design research process.
This chapter presents a series of design studies with a particular structure for conducting each study. I present seven design studies in this chapter that address the investigation and experiences of the relationship between user participants with the digital wall in the Lab environment. First, I describe the map of design studies that shows the organization and connection of all of the studies. The seven design studies are classified into two parts: four Supportive studies and three Main studies. For each study, combination methods were used to document the experiences of participants in the study sessions. However, the design studies were constrained due to time, technology, and budget limitations. The flow of the design series indicates the results and insights of each study that gradually approach answering the research question. The result of the studies does not attempt to prescribe a concrete answer for the usefulness of using digital walls; instead, the elaboration of each study demonstrates varying degrees of relationships between people and the artifact in probable future scenarios. In this exploration process, while each Supportive study serves as a piece of the basic understanding about relationships of the participants with the digital wall in the Lab, the Main studies have a significant role in interpreting the arrangement changes in such an environment.

The map of design studies

In Chapter 3, I argue that this design research is complex, and it holds a holistic attitude to interpret a design situation. The previous chapter has described the distinction between design research and traditional scientific research (Nelson & Stolterman, 2012, pp. 123–124; Simon, 1996). Notably, the results of the research approaches that create varied contributions where “the hypothesis ideally should be quite precise and “testable”, a design program needs to be suggestive and
open for the unexpected” (Brandt et al., 2011). These arguments provide an understanding to frame the methodology structure to build design studies in this thesis. Here, I design the map of design studies to illustrate the cluster of design studies and the connection of each study to the whole contribution (Figure 14).
In all seven studies, people are in the center of design studies; their opinions are the essential materials of building blocks of the whole contribution. The model, Figure 14, is the representation of the chronological order design studies, starting with the Supportive studies and then going on to Main studies. The studies begin in the middle of the map, and several design interventions developed these in the research process: questions, literature, theories, examples, user participation, Ph.D. courses, and research presentation in seminars. The design explorations and the growth of each round help to make sense of understanding the arrangement changes by experiencing the digital wall at home. This map was improved throughout the entirety of the research process. The map of the design studies consists of four rounds:

a- Supportive studies: It comprises four studies, and it has a vital role to reveal the potential of using the Design Research Lab, a system of documentation, setup, limitation of participations, simulation of the digital wall, trying ways of using appropriate user interfaces. While explorative Supportive studies provide a fruitful contribution to the Main studies; they do not directly answer the main research question in this thesis. Supportive studies are seen as significant pillars for establishing Main studies, however.

b- Contribution of supportive studies: This round presents perceptions about the possibility and constraints in the Lab for the Main studies. In this thesis, without conducting Supportive studies, it was hard to construct the Main studies appropriately. In this round, each Supportive study sends some fragments of understanding into the next round of the map. The exploration of Supportive studies is reviewed and polished to consider for a more focused investigation in the next design studies.

c- Main studies: This round of the map shows three Main studies. This step aims to answer the main research question: the investigation of the varied impacts and the arrangement changes in the presence of the digital wall. In this round, while the Supportive studies supply the contribution to three Main studies, the results of Main study 1 are given to Main study 2, and subsequently, pieces of knowledge from Main studies 1 and 2 are served to create Main study 3.

d- Contribution of whole studies: The last round is about learning, reflecting, and understanding the whole of the design studies and room for further discussions. This round presents insights and implications of the Main studies. I use this round as a resource to interpret and “create meaning in a situation as a whole” based on the “design judgment” (Nelson & Stolterman, 2012, pp. 124–125).
This round is closed by a dashed line; it holds open-ended discussions in which various opinions would rise beside each other, and it might relate to future work.

### 4.1 Supportive studies

Supportive studies were the foundation to construct the Main studies; they consist of four studies. A combination of methods was applied to each design study. These explorative studies demonstrate several aspects of user experiences in relationships between people and the digital wall. Supportive studies have the iterative and evolving process to conduct the studies in the Lab, but each one has a particular structure.

*Supportive studies 1 and 2* demonstrate the emotional responses of participants while they are experiencing different audio-video contents on the large display in the Lab. These two studies were conducted before I started my Ph-Licentiate program; they were framed with a different aspect from the rest of the design studies. Supportive studies 1 and 2 were set up to conduct appropriate studies in the design Lab environment and identify the potential for using psychophysiological instruments for measuring emotional responses of users besides traditional evaluation studies (Abdipour et al., 2016). In these two first studies, the digital wall was prototyped in the Lab environment, and physiological measurement tools were set up to capture participants’ emotional responses during the study sessions.

*Supportive study 3* focused on cooking performance and the possibilities of using the kitchen to study arrangement changes in the presence of the digital wall. A kitchen is a place in the home that is a social gathering space of the domestic environment. While the examples demonstrate the living room is a spot for social gathering space (Halttunen, 1989), other ideas emphasize the dining room and eating times have a high potential for gathering people in the home (Downey, 2013). In addition, during the first and second studies, some participants spoke out that their family members gather in the kitchen. Because of the use of a single set of tangible prototypes of kitchen appliances, there was facility limitations for the participant in this study. Therefore, I desisted from using the kitchen space as a social gathering space in further design studies.
Supportive study 4 focuses on using the digital wall while several participants experience the session at the same time. This study examines the usability issues and interaction with the digital wall when several participants in parallel perform the session.

The Supportive studies had essential roles in identifying the limitation and possibilities of using the Lab. In addition, these four studies provide knowledge and essential understanding for investigation about arrangement changes in the presence of the digital wall. Each Supportive study has its motivation and structure; they evolve from the explorations to help to construct the Main studies.
4.2 User’s Emotional Responses during the experience of the digital walls

Supportive study 1

User participants have different reactions during the experience of a design scenario that some reactions are visible to be analyzed, and some are hidden reactions, such as emotional responses. Supportive study 1 focuses on participants’ emotional responses by experiencing the audio-video contents on the large display in the Lab. The primary purpose of this study was to reveal the hidden emotional reaction of users while they were experiencing large displays. The secondary purpose of this study was to examine the psychophysiological measurement tools on the platform of the Lab.

Five participators were included in study 1, and they were selected for this study randomly. In each design study session, users experienced 12 pieces of audio-video content that had been already prepared to display on the large display in the Lab. A combination of methods was used to document the study sessions: questionnaire, observation, and physiological tools. Participants were questioned to choose an emotional label for each piece of content based on the eight primary emotions. The results led to improvement of the physiological tools to register emotional responses. It is acknowledged that the sessions were conducted with constraints, and participants experienced the study sessions with the given condition in the Lab environment. In this Supportive study, emotions provide a broad sense in user experience sessions, and the Lab was equipped with physiological tools to provide deeper insights about users.

Emotions

Emotions have a vital responsibility in the design process; this has been discussed in multiple disciplines, i.e., psychology, and design. From a psychological aspect, emotions are “the most confused (and still open) chapters in the history of psychology; mainly due to the ambiguity of natural language” (Cambria et al., 2012). In the design field, emotions are a valuable element in the design evaluation process; however, “it seems to be difficult, if not impossible, to find relationships between design features and emotional responses” (Desmet et al., 2001). Donald Norman, who has worked in both design and psychology fields, argues that emotions have “a critical role in daily lives, helping assess situations as good or bad, safe or dangerous” (2004, p. 19). Among various articulations, (Marvin Minsky (2007) states that “Emotions are different Ways to Think that
our mind triggers to deal with different situations we face in our lives” In this sense, people apply a variety of ways to express their opinions; emotions in design is a broad subject and can be related to different levels of people’s lives.

Creating insight into emotional responses is valuable in the design process, but this comes with some difficulties. First, it is the relationships between emotions and language that are complex and difficult to verbalize (Cambria et al., 2012; Desmet et al., 2001). Cambria et al. argue that the difficulty of expressing emotions might deal with the limitedness of language to label emotions and describe the complex range of emotions. In this regard, Cambria et al. clarify that “A common language used by both designers and users seems to be lacking”. Second, people have various personalities, and it might be problematic to reach emotional responses as an invisible factor. Koskinen et al. describe this issue as “observer effects”, and errors can emerge in the Lab environment; they elaborate, “If people understand a researcher’s intentions, they may change their behavior to please or to confuse the researcher” (Koskinen et al., 2011, pp. 56–57). This obstacle cannot be generalized to a specific group of users, but there are some issues. Lastly, few designers have access to the techniques that are required for registering emotional responses (Desmet et al., 2001). For instance, it requires specific research skills and much time, both of which are usually not available to designers. Desmet et al. describe this situation that “designers are forced to rely on research reports or design briefings”, and “inspired much more by direct contact with their users in such a way that they can understand the concerns of the users in their own language”.

Recording emotional responses

Emotional language needs to have the possibility to communicate with others. Particularly this requirement is seen between designers and people, i.e., in HCI “measuring how much the user is amused by interaction modalities (Pleasantness)” (Cambria et al., 2012). In research, several ways are suggested to record emotional response, but this does not refer that the solutions can fully capture all the complex emotions. For instance, “physiological recording equipment is widely available and relatively inexpensive” (Kreibig, 2010). Donald Norman suggests three different solutions that can be used for recording emotional response: “Heart rate, blood pressure, breathing rate, and sweating are common measures that are used to derive the affective state. Even amounts of sweating so small that the person can be unaware of it can trigger a change in the skin’s electrical conductivity. All of these measures can readily be detected by the appropriate electronics” (2004, p. 185). Physiological laboratory studies are asserted to register quick changes of emotional responses like “within the first
second following the accident, heart rate and skin conductance both increase sharply” (Kreibig, 2010). It is necessary that the acquired data be registered and verified by skilled expertise.

Designers implement varied ways to use emotional responses in the design process. For instance, ‘emocards’ were tested to identify the emotions of the users to increase the feelings of satisfaction for using a mobile device (Desmet et al., 2001). This project was used to communicate between the designer and the users. During the exploration of design studies, the authors noted “it is not possible to conclude whether or not the proposed design approach is guaranteed to lead to designs with added emotional value” and have a limitation (Desmet et al., 2001)

Primary emotions

We use many emotions on different occasions in daily life. In fact, “Humans have emotions all the time” (Kreibig, 2010); people use some emotions more than others. There are numerous discussions about the most daily used emotions, and authors and psychologists have different opinions in this regard (Cambria et al., 2012). There are attempts to classify several basic emotions that people use the most in a tabular format. For instance, Ekman, Frijda, and Parrot classified 6 different emotions as primary emotions, Plutchik organized 8 basic emotions, Tomkins presents 9 main emotions and Matsumoto nominated 22 basic emotions (Cambria et al., 2012). Each classification concerns some values, in this thesis, I have used “the bi-dimensional model, Plutchik’s wheel of emotions, which offers an integrative theory based on evolutionary principles” (Cambria et al., 2012; Plutchik, 2001). Plutchik articulates that there are a few hundred emotion words in the dictionary. However, he classified only eight primary emotions in a circumplex model defined by theory to be arranged into four pairs of opposites. The eight primary emotions, classified by Robert Plutchik, comprise acceptance, anger, anticipation, disgust, joy, fear, sadness, surprise (Plutchik, 2001). In this thesis, Plutchik’s classification in the emotional wheel is used as an instrument for Supportive study 1 and 2.

To summarize this section, emotions are an essential value in the design process to understand the feelings and opinions of users; however, it is difficult to capture the exact emotions felt by participants during the test. Human emotions are complex, and multiple numbers of emotions may overlap with each other. Two examples were explained for recording emotional responses: A. designerly way, B. using psychophysiological methods, like measuring heart rates and sweat glands skin responses are captured to display emotional stimuli of users in a particular time duration.
Procedure

Supportive study 1 was the first conducted study in the Design Research Lab. Before starting to conduct study 1 in the Design Research Lab, I set up the data acquisition system to record the study sessions. In parallel, I updated the large screens system to prototype digital contents on the big screens in the Lab environment. Due to the complex system of the Lab, I needed to plan and prepare for all studies before conducting performances. In this study, I acknowledged that the Lab was a new system in the Industrial Design program, and I was expecting some glitches that might occur during the test sessions.

Materials: Among several selected videos, 12 pieces of audio-video content were prepared as material for the test sessions. The videos were selected from the internet and mainly from YouTube channels; from each video, only limited parts were prepared to demonstrate in each study session.

Participation: User participants were chosen by a randomized trial system (Koskinen et al., 2011, pp. 58–59) with non-particular order. After sending twenty invitations to people, seven participants accepted the test request, but only five participants turned up at the study sessions. Two participants could not attend the study day due to personal reasons. Since several facilities were set up on the user’s stage, the Lab was booked for seven people with a certain amount of time. With two cancellations, it was not easy to replace immediately new people in the slot of test times. There was one set of psychophysiological measurement tools in the Lab; therefore, each study was conducted with one person for each test session.

Data collection

Combination methods were used in Supportive study 1: Observation, Questionnaire, and psychophysiological tools.

A. The questionnaire, participants used a card that contained eight basic emotions to answering the questions; the emotions were written on one side of an A5 page. This technique was based on repeating the same questions to the participants about what you feel about the audio-video content? This A5 page aimed to help participants find the types of emotions and express their responses after performing each content. This card could help them to expand the expression of participants by talking about their feelings.

B. Observation, this method was applied based on two techniques: direct
observation by the researcher, i.e., myself, as an online form of observation. So, I noted the points and feedback of participants during the test sessions. Second, I recorded the sessions with film in installed cameras; this was used for offline observation. The main purpose of the second method was to record the unseen moments of the sessions from multiple angles and review the users’ comments in the analyzing phase. Both observation methods were useful for data integration from multiple channels together with physiological data.

C. Psychophysiological measurement, this method consists of three measurement tools: Electrocardiography (ECG) (Cacioppo et al., 2007), Electroencephalography (EEG) (Pizzagalli, 2007), and Galvanic Skin Response (GSR) (Dawson et al., 2007). The purpose of this measurement system was to record the signals of emotional responses through multiple channels. Each channel of psychophysiological measurement tools was considered to reveal the changes in variability of participants’ emotions as unconscious reactions (Abdipour et al., 2016).

At the beginning of each session, the Lab environment was introduced to the participants for 10 minutes. This introduction was given to participants to explain the sessions and structure of experiencing the tasks. For each participant, installing the physiological measurement tools (ECG, EEG, GSR) took about 15 minutes (Figure 15).

Figure 15: Prototyping audio-video contents in the Design Research Lab. The image on the left: One participant experiences the content on the screens of the Lab. Content on the large screens (GoPro HD, 2011). The image on the right: setting up the Lab, using psychophysiological measurement tools (EEG, ECG, GSR) to register the emotional responses of the participants. Photo of study sessions by Morteza Abdipour.
Data and emotional responses needed to be appropriately registered to generate the results of the sessions. At the beginning of each session, some short samples of audio-videos were screened to bring the participants’ feelings to the baseline of the emotional responses. The physiological data were collected through Mindware Bio Nexlin. The contents were directed with three video projectors on the three walls of the Lab. During the sessions, the list of basic emotions was given to the participants to inspire them for choosing an emotion in relation to each piece of content. The selected contents were prepared for a short time period, approximately 60–80 seconds.

**Analysis**

*Integration of data*

The integrated system consists of hardware and software that has been designed to promote experiments in a wide range of behavioral studies with design research proposes (Abdipour et al., 2016). Physiological values, such as brain activity, heart rate, and hand sweat, were used to register carefully emotional reactions by sensitive and reliable measurement tools. Video cameras and photography captured the whole session, and to synchronize the acquired data, I used the OBSERVER XT to integrate the acquired data. The analysis of data was aided by selected videos and the OBSERVER XT for psychophysiological measures and compared with the questionnaire and other components of observational studies.

Three different data sets were synchronized. First, psychophysiological data, the second, observation from two cameras, and third, speak out from the participants. To synchronize data, each session needed to be transferred from the Mindware system, a hardware-software system for registering the physiological responses, into the OBSERVER XT, software to integrate film recordings and psychophysiological responses.

The list of basic emotions and selected contents were evaluated to identify the results of emotional responses. Table 3 demonstrates the categorized data and feedback of participants in Supportive study 1. The speak-out data were assessed and compared with the results of emotion matches. This analysis is beneficial to compare different types of data and identify the similarities and contradictions in the user’s responses.
Results

Two types of results were expected from this study: A. physiological responses as unconscious behavior, B. results of the questionnaire, and observation data.

A. During the psychophysiological measurements’ documentation, some hidden technical problems occurred in the process, and I had to ignore the acquired data. In this study, I used 9 mm reusable stamped Tin Cups for the EEG tests; following the instruction, the small EEG sensors are needed to attach to the skin of the scalp with paper tape. The position of the EEG cups was stable, and participants did not have significant challenges with the process of data acquisition. However, participants were tilting their heads during the sessions, and those movements caused some glitches in recording the sensitive EEG data. Therefore, this group of data was delisted from the analyzing phase.

After collecting psychophysiological data, I sent the results to the supplier of physiological measurement tools for a second opinion and verifying the data. This process was part of their services to support the researchers’ questions. In the supplier team, behavioral study experts reviewed the acquired data; they concluded that the studies were conducted accurately, but perhaps some technical problems had occurred during the test sessions, and there was insufficient evidence to verify the results. The experts recommended updating some tools, for subsequent studies, i.e. replace the EEG cap instrument instead of the Tin cups version. The suppliers were located in the Netherlands, and the Lab was located in Sweden; it was difficult for them to give a decisive comment about the technical problems by distance. Delisting the physiological data was a tough decision due to the massive amount of work. Since this group of data was not verified, I had to leave out the physiological measurements data from the analyzing process.

B. This group of data was expected to reflect participants’ opinions based on their experiences of various audio-video contents. During the sessions, participants were satisfied to have a list of basic emotions because the list was helpful to choose an emotion label. Here, Table 3 presents the classified results of the questionnaire and the extra explanation of participants when they were matching emotional labels on contents. The results indicate that most of the participants had common opinions about the displayed content. However, for some content, the result of emotional labels was not clear enough to distinguish
between emotions. For instance, for content 7 from Table 3, participants expressed high contrast of emotions between a mix of sadness and happiness emotions. Also, content 6, 11, and 12 did not show similar expressions. Among the 12 pieces of content, eight received the most similar emotions match in terms of participants’ opinions in Supportive study 1. These eight pieces of content were selected to be used for the next Supportive study: items 1, 2, 3, 4, 5, 8, 9, and 10.

Making a clear distinction between emotions is difficult. The various reasons might influence decision making: the aspect of participants, previous participants’ digital display experience, age, and cultural backgrounds. In addition, other factors might impact, as well. For example, the content was arranged in a non-particular order.

Observation was beneficial in this study; it allowed me to carefully observe the users’ behavior. However, in this study participants experienced in a particular position, and they did not have significant physical movements. Instead, offline observation served essential data that I had missed in my notes during the session. In this regard, the observation was reviewed after the study session and I listened other times to the participants’ comments.

To sum up this section, the results of Supportive study 1 demonstrate several aspects of the emotional responses of participants. These findings mainly were achieved through observation and questionnaire methods. Although the psychophysiology measure was delisted from the final results, the lessons learned were useful for the next study. The remaining results demonstrate that in most of the sessions, the emotional responses of participants were similar to each other, and emotional labels were matched with the contents. This finding might look trivial, but it provides a message for content producers of the digital wall. The result demonstrates that contents with particular purpose are shown on the digital wall; most people could react with similar emotions. This finding is based on the limited number of participants, and the results are not generalized to many people.
Table 3: Contents of Supportive study 1, emotion labels, and comments of the participants.

<table>
<thead>
<tr>
<th>Selected contents</th>
<th>List of basic emotions</th>
<th>Users</th>
<th>Female or Male</th>
<th>Age</th>
<th>Emotion matching</th>
<th>Feedback of users</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Walking in a forest</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Calm-Deep</td>
<td>I was waiting for the side images to change.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Joyful-Interesting</td>
<td>I was feeling calm, but images were repeating.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Trust-Serenity</td>
<td>It had a calm feeling and mediated state.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Calm</td>
<td>Warm feeling.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Bored</td>
<td></td>
</tr>
<tr>
<td>2-Water printing</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Attractive-Interesting</td>
<td>Very interesting and exciting, I would like to see more details.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Surprise-Curious</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Amazement Interest</td>
<td>It was exciting and hope to see more in the future.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Joy</td>
<td>I had a warm feeling and a bit enjoyable.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Interest</td>
<td></td>
</tr>
<tr>
<td>3-Riding a Bike</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Excited</td>
<td>It was a bit scary. I am happy that I was not there! The sound of breathing even scared me more.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Fear-Terror-Adventure</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Joy-Fear-Amazement</td>
<td>A mix of feeling fresh and fear. A bit jealous that I am not to do that.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Excited</td>
<td>Dizzy and a bit excited, but not scared.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Fear</td>
<td></td>
</tr>
<tr>
<td>4-Leaking a tap water</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Annoyance Angry</td>
<td>If I watch this video for a long time, I will probably get irate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Thinking-Rhythm of thinking.</td>
<td>It brings me to a dream and sense of time. It was not boring, but I wanted to fix the tap.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Annoyance Discomfort</td>
<td>Something was needs to be fixed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Boring</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Boring</td>
<td></td>
</tr>
<tr>
<td>5-Traffic jam</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Fear</td>
<td>Traffic is stressing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Stress</td>
<td>I got worried and feeling the tension of the city. However, to get more feeling, the time of the videos was short.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Annoyance</td>
<td>I like to live in a city. But, if this video were longer, I would become angry.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Stress</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Fear</td>
<td></td>
</tr>
<tr>
<td>6-Tennis game</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>trust</td>
<td>I would like to see fans as motion images or videos on aside screens.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Interest</td>
<td>Not surprising.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Joy-Amazement</td>
<td>Truly surprised.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>confused</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Interest</td>
<td></td>
</tr>
<tr>
<td>Selected contents</td>
<td>List of basic emotions</td>
<td>Users</td>
<td>Female or Male</td>
<td>Age</td>
<td>Emotion matching</td>
<td>Feedback of users</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------</td>
<td>-------</td>
<td>---------------</td>
<td>-----</td>
<td>-----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>7- Coming back home</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Happy</td>
<td>It was a sense of ‘Nice Pain’. Homesick. It was a private environment and moments.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Joy</td>
<td>I do not want to watch this type of video.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Sadness</td>
<td>It was a little surprised and disgusted.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Happy</td>
<td>But happier and surprised for them.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Sadness-Happy</td>
<td></td>
</tr>
<tr>
<td>8- Manufacturing hot dogs</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Disgusting</td>
<td>The picture on the side was disgusting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Disgust-Annoyance</td>
<td>I do not want to watch this type of video.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Disgust</td>
<td>It was a little surprised and disgusted.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Very disgusting</td>
<td>[After a few seconds, participants did not want to watch this video]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Annoying</td>
<td></td>
</tr>
<tr>
<td>9- A Man calling on the phone</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Anticipation-scary</td>
<td>It was a little bit scary.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Anticipation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Bored-Annoyance</td>
<td>A bit was waiting for something or someone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Confusing</td>
<td>It has no story, and I got confused</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Anticipation</td>
<td></td>
</tr>
<tr>
<td>10- Commercial</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Confused</td>
<td>Distraction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Distraction</td>
<td>I could make a group in the end, but it has too much information.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Confused</td>
<td>It was out of focus. Make me confused.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Distracting</td>
<td>Very confusing to watch three videos at the same time. It was a big mess, but I tried to focus on the middle screen.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Distracting</td>
<td></td>
</tr>
<tr>
<td>11- Skiing</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Boring</td>
<td>No sense</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Movement Sense</td>
<td>It had movement sense, and less fear or scared.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Excitement- Joy</td>
<td>Similar to the Riding a bike video. It was Wow!</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Excitement-Amazement</td>
<td>[The participant was watching this video in a standing position]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Fear</td>
<td></td>
</tr>
<tr>
<td>12- People protest on the street</td>
<td>Joy Trust Fear Surprise Sadness Disgust Anger Anticipation</td>
<td>User 1</td>
<td>Male</td>
<td>32</td>
<td>Aggressive</td>
<td>Something bad happening.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 2</td>
<td>Female</td>
<td>30</td>
<td>Anger</td>
<td>[After a few seconds the participant did not want to experience this test]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 3</td>
<td>Male</td>
<td>24</td>
<td>Worry-Annoyance</td>
<td>Disappointment and empathy with arrested people.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 4</td>
<td>Male</td>
<td>16</td>
<td>Scared</td>
<td>I do not know. Not really like it. Many things happened. It was people scared.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User 5</td>
<td>Male</td>
<td>30</td>
<td>Fear</td>
<td></td>
</tr>
</tbody>
</table>
**Unexpected feedback**

During the performances of Supportive study 1, some unexpected results emerged that were not planned in advance for this study. Almost in all sessions, from the first minutes, participants were excited to experience the digital wall in the Lab, perhaps because of the scale of the image or ambient display environment. After a while, without asking any questions, they started to speculate how their home would look like if they were using a digital wall at home. They started to express what they loved and what they did not like about the digital wall. However, not everyone was interested to use this artifact in their homes, regardless of price and possibility to install this artifact in their home. Some of this feedback is demonstrated in the speculation section at the end of this thesis.

**Insight**

The Design Research Lab was chosen as the foundation of this study and prototyping different scenarios in this project. Participants could experience a large-sized content similar to the scale of the final concept of a digital wall. The Lab provided a control room with particular methods for the behavioral study of users. The simulation of the big display offered a similar size of the screens that can be used in the future.

Identifying the accurate emotional response that happens in the body is a complex subject. The meaning of emotions is a verbal definition that we can use to describe the characterization of the emotion, but there are many definitions included that are not clearly defined among different participants (Gross, 2002; Minsky, 2007).

Emotional responses indicate multiple variables that can be considered in data acquisition and the analyzing process while participants experience audio-video contents (Bos et al., 2013; Thayer & Levenson, 1983). The Lab model was utilized to collect the multiple behavioral data of participants; however, analyzing the acquired data was different among disciplines. For instance, psychophysiological responses can be analyzed deeply in other disciplines, i.e., the neuroscience field. Whereas, in this study, results have been articulated as general patterns of content stimuli.
4.3 Emotional responses- Users with and without ADHD

Supportive study 2

This study presents the comparisons of emotional responses with two groups of participants with and without Attention Deficit Hyperactivity Disorder (ADHD), while they were experiencing the audio-video content on the large screens in the ambient Lab environment. Seven participants, three female and four male, undertook Supportive study 2 which included two people diagnosed with ADHD and five people without ADHD. In this study, two persons with ADHD were chosen because they were available and keen to join the test sessions. Each study session was set up individually in the Design Research Lab, where the participants were surrounded by three different commercial film clips projected onto three walls in the Lab. In this study, three combination methods were used to document the participants’ reactions: Galvanic Skin Response (GSR) was used to measure the psychophysiological reactions of the user participants, an interview was made to find out the conscious experience of the participants, and observations were conducted to capture the participants’ position and the physical reaction of the participants. The results of the GSR data showed that people with ADHD had significantly higher emotional reactions compared to participants without ADHD.

Cognitive disability

Cognitive disability can be thought of at different levels in clinical terms. People with ADHD can face difficulties in some situations of experiencing multiple information with the digital wall. A cognitive disability such as ADHD “is a pattern of pervasive behavioral and cognitive symptoms, characterized by excessive and impairing hyperactive, inattentive, and impulsive behavior” (Hill, 2005)Honorary Consultant in Psychological Medicine at Great Ormond Street Children’s Hospital, introduces this supplement on attention deficit/hyperactivity disorder Attention deficit/hyperactivity disorder (ADHD. These impairments can impact many aspects of behavior and performances: increased levels of stress, executive dysfunction, commonly face barriers to electronic communication such as using the web (Borg et al., 2015; Faraone et al., 2003; Friedman & Bryen, 2007; Seidman, 2006). Due to the health condition, Borg et al. recommend cognitively accessible service to that “a relatively large group of people [with cognitive disabilities] can participate in the society, the environment, including products and services for electronic communication” (Borg et al., 2015).
Accessibility should not be considered as an alternative in design; instead, it is an essential design element for people with special needs in varying degrees. Inaccessible solutions can cause multiple issues for people with ADHD: they may experience difficulties in electronic communication due to reduced capacity in mental functions, such as orientation, attention, memory, abstraction, organization and planning, experience and management of time, problem-solving, language, and calculation (Borg et al., 2015; Scherer et al., 2012; Üstün et al., 2003). There is an unclear situation to consider all features of accessibilities in related to the digital wall. Supportive study 2 was aimed to understand the emotional responses of different groups of people, with and without ADHD, while they experience the digital wall.

**Design for inclusion**

Diverse groups of users must be considered in design projects, particularly the group of people with special needs. A UN Convention (Hendricks, 2007) on the discrimination of people with disabilities requires methods to involve a wide range of users with equal conditions in design user studies. Equitable use is also the first principle in Universal Design (Story, 1998). Involving persons with disabilities in user studies enriches design input (Van Der Geest, 2006; Wever et al., 2008). In the process of involving users, the inquiry methods need to be selected carefully, paying particular attention to the role and condition of the participants (Stephanie Wilson et al., 1997). Some participants are not able to be involved comfortably in every design project. In the meantime, it is essential to understand the users’ behavior and specific needs to implement in design solutions (Wever et al., 2008). In these circumstances, the Design Research Lab is used as a platform to fulfill the necessity of involving a diverse group of users and provide an equal study experience for people with and without special needs (Abdipour et al., 2016).

**Procedure and data collection**

In this study, the insights and experiences of Supportive study 1 were used as the conducting procedure and setting up to frame the evaluation sessions. I used the combination methods to document the participants’ reactions. I applied three methods: observation and semi-structured interview to collect participants’ feedback, as well as psychophysiological measurement tools in this study to register emotional responses. Some part of the physiological system was updated in contrast to the previous study. The major changes were the EEG cap that was
replaced with EEG metal sensor cups; I used the EEG cap with 20 conductors to provide tight connections of sensors with the scalp. However, in Supportive study 2, only GSR data were considered in the analysis phase. The first Bipolar electrode of GSR was mounted on a Distal phalanx with the non-dominant hand. Two other tools, EEG and ECG, were conducted simultaneously to identify the instruction and possibilities of using these tools for future research projects, Figure 16. All study sessions were conducted in the same Lab environment as the previous study.
Seven participants, three females and four males participated in Supportive study 2. Two participants had already known they had ADHD, and five participants were joined without ADHD. The other healthcare situations were not considered in the analysis phase in this Supportive study 2. None of the previous participants were included in Supportive study 2.

At the beginning of each session, participants received an introduction to the Lab that took about 10 minutes. Next, physiological measurement tools were installed, which took approximately twenty minutes for each person. Then, participants were told to watch short videos on the big screen, and some questions were asked after experiencing each content. The Lab condition was prepared for each study a day before the evaluation sessions. This procedure was required for cleaning the equipment and the measurement tools before the next sessions.

The eight selected contents from Supportive study 1 were used in Supportive study 2 in each evaluation session. Content 1 was not considered in the evaluation session; instead, it was used to prepare participants for the Lab environment and identify participants’ emotional baseline, Figure 17. The content of the commercial film clips was displayed as the primary material to be analyzed in this study. The rest of the six studies were considered for comparing the validity of the data acquisition process and identifying the process and examination of the instruments. Between each content, participants rested a few minutes until the next observation. The duration of each content was between 80-120 seconds in length; the whole procedure of each session was conducted between 60-80 minutes.

**Analysis and results**

Using Lab technology generates a large amount of data that are required to be classified appropriately. This classification of data illustrates the individual measurement with several layers of the evaluation sessions, Figure 18. This sorting process took a substantial amount of time, and I was the only person who compiled and analyzed data from the beginning to the end of the process. In this Supportive study, two types of data were analyzed and compared: Interviews and data from GSR.
All of the seven participants briefly described their experiences after watching the contents of three commercial film clips on the three walls. Participants without ADHD had no significant difficulties during this session. In contrast, participants with ADHD explained that commercial film contents were remarkably stressful:

“It was too much information, and I had to focus on everything. I was working hard on it”.

“I mostly had stress and too much interruption some scenes of happiness but mainly stressful”.

Observation data demonstrate that all participants with and without ADHD did not show significant expression while they were experiencing the contents. Therefore, observation data did not have remarkable input for analyzing; however, it was a useful document to consider after the test for reviewing the sessions and identifying different moments of the study. The last group of data reflects the emotional responses of participants by GSR patterns that demonstrate the contrasting emotional responses of two groups of participants.
Figure 19: Above: GSR patterns of emotional responses of non-ADHD participants to the commercial contents, Example of three participants.

Figure 20: Below: GSR patterns of emotional responses of the two ADHD participants. Data is from the commercial audio-video contents.
The GSR data from participants without ADHD demonstrate a steady signal with almost no variation of emotional reaction, Figure 19. In contrast, the results of GSR in the group of people with ADHD show a significant variation during the session experiences with film clips on the large display, Figure 20. In this study, the acquired data from GSR was verified by the supplier of the Lab psychophysiological tools. The changes are evident in interviews with ADHD participants who described the stressful situation. Participants without ADHD also complained about too much information on the large screens; however, data from GSR did not show significant emotional variations. In this Supportive study, the evidence demonstrates that people with ADHD can be under stress with a group of contents on the digital wall, the people without ADHD may experience less stress.

Using the digital wall at home?
Similar to the previous Supportive study, during the sessions, participants expressed their feelings about using the digital wall concept in their homes. These reflections mainly were registered between experiencing the contents or at the end of the session. Although these feelings were stated spontaneously, participants pointed out a model situation for future scenarios. Their opinions varied between accepting and refusing of using the digital wall in homes:

Non-ADHD participants:

“I don’t know! I don’t have a feeling now to have it at home”.

“I don’t think that I should have it at home. Actually, I don’t need it because for me noise and repeating noises are stressful”.

“Maybe I will feel fine with this at home”.

“Yes. I feel ok. We can change the contents depending on what type of mood you are”.

ADHD participants:

“Yes. I will have fun. Easily, I can be with Large displays for hours”.

“Not me. But I could recommend it to others. The idea of the digital wall is nice, but it’s not suitable for my lifestyle and my private spaces”.

This unexpected result was not planned in advance; however, in this study participants were engaged with this artifact. GSR data demonstrate that participants with non-ADHD, emotionally, were not influenced by the digital wall, but rather whether they are keen or not to use this artifact at home. The explanation of the ADHD participants is notable, due to the GSR data shown during the experiencing session he was under the pressure of too much information. Participants from the ADHD group had difficulties managing multiple contents on multiple places of big screens. This finding indicates that the digital wall distinctly has some emotional influences on a group of participants with special needs.

**Insights**

Participants responded emotionally to a design situation, whether they realized it or not; different methods can identify their emotional responses. Two important results from this study are: Firstly, the Lab provides equal study conditions for diverse groups of users with different abilities. This study demonstrates the prototyping contents and simulating the digital wall in the Lab with controlled performances. However, laboratory baseline conditions may not closely represent real-world functioning (Wilhelm & Grossman, 2010). The second, the acquired data is reflecting various conscious and unconscious reactions of users. This combination of data helps design researchers to understand what user participants are looking at and what makes them show specific behavior. The results can be presented with a variety of visual methods such as graphs that researchers determine which method is appropriate. This small study indicates that we need to further investigate the impact of large displays and how they are placed in home environments and places to be able to design inclusive solutions.

**Future research area**

Perhaps a question can be raised: In relation to experience the digital wall, what if one of the family members is challenged with ADHD? Notably, it needs to be considered a situation if a family member has a child diagnosed with ADHD. These are vital ethical research concerns that require further investigation.
Transition in supportive studies

In the subsequent studies of this thesis, the structure of studies is changed to observe various aspects of users’ interactions in the presence of the digital wall in the Lab. The first two supportive studies were conducted by using combination methods to understand different behavioral experiences of the participants throughout the design process. During these two supportive studies, I realized that the psychophysiological system had some limitations: only one participant can join the session at a time due to one series of the measurement tools, participants cannot move around to interact with the ambient display environment in the Lab. Moreover, the subsequent studies are related to my Ph-Licentiate study, where I considered doing designerly research and exploring in user participation sessions. Therefore, the next five studies were conducted without using the psychophysiological system. However, the findings of the first two Supportive studies provided a valuable understanding of the potential of the Lab for setting up various interaction aspects.
4.4 Depiction of social gathering spaces at home

Supportive study 3

This study focuses on identifying the possibility of using the digital wall in a social gathering space in a domestic environment. In this study, two spaces of the home were simulated for understanding the social gathering spaces: kitchen and living room. Here, a kitchen represents a possible space where people gather and socialize at home. In the first part, a participant engaged in a ‘cooking performance’ in the presence of the digital wall. A cooking station was prototyped in the Lab environment with limited performance. In the second part, ‘entertainment’ was considered as a daily activity at home to be experienced with the digital wall. In this part of the Supportive study, the user stage of the Lab serves as a living room and participants choose the placement of a movable sofa, by wheels, to experience the contents on the large display. One participant joined this study; the goal was to gather quick feedback to identify the potential of one of these spaces for the next studies. The findings demonstrate a perception of two spaces. In this regard, both spaces could be chosen for socializing at home; choosing the living room space is feasible and compatible with studying arrangement changes with the digital wall in the Lab.

The dichotomy of using a living room or kitchen as a social gathering space has been seen when designing homes. Indicating one of these spaces for socializing depends on several factors of homes: the size of a home, cultural backgrounds, and activities in the home (Downey, 2013; Halttunen, 1989). For instance, a trend has been seen to consider a kitchen space as a hub for home and gathering activities (Ahluwalia, 2007). In addition, this trend is used for blending the space, technology, and activities at home in modern architecture design: “We cook while watching television, monitor children sleeping in the bedroom while entertaining friends in the living room, and work while listening to music” (Venkatesh, 1996). Each of these spaces, kitchen and living room, represent functions and relativity to home space, although in this study, these are familiar areas of a home that the participant could connect with the study. Here, it is essential to know which one of these spaces can be appropriate for studying the socializing activities in the Lab environment. In the future, the digital wall can be installed in other spaces at home for socializing whether in the name of the living room, kitchen, or other areas of domestic environments.
Setup

Supportive study 3 was set up in the Lab environment; the participants experienced two parts of this study. This study was the first design study without installing physiological instruments. In the beginning, the session and the Lab stage were introduced to the participants in 10 minutes. The study sessions were set up in two parts and took nearly 80 minutes. Data of the experiment were collected by several channels speak out, non-structured questionnaire, and observations. The sessions were recorded by two cameras from two directions in the Lab to register user’s behavior for offline observations to analyze the acquired data.

Part A: The cooking performance in presence of the digital wall

Two materials were provided to accomplish the cooking performance: a portable cooking station, audio-video contents to be experienced on the large screens. The cooking station was prepared by a portable table with some cooking appliances. There were some restrictions with regard to this part of the study, such as setting up an actual cooking activity was banned due to safety regulations. In addition, there were some limited resources for providing other facilities of a kitchen system like a refrigerator or making a smart cooking table. The online content was sourced from multiple internet channels to display on the big screens in the Lab. In this study, the participant could freely choose where to place the portable cooking station in any spot of the user stage during this part of the supportive study, Figure 21.

Body positions as an element for interaction

The participant placed the cooking station nearly in the middle of the user stage in the Lab. It takes some minutes to find a balance between the cooking activity and interaction with the screens. This challenge was discovered when positioning to work with user interfaces and identifying the appropriate ways to interact with the screens. The participant pointed out the lack of a variety of positions to interact with the screens together with the cooking activities. She described this experience from different aspects:
“I would like to set up space around of cooking performance with appropriate seating position in this environment. Then, I can be with my family for socializing, and at the same time, I can experience cooking with big screens. [In this part of the test] Body movements are strange; it is disturbing to interact because several screens are around me. Using a second screen, such as a digital tablet, is not an easy way to interact with big screens. I would prefer to interact with screens like pointing out on the screens by distance, then I can reach different parts of the screens”.

Figure 21: Prototyping the cooking station for the cooking performance by using a few numbers of kitchen appliances and objects in the Lab environment. The participant performs cooking activities while experiencing the contents on the digital wall in the Lab environment. Content on the large screens: Below-Right, from YouTube (2016) and Metrolyrics (2016). Content on the large screens: The above image, Google maps (2017) and YouTube (2016). Photo by Morteza Abdipour.
This session was set up with few kitchen facilities; the participant could move around the space and interact with the screens. In a situation to communicate with family, the participant tried to place herself in an appropriate direction in order to communicate with family members in the presence of large displays. But in reality, the cooking performance is associated with working with wet hands, high and low temperatures, steam, smells, the structure of a kitchen system, and space for multiple kitchen appliances.

**Results of the cooking performance**

In this session, to some extent, it was a chaotic situation with the combination of body movements and cooking performances. Here, the participant was challenged with her situation and the small workplace of the cooking station. She started to figure out how to manage the contents together with accomplishing activities. The interfaces were complicated to work with and inaccessible due to several activities. The participant needed to place her position near the cooking station to operate the screens while she felt tired of constantly standing after 20 minutes. The participant showed her desire to choose other positions than standing. However, in this part, she adjusted her activities via a standing position to manage the cooking performance and interact with the big screens.

**Part B. Daily activity**

The second part of this study demonstrates the user experience in a short period of daily life in a simulated living space. The session was arranged at the same place as the cooking performance at the Design Research Lab. This part of the study, daily activity, was experienced with the same participant of the cooking performance. The purpose of this part was to understand the user’s positions for communicating in a social gathering space like a living room. The participant could choose the contents: images, pieces of music, videos from the internet to display on the big screens. Two using positions were offered in this part: standing and sitting positions. A portable sofa was prepared to place in the space if the participant preferred to choose a sitting position, Figure 22.
Various forms of socializing

At first, the participant was asked to choose the desirable position, and she moved the portable sofa into the middle of the user stage in the Lab. She decided to move into the center of the user stage to experience all screens. Arguably, the first part of this study had some influence on this quick decision to choose a seated position. However, in the second part, the participant was interested in moving her place for experiencing the space with large screens. She described different reflections for the second part of this Supportive study:

“I don’t want to have many products or furniture in the living room. Instead, I would rather have more free space. Because this [simulated] environment encourages me to move around and experience more features of the digital wall with easy ways of interaction. About socializing, I would like to do some social activities by distance as a virtual connection, [for instance] I would like to try working out activity together with other people in gyms or watching movies together with other people whom they live somewhere else”.

Figure 22: Simulating a daily activity in the Lab environment. The participant prioritizes the sitting position in the experience of daily activity. Content on the large screens: left image, from YouTube (2016)\textsuperscript{17}, and Metrolyrics (2016)\textsuperscript{19}, and YouTube (2012)\textsuperscript{21}. Right image, Metrolyrics (2016)\textsuperscript{19}, and Google maps (2017)\textsuperscript{18}. Photo of the study sessions by Morteza Abdipour.
The participant was engaged by experiencing a large display in the Lab. This part of the study explains the model of observation and structure that can be used for characterizing the relevant positions in living space. However, there was a constraint because the participant only experienced a brief moment of daily life in the Lab.

**Results of the daily activities in the living space**

The results showed the participant’s required appropriate positions when she used the big display in the Lab environment. Although a standing position provided movement possibility, she preferred to use the sitting positions as a favored position to experience the study session. The observation of the second part demonstrates that interface choice is an essential factor to experience daily activity and communication. Moreover, the participant was interested in joining the online events with several friends, where at the same time they can experience the same event together.

**Findings**

The participant experienced two parts of a small study in a short amount of time in the Lab. Two crucial findings can be highlighted in this study: First, both of the spaces, kitchen, and living room have the potential to experience a social gathering space with the digital wall. Nevertheless, prototyping the kitchen system was somewhat challenging due to the limitation of prototyping in the Lab environment. A living room space can be an appropriate alternative for subsequent studies. Second, the position of the body has a central role in identifying the ways of interaction with the large display. Even though the standing position is a possible way to experience the screens, the appropriate sitting position is essential. The body position is a vital feature when considering communication between people in a social gathering space in the presence of the digital wall. As the main recommendation, the finding of Supportive study 3 needs to be considered in a situation with several participants in the Lab.
4.5 Interaction experiences with the digital wall

Supportive study 4

This Supportive study focuses on exploring the participants’ positions to experience interaction with the digital wall. The study focuses on the body position and movements of four participants as a key to addressing different user experiences and revealing the possibility to explore the arrangement. In the previous Supportive study, it was visible that the participant tried to discover the possibilities of experiencing the digital wall, but there was a need to change the experiences with the standing position to sitting positions. In this study, four participants experience an interaction session by using a ‘wearable mouse’ (Mycestro, 2017) and the ‘computer station of the Lab’ to work with the contents on the large display. The observation shows that participants were interested in having different movements in the environment with the digital wall; however, there was a lack of appropriate desired furniture for different positions for participants to interact with the screens. The main challenges that were seen when participants realized interaction in a standing position had a limit due to tiredness from remaining in a standing position for a long time. The body movements are identified as essential design materials to consider for a wide range of user experiences with the digital wall.

Positions as design material, are considered to reveal participants’ interaction experiences. Positions have various elements, for instance, in Goffman’s world view positions are described as a performance (Goffman, 1959; Hansen & Morrison, 2014). The classification of position movement can be varied in interactive experiences with the digital wall. To identify the characteristics of the position, as design materials, Hansen and Morrison emphasis that it is essential to reveal the approach for describing the interaction experiences with technology (Hansen & Morrison, 2014). In this Supportive study, I explore body positions by focusing on participants’ interaction experiences during a limited period of time. Learning about body movements can be beneficial because design materials “encourage exploration of rich and non-obvious spaces of opportunity” (Mallgrave, 2013).

In this Supportive design study, I used the observation methods and speak-out sessions to collect the data. The collected data were acquired by two cameras and recording of the user’s behavior that I could possibly use as a reference to
pay attention to the details of the tests. The goal of conducting speak out was to generate some information that was hidden from understanding by observation alone. This method helped participants to share their experiences and describe their inclinations during the experiment.

This study was set up at the Lab environment with four male participants who were from 20–24 years old. At the beginning of the test, users received an introduction about the test and the general structure of the Lab. The study session took about 80 minutes, including 10 minutes for the introduction. Participants used audio-video content to experience and work on the wall-scale of the digital wall. Two methods were used to interact with the large display: A PC station in the control room of the Lab and a wearable mouse through Wi-Fi to interact with contents on the screens. The PC station was introduced to provide content and select the audio-video content from the internet.

A wearable mouse allowed participants to interact with screens while they experienced contents on the large screen. To analyze the participants’ experiences, two forms of posture have been considered: Seating and standing positions, which may show the personal level of desirable form of the posture. Meanwhile, communication was observed through verbal and non-verbal user experiences.

Participants were curious about discovering the possibilities of the technologies in the Lab and interacting with the digital wall. There were two groups for interaction: in the first group, two participants used the computer station to display the internet contents on the large display. In the second group, two participants started to use the wearable mouse to interact with the contents (Figure 23). Participants tried to reach to the corners of screens and discover the entire content on different spots. This interaction required that participants experience the screen in the standing position. When the standing position was chosen, the location of the participants was very close to the screens. However, after 20 minutes, they preferred to choose a seating position; participants realized that they could adjust their distance with the screens when they started to use a wearable mouse to interact with screens. This experience was similar to the previous Supportive study when the participant realized the seating position as an available preference (Figure 24). It was notable that the standing position was not a preferable posture for long time interaction with the large display.
Interaction with multiple interfaces

The digital wall provides a big screen on which participants could experience several types of content at the same time. In this situation, the wearable mouse was not an appropriate solution for interacting with the large display. However, a single channel was insufficient to interact with the screens because everyone felt they needed an independent interface. Data from observations show difficulties of the participants’ interaction experiences. On the one hand, participants cannot stay in a standing position for a long time, and on the other hand, in the seating position, they needed a possibility to interact with the screens individually.

Interaction and the participant’s position are linked to each other. This interwoven situation does not mean good or bad in terms of interaction; it is a complex relationship. In the future scenario of using the digital wall, it can be natural that several participants experience the artifact at the same time. The current system of furniture does not provide appropriate support for the standing position. Therefore, they are forced to choose a seating position. By choosing this seating position, participants might need to ignore some of the interaction with the screen, such as a haptic system.
Figure 24: Several participants experience interaction ways with the digital wall at the same time in the Lab environment. Images on the large screens: Above, the default view of Google Maps (2017)\textsuperscript{18}. Below, the street view of Google Maps (2017)\textsuperscript{18}. Photo of the study sessions by Morteza Abdipour.
Sound is another obstacle in the interactive experience with the digital wall in the Lab environment. For instance, two participants explained that

“Even each of us has an independent solution to interact with the contents on the screens, and still, each of us may need to have an individual sound control as well. We are also thinking about experiencing this environment for a long time”.

Audio-video contents create a complex scenario for the interaction experience. In this situation, a still seated body position is a dominant position to the interaction with the large display.

Findings

This Supportive study emphasizes the importance of body movement and posture; however, further research is required to elaborate on this situation to link to the domestic arrangements. Here, two findings are highlighted: First, the main findings show the lack of alternative of experiencing the digital wall in standing positions; therefore, the sitting position becomes the dominant position for group experience interaction. Second, this study reveals the value of privacy during the interaction with the large display, where participants expected to have an individual interaction with the audio-video contents with the digital wall. This means, in probable future arrangements, it is essential to ponder two values for a group experience: communication between participants and ways for individual interaction with the digital wall.
4.6 Main studies

Three main studies were framed to answer the main research question and investigate the arrangement changes in the presence of the digital wall in the domestic environment. The previous Supportive studies provided useful knowledge and experiences for conducting three Main studies. Notably, the experiences of the supportive studies helped to understand the mechanism and potential of using the Lab and appropriate methods for applying to each study. In the Main studies, a combination of methods was used to collect data from each study session, such as observation, film recording, semi-structured interview, speak out, and noting of conversations. After conducting the studies, offline observation had an essential role in analyzing the acquired data. These three main studies provided sufficient evidence to prepare and interpret to answer the main research questions.

Figure 25: Expanding the map of three Main studies. Each Main study consists of two parts.
The structure of each Main study consists of two parts that are interrelated to each other (Figure 25). Each Main study was set up by a various number of participants: one participant in Main study 1, two participants in Main study 2, and four participants attended Main study 3. The optimal number for participation was 4–5 persons in each study due to the safety requirements and limitation of the space for arranging the user stage. The user stage in the Lab was considered as a simulation space for the social gathering space of a domestic environment. The beginning of the Main studies was a turning point to revisit the main research question: ‘How will the introduction of the digital wall influence the arrangement of the domestic social gathering space, such as the space we nowadays call the living room?’ The goal of the Main studies was to provide a holistic understanding of the probable relationships between people and the digital wall in future scenarios.
4.7 Arrangement and usability issues

Main study 1

The digital wall is a large screen that people can interact with at different heights in domestic environments. This characteristic of the digital wall may offer a variety of possibilities of tasks that can be accomplished in different user’s positions. In Main study 1, I investigate two interaction positions with the digital wall: sitting position and standing position. This study was framed based on results and experiences from Supportive studies 3 and 4. The findings in the Supportive studies demonstrated that usability is the main obstacle for experiencing the contents on the screens. In this Main study, I used a combination of methods, such as observation methods to collect data of user’s interaction experiences. In addition, the studies were documented by noting, photography, and film recordings. Moreover, I used the speak-out sessions to collect the conversations of user participants. This study aims to understand the effects and compatibility of using a position for considering an arrangement in the presence of the digital wall.

Setup

This study was conducted with one participant in two parts; she experienced study tasks in both parts of this Main study. This study was carried out in the Lab environment, and the participant was familiar with the circumstances of the Lab. I skipped the introduction of the Lab setting, but the study procedure and purpose of each part were introduced to the participant. In each part, the participant could pick a variety of digital materials from the internet to perform on the large screens. In each scenario of this study, sitting and standing positions, the participant was asked to accomplish two tasks: 1. type a message on the screens, 2. log in to Facebook and surf some pages on the large display. There were multiple choices to work with digital content, such as changing the window sizes and customizing the contents on the large screen.

In this study, four different types of interfaces were offered to interact with the large screens: A. Laser pen (Cheng & Pulo, 2003), to simulate a spot control on the screens for adjusting and choosing the contents for tracking on the screen and access to all over the screens. B. Leap motion controller (Leap Motion, 2017) to use for gesture movements. Users could interact with contents on screens by moving their hands and fingers on top of the device. C. A regular
tablet, an iPad air, was used as a second screen (Kister et al., 2017) to interact with contents by sharing the screens between tablet and big screens. D. Haptic system (Hayward, 2008; Westing et al., 2011). These interfaces were considered to offer appropriate ways for the participant’s interactions.

**Part A- Standing position**

This part shows the movement and location of the participant in the standing position when the participant experiences the digital wall. Two tasks were required in this part, login to her Facebook account, and experience searching and texting a message. To provide a space for movement in this task, the user stage of the Lab environment was arranged without domestic products. The participant started using interfaces by ‘Leap Motion’ product when it was considered for the gesture-based interface to interact with a Facebook page on the screens. She described that the Leap Motion interface was not accurate to interact with the small items on the screens. For the next choice, she continued the exploration by using a haptic system and simulated the interaction by touching the screens to scroll the Facebook page (Figure 26). The participant described that using the haptic system it was challenging to reach the corners of the large screen. In this part, the participant was not interested in using the Laser pen point solution nor the Tablet to interact with the screens. The participant realized the last two interfaces were not comfortable to hold in hand, while she was moving between the screens during the experience in standing position.
The standing position provides the freedom to move in the space; the participant could change her location in the Lab to interact with different spots of the digital wall. Being able to observe was useful for viewing how the participant used different locations while she experienced the digital wall. She expressed:

“Using the Leap Motion device has comfortable feelings, because it allows me to move around, and I am not forced to carry a device to interact with the screens. However, it [in the standing position] is not comfortable to choose a specific spot area on the screens”.

Similarly, the participant described the experience of the haptic system:

“It was so comfortable to use the touching system to interact with screens, especially for writing a message. At the same time, [by using a haptic system] it was difficult to reach all parts of the screens, such as top corners”.

In this part, the participant expressed that she ‘desired’ to have multiple solutions for interacting with screens in standing positions.

**Part B- Sitting Position**

In this part, the participant explores the interaction with displays in the sitting position by placing a portable sofa in the user stage of the Lab. In the second part of this Main study, the participant started the task by using the gesture movement interface by using the Leap Motion device. However, she changed this interface quickly to the tablet as a second screen. She explained: “the tablet gives more options for interacting with displays in the sitting position” (Figure 27). She continued her task by using the Laser pen; this interface had slow interaction responses, but it helped her to access different spot areas on the screens. The participant did not try the haptic system in this position since the sofa was placed in the middle of the user stage where hands could not reach the screens.
Similar to the first part of this Main study, in the seating position, the participant desired to have a possibility of using multiple ways for interacting with the digital wall. She explained:

“I would like to have an easy framework that I don’t feel fixed [immovable] too much for interaction with the screens. I realized that typing the text was challenging. Apart from the limitation of interfaces, the idea of using the large display at home is a new window to bring me in different experiences”.

In the second part of this Main study, the placement of the sofa provided some distance to see the contents of the display and made it possible to compare the interfaces.

**Results**

The results of Main study 1 focused on two parts: experiencing the digital wall by standing position and sitting position. The main results were achieved by analyzing the methods of the user’s experience session: observation, film recording, and speak out. I reviewed the observation and film recording after the study, which was useful for viewing the details of the participant’s experiences. The comparisons of data acquisition demonstrate two directions: the dominance of the sitting position in interacting with the large screen and identification of usability issues.
Here I compare both parts of the task to understand the differences between sitting and standing positions. Observation data from the standing position demonstrate that the participant had more tendencies to move in the space in order to interact with multiple spots of the screens. These movements are seen as divergent attention on all wall screens in the Lab. In addition, reviewing the film recording shows locations of the participant were identified in three areas near screen surfaces. It was no surprise that participants settled quickly after the first part, the sitting position provides a comfortable situation for the participant to interact with screens. The participant decided to place the sofa in front of the middle screen, although the sofa was prepared to move easily to any part of the user stage. In this situation, the frontal screen was the major attention spot while the contents on the side screens had low attention spots (Figure 28).

Figure 28: Illustrations of the top view of the user stage in the Lab environment in Main study 1. The left image presents the first part of the study and the placement of the participant in a standing position. The result shows the scattered locations of the participant’s experience with several screens in the Lab. The right image presents the second part of Main study 1 in the sitting position. In this part of the session, the content on the middle screen captured the most attention of the participant’s experience.
Usability issues and interaction body position

The suggested interfaces could not support interaction with the large screen in the sitting and standing positions. For instance, the participant was satisfied by using the gesture movement in the standing position; this interface was suitable for moveable interaction. At the same time, the gesture movement did not fulfill the accuracy of working with small items on the screen. Similarly, using a gesture interface had a limitation when using in the sitting position, especially for typing a message on the large screen. The haptic solution was preferred in a standing position near areas of the screen. Using the Tablet as a second screen provided more accurate control of working with content on the screens in the sitting position. The participant realized that she required extra attention both on the small and big screens. The last interface was the Laser pen that provided easy control on the screens in a sitting position because it provided accuracy to write on the screen by distance. In this study, the possibilities of suggested interfaces can be classified into two groups: gesture and haptic interfaces are suitable for use in the standing position; the Laser pen and the second screens serve as appropriate interfaces to use in the sitting position.

Reflections of the participant

At the end of the session, the participant described some of her points and ideas to improve the experience of the digital wall. This reflection was not planned to be described during Main study 1; however, it was relevant to be presented for this Main study. Here, I summarize three thoughts from the participant after experiencing this Main study 1:

“Typing a message was a common challenge with all interfaces, by contrast, pointing out, clicking on the tabs of applications, and dragging the contents were easy actions”.

“The large screen shows the details of visual contents; I was thinking about a protection solution for displaying personal data such as my Facebook page. Especially when I experience this screen with family members”.

“I would like to have an easy framework for interaction with the screens. I don’t want to spend too much time to change several interaction ways instead of spending pleasure time with screens”.

“
Findings

In this study, two important results were identified that are interrelated to each other. First, the participant considered that the sitting position was the dominant position choice. The sitting position is crucially important to understand the impact of the digital wall on arrangement changes in domestic environments. Since participants are reluctant to interact in a standing position, the relationship between the participant and the digital wall is seen in a sitting position. This finding is similar to the previous experiences in Supportive studies 3 and 4, where participants preferred sitting positions for having an appropriate interaction.

Second: There is a lack of identifying an appropriate user interface to interact with the digital wall. There are uncertainties of the probable technology and application form using the digital wall. Moreover, the current interfaces are fulfilling only partial demands of the user interfaces. This is another research area of the digital wall, and it requires further investigation. However, this was an important result to frame the next Main studies, where I focus on arrangement changes in the domestic environment.
4.8 Arrangement changes in a plausible domestic space

Main study 2

This Main study was conducted to investigate the arrangement changes in a domestic environment in the presence of the digital wall. Explorations and results from previous studies provide knowledge and experience to frame Main study 2. This study consists of two parts: ‘prearrangement’ and ‘rearrangement’. I used The Design Research Lab to simulate a space of the home as a social gathering space such as a living room. Two participants experienced each part of this study, while some domestic products usually found in the living room were arranged in the Lab. The results of acquired data show that having eye contact is a primary requirement to establish communication in such an environment in the presence of the digital wall. In addition, participants realized some of the physical domestic products caused obstacles for experiencing the large screen in the Lab. Participants proposed some changes in the rearrangement part of this study to create an appropriate experience in the presence of the digital wall in a social gathering space.

Introduction

The previous design studies of this thesis have provided a holistic aspect of experiencing the digital wall. For instance, usability issues were identified as an essential element for accomplishing the appropriate interaction. User interfaces were not sufficient to support the interaction with the digital wall. Also, obstacles of user interfaces were seen in different participant’s body states, such as standing and sitting positions. These two results led me to the following decisions for this study: first, I considered that usability has a central role concerning the large screen, but I did not focus on this aspect due to the immaturity of the interface’s examples. Second, participants were interested in experiencing the digital wall in the standing position, but it was difficult for them to stay in a standing position for a long time.

The previous study also demonstrated that the number of participants could be influenced by the results of experiencing the digital wall. While one participant focused on the relationships between herself and the screen, several participants considered multiple elements in a group experience such as screen in one hand and communication between participants from the other hand. Design inputs provide a broad picture to draw a guideline to frame this Main study. In Main
study 2, I attempted to answer the main research question, investigating the probable impacts of arrangement changes in domestic environments in the presence of the digital wall.

**Setup**

In this study, participants were given the task to explore the study scenario, but they also took action to influence the existing situation to rearrange it into an appropriate socializing environment. In the beginning, I introduced the Design Research Lab to the participants, the two parts of the procedure, and the tasks of the design study. Participants gave consent to capture photos and film recording during the experiments and use the acquired data in my thesis and publications. Each part of the studies took approximately 30 minutes, and a 10-minute pause was taken between each part.

**Methods**

A combination of methods was used to collect data from the user-experience parts: observation, semi-structured questionnaire, film recordings, noting, and speaking out sessions. Using multiple methods allowed me to compare the behavioral changes of participants in the prearranged and rearranged parts. The semi-structured questionnaire was used to encourage participants to express their experiences related to the arrangement topic. Using film recording helped me capture the details of experiments in the post-observation phase to review the moments of the study that I had missed noting during Main study 2.

**Part 1- Prearrangement**

In the prearranged session, participants experienced some domestic products that had been considered for this study in the Lab environment. These domestic products were randomly selected as familiar products in living room spaces. The selected domestic products were placed on the user stage a day before conducting the study: one bookshelf, several magazines and books, one television, one furniture table, one flowerpot, two different models of sofas, two frames with photo, and one round rug.

Two sofas were placed next to each other, and each participant could see two sides of the screens. The carpet was placed in the middle of the user stage. The flowerpot was placed in the corner of two screens. Sofas were placed intentionally in the corner of the Lab because, in previous studies, I realized participants were willing to experience the digital wall in the middle of the Lab. This prearrangement with sofas was useful to reveal the hidden challenges
for establishing appropriate eye contact and communication between two participants. A bookshelf and television were placed on one side of the screens (Figure 29). The prearranged part of this study did not follow a standard layout or logical format. The purpose of the prearrangement part was to demonstrate probable obstacles to experience the digital walls.

In the prearranged session, participants were offered both seated and standing positions. However, mostly they preferred a sitting position to experience the prearranged part; they decided to sit on two different sofas. They changed body positions a few times to identify appropriate body positions to see each other. Participants emphasized that in a situation of experiencing the large screens together with someone else “having eye contact was crucially important” for them (Figure 30). In this part of Main study 2, one long film clip about underwater nature was displayed on the large screen. After adjusting the communication, position participants asked us the sound of the film clips to be decreased. They explained that

“the loud sound could distract our communication despite experiencing an attractive environment with large screens”.

While participants ranked eye contact as the primary attention, the visual content on the screens was the secondary level of their attention (Figure 30).
Domestic products as a barrier

The domestic products in the Lab helped to simulate a social gathering space, such as a living room. Participants realized the prearranged items created barriers to experience the whole screen. For instance, one of the participants mentioned:

“If I want to use the digital wall in my living room, I will remove the television from this space, because with this artifact I can have a screen as television on every wall and adjusted in different sizes”.

The placement of sofas created other obstacles to see the contents on the screens in the prearranged part. They mentioned:

“We need to experience this artifact [large display] in this space, but these sofas occupy a big part of the screens”.

They were reluctant to use the bookshelf because physical products created a “distortion” of the visual contents (Figure 31). They suggested changing the high shelf. Participants explained:

“if I need a shelf in this space, I will choose a short one”.

Moreover, a participant believed that physical frames of pictures were unnecessary since

“I can merge these images with the visual contents and display it on the wall”.

Figure 30: A front view of the prearrangement part of Main study 2. On the left: Participants choose sitting positions and adjust the distance to establish eye contact for communication. On the right: A silhouette effect of the left image to show participants’ eye contact and a range of seeing to experience the visual contents on the large screens. Content on the large screens from YouTube (2015). Photo of the study session by Morteza Abdipour.
Participants identified that several domestic products were irrelevant to this space; they planned to move some items from the space in the rearrangement part of this Main study. Figure 31 clearly illustrates the importance of getting a configuration right with physical objects and digital objects. The illustration with the line on the sides and the spatial physical outline clearly shows the importance of getting the configuration right so both physical and digital objects can occupy this space together.

Figure 31: A front view of the prearrangement part of Main study 2. Above: Participants are experiencing large screens in a standing position. Below: A silhouette effect of the above image to show participants’ eye contact and at the same time, experiencing the large screens. Participants realize domestic products create barriers to experience the visual contents on the large screens. Contents on the screens from YouTube (2015). Photo of the session by Morteza Abdipour.
Part 2- Rearrangement

After accomplishing the prearranged part, participants had this opportunity to rearrange the domestic products in the Lab environment. Between these two parts, a ten-minute coffee break was considered so that participants reached a baseline of each other’s feelings. In this short time, they were exchanged their ideas to customize the organization of given products, remove the obstacles from the user stage to prepare an appropriate situation for experiencing the digital wall. Observing this part of the study was valuable to identify problems in the prearrangement part to make a preferable organization for the rearrangement part.

Two participants decided to move barriers away from screen sides for the rearrangement part. They intended to organize a space to provide a comfortable position for communication and having eye contact with each other. The primary support for reorganizing was their experiences from the first part. For instance, participants started to move the flowerpot, the television, bookshelf, and frame of the pictures. They also rotated one of the sofas towards large screens, Figure 32. In addition, participants decided to choose contents with less visual motion on the screens, one participant mentioned,

“I think this background [video on the screen] is too fast and bothers me and while she is talking to me the background moving fast and contents are huge on the screens”.

Rearrangement for interaction

Participants realized the rearrangement part could provide a space for interaction with the digital wall. Using several domestic products not only created barriers for seeing the contents but also caused several obstacles to interact with the large screen. Participants preferred seating positions, but during some moments of the rearrangement part, they tried to experience the screen in the standing position. In the rearrangement part, participants had more space to choose content and ways for interaction with the screen. One participant explained:

“I want to see fewer objects on the floor of the [Lab] space. Of course, this depends on how much space you have at home. I think these common physical objects [domestic products] are not compatible with this space to work [to interact] with screens. This
artifact, [the digital wall], that looks modern and advanced has conflicts with those physical objects. For instance, I don’t want to keep the bookshelf in this environment.”

During the verbal conversation, participants pointed out that they preferred to socialize in a space that family and friends could gather together. They considered the space for communication, and socializing has a very individual organization and customization. Participants described a space capable of both socializing with several people and at the same time, an appropriate ground for interaction.

**Findings**

These two parts of Main Study 2 demonstrate a complex scenario of experiencing two participants with a simulated social gathering space. Two important findings are revealed by comparing two scenarios of prearrangement and rearrangement: Convergence for communication and Divergence for interaction.

*Convergence for communication between participants:* Eye contact between participants is an essential need for establishing appropriate communication. Unlike a single participant’s interaction, two participants care less about the screen, rather their connection and properly finding each other are prioritized. The elements in the environment, including the physical objects or digital contents, need to be arranged in harmony with communication with participants.
Divergence for interaction to experience the digital wall: The digital wall is demanding a space to display contents. Participants need free space to move around and have the possibility to experience or interact with the digital wall. In this study, the existing domestic products caused some obstacles and created physical distance. Therefore, in the rearrangement part participants have less accessibility to the contents and interaction on the large screens. These findings show a picture of a complex situation that there are many ways to interact with the large screens to accommodate in a social gathering space. This Main study was conducted in a limited time in the Lab environment; further research is recommended with a more extended observation and more participants.
4.9 (Re-)Arrangement in the social gathering space

Main study 3

In this Main study, I used a similar structure to that of Main design study 2 to investigate the arrangement changes in a simulated social gathering space with the digital wall in the Lab environment. The Main 3 study was conducted in two parts: ‘prearrangement’ and ‘rearrangement’. Four participants experienced each part of this study. Prearranged domestic products are seen as an obstacle to experience the large screen properly. At the same time, participants need free space to interact with contents without physical barriers in the space. The results show that having eye contact is a primary requirement to establish communication between participants; communication between participants is prioritized more than attention to the large screen. Main study 3 demonstrates similar findings to the previous study with small differences in participants’ communication structure and at the same time a willingness to interact in the rearrangement part.

Set-ups

Main study 3 was framed with the same setup as the previous study with minor changes. Similarities are seen between Main studies 3 and 2 in several items: using the same methods, dividing the study into two parts, prearrangement and rearrangement, a coffee break between the two parts, documentation method, and analysis. I also used the same domestic products, the same film clip\(^2\) in the prearrangement part and using the Lab environment for conducting this Main study. There are some minor differences with the previous study, however: Four participants joined this study, each part of the study took approximately 35 minutes, and two single chairs were added in the prearranged part (Figure 33).

Part 1- Prearrangement

Four participants, three females and one male attended Main study 3, and all of them experienced both study parts, prearrangement, and rearrangement. In the beginning, the Lab and the structure of the study were introduced to the participants. They chose to start the first part with the sitting position (Figure 34). The semi-structured questionnaire was printed to be used during the prearrangement part. This text provides an instrument to collect participants’ opinions, but it was not designed for generating statistical results.
In the prearranged part, participants started to identify the preferences in the environment, such as seating place, adjusting the position, and connecting to the large screen. At the beginning of this part, they explained that the given domestic products in the prearrangement provided familiarity to experience a social gathering space at home. They were trying to find an appropriate position for communication; establishing eye contact with each other in their sitting positions.

Figure 33: Above: Top view of the placement of some domestic products in prearrangement part in the Lab environment, Main study 3.

Figure 34: Below: On the right: Participants choose sitting positions and describe difficulties in keeping eye contact with the others. On the left: one participant shifts to a standing position for a short time to communicate with the others in the presence of the digital wall. Contents on the large screen from YouTube (2015)20. Photo of the study sessions by Morteza Abdipour.

In the prearranged part, participants started to identify the preferences in the environment, such as seating place, adjusting the position, and connecting to the large screen. At the beginning of this part, they explained that the given domestic products in the prearrangement provided familiarity to experience a social gathering space at home. They were trying to find an appropriate position for communication; establishing eye contact with each other in their sitting positions.
positions. The first problem was identified when two persons used the same sofa. Since the space between the two persons was minimal, they had difficulties in turning their necks to see the person seated beside them and at the same time experience the large screen. After some minutes, one of the participants decided to change to the standing position. He described:

“Standing position gives more freedom to see the other people and the screens at the same time, but I cannot stay in the upright position for a long time, the seating position is inescapable”.

In the prearrangement part, participants did not change their sitting positions, instead, they were curious about their relations with the domestic products and the large screen (Figure 34).

Two obstacles
In the prearrangement part, participants noted two barriers during the experience of the large screen. First, they all agreed that placing some of the domestic products blocked the space because those physical items occupied the space and created an obstacle to experiencing the visual outputs of the screens. For instance, the bookshelf and frames took up some part of the screen. The placement of furniture also had covered some parts of the screen. Second, loud music disrupted their concentration. Participants emphasized,

“communication between them was more important than the contents on the screen”.

They wanted to experience the information as background audio-video content. These two obstacles made up the main discussions between participants and they discussed different ideas for the rearrangement part.

Part 2 - Rearrangement
Between the two parts of Main study 3, participants had a short coffee break for about 10 minutes; during this time, they exchanged their opinions for reorganizing the space to experience the rearrangement parts. Participants kept the flowerpot and the short table in the space because they thought the height of these objects did not interfere with their experiences. Both sofas were moved to
provide better communication between participants with the possibility of having eye contact. They explained that

“the space is small for using those big sofas, and it does not provide sufficient freedom for moving around”.

In addition to moving domestic objects, participants decided to watch different content on the screen (Figure 35).

Figure 35: Above: Participants exchange opinions to adjust the space from the prearrangement experience to the rearrangement experience, Main study 3. Contents on the large screens from YouTube (2015). Photo of the study sessions by Morteza Abdipour.

Figure 36: Below: Participants examine different body positions in the rearrangement part, Main study 3. Photo by Morteza Abdipour.
Despite knowing the possibilities of user interfaces for interacting with screens, participants decided to focus on communication between each other. In the rearrangement part, they tried four positions to experience the contents: standing position, sitting on a sofa, sitting on the floor, and laying down on the sofa. There were different arguments for selecting variations of positions:

**Sitting on the sofa:**

“I feel comfortable on the sofa, and I can change my position, but if I want to share the sofa with others, then I will feel similar problems in my neck that I experienced in the first part”.

**Standing position:**

“Now I can see the screens better than the first part; I have more flexibility to move around and communicate with others. But still, this position is temporary, and I need to move to the sitting position soon”.

**Lying down position:**

“It’s a comfortable position, I can see the others, and the screen is big enough, and I can see many things, it is not important to capture all screens at the same time”.

**Sitting on the floor, Figure 36:**

“If it is possible, I would like to sit on the floor. It’s a very similar position to the seating position on the sofa that I experienced in the first part. But now I have better eye contact with the others, and I can see the screens very well. It’s useful to have the short table somewhere around because I can put the cups and my mobile on the table. If the short table and the flowerpot interfere with the screen, I move the entire visual contents up, but not using the other physical objects like bookshelf”.

In the rearrangement part, participants’ interaction with large screens was less important. Although domestic objects were vital for them, communication with eye contact was essential for experiencing the digital wall.
Figure 37: Time-lapse of participants’ positions and coding each body position from prearrangement to rearrangement experiences in Main study 3.
Results

Four participants experienced both parts of Main design study 3: prearrangement and rearrangement. The results of this study were acquired from various methods: observation, noting during the study, film recording, speak out, and post-observation. By analyzing the film recording and comparing it with participants’ explanations, I illustrated seven moments of time-lapse in this study (Figure 37). The results show the arrangements change in different degrees between two parts of this Main study.

In the beginning, participants realized that physical domestic products caused problems for experiencing large screens. These problems created obstacles for communication between participants. Although they tried different positions, such as standing position, participants had to return quickly to the sitting position in the first part of this study. In the rearrangement part, several domestic products were removed from the user stage to create a better flow of communication. Participants paid less attention to interacting with the screen; instead, they tried various positions for establishing a convenient communication channel. The rearrangement part provided a better organization for socializing in the space, but still, the given physical domestic products were not combined entirely to the design scenario because participants experienced multiple forms of information in the Lab.

Experiencing two levels of information

The results show that participants tried to balance two different information sources: listening and responding to information from the other participants and audio-video information from the screen. These two pieces of information were generated in parallel for each participant but on two different levels (Figure 38). The results show that participants accepted both information from two sources. But they had difficulties in identifying the mechanism of working these two pieces of information together. When it comes to communication with the participants, the rearrangement changes were somewhat successful. For several participants, the current domestic products did not provide sufficient support to experience the digital wall. The current domestic products were not suitable for such a piece of dynamic information on the large screen. Therefore, participants tried to experience both sources of information by sitting on the floor. Perhaps, this position provides a more flexible movement for managing the socializing in such a situation with two forms of information.
Figure 38: Above: Four participants identify the sitting position in a circle form as an appropriate position to experience socializing with each other in the presence of the Large screen. Below: A silhouette effect of the left image, participants describe that they receive two forms of information: information from socializing and eye contact with each other and information from the large screens. Contents on large screens from YouTube (2015). Photo of the study sessions by Morteza Abdipour.
Findings

Main study 3 demonstrates the participants’ experiences with two parts: prearrangement and rearrangement. This study was conducted in the Lab environment with a limited time duration. Two significant findings are seen in this study about experiencing socializing space with the large screen: First, including physical domestic products in the space for participants to experience the communication has little support. The rearrangement of domestic products can be useful, but participants had difficulties finding a solution during the study. Second, participants asked for an arranged system that could provide several activities simultaneously in the presence of the large screen for socializing. This demand refers to the domestic products, and the shape of space is essential to set the large screen and room activities. For further investigation, this Main study suggests rethinking the relationships between domestic products, and people using the large display at home. Notably, this finding recommends some choices regarding furniture may serve as preferred positions for the participants.
4.10 Conclusion of all design studies

This chapter presented the seven design studies separated into two groups: Supportive studies and Main studies. Each was conducted with particular considerations to provide evidence for answering the research questions. I used a combination of methods to demonstrate the participants’ experiences from different perspectives. In this part of the chapter, I share the insights of each study. The iterative investigation design study helps to approach the arrangement changes of social gathering space in homes. Each of the design studies is part of the contribution of whole design studies.

All seven studies were conducted in the Design Research Lab environment, which provides the possibilities of exploring different scenarios. The Lab was chosen as the place for this study for several reasons: prototyping different studies, involving participants in similar experiment situations, experiencing a size of content similar to the scale of the final concept of the digital wall. However, there were some limitations in conducting the studies. For instance, the optimal number of persons for each study was limited to 4–5 persons because of following the safety regulations. In Supportive study 1 and 2, there was only one set of psychophysiological measurement tools. Therefore, only one participant could join in each study.

Summary of findings in Supportive studies

This group of studies demonstrates a broad perspective about the Lab and ways of setting up the design studies to investigate the arrangement changes in the presence of the digital wall. The first study group had an essential role in building a foundation and preparing knowledge for using the Lab. The contribution of the first group of studies shows examining multiple possibilities to identify the potential of performing in the Lab. In this group, Supportive studies 1 and 2 belong to the same cluster to identify the participants’ emotional responses. In Supportive study 3, I investigated the potential and limitation of using a kitchen as a social gathering space. Supportive study 4 demonstrates the scenario of experiencing the digital wall with several participants at a time. Here, I present the central insights of each study separately. It is worth pointing out that if it were not possible to conduct the Supportive studies, it would be challenging to accomplish the Main studies.
Supportive study 1

- With regard to experiencing audio-video content, the label of each emotion can be defined differently from one participant to another.
- Unsurprisingly, there are visible and hidden factors, i.e. cultural background, previous experiences, to characterize an emotion for consideration in a design scenario.
- The Lab platform was useful to collect the multiple behavioral data from participants; however, analyzing the psychophysiological responses require a significant amount of time in the process of collecting data and analyzing data.

Supportive study 2

- People can be influenced emotionally by using a large screen. People with special needs, i.e. individuals with ADHD, are influenced significantly, which can unconsciously impact or be hidden in this group.
- Using a combination method, conventional and psychophysiological systems can generate a holistic understanding of people’s behavior; however, this comes with the limitation of participants’ movement during the design study.
- Using the Design Research Lab provides equal study conditions for diverse groups of users with different abilities. Notably, this Lab system is useful for interpreting and reflecting data about conscious and unconscious reactions of users.

Supportive study 3

- The kitchen and living rooms have possibilities to experience the digital wall as a social gathering space. This study demonstrates that a living room is a better choice than a kitchen for setting up design studios in the Lab.
- Sitting is the superior position of the body for experiencing the digital wall. However, there is interest in using other positions, i.e. standing position, to interact with the large screens.

Supportive study 4

- The sitting position is selected as the dominant position for a group of user experiences to interact with the large screen.
- The importance of privacy for each person is essential in terms of interaction with digital screens, together with several people at the same time.
Summary of findings in Main studies

In the second group of design studies, the Main studies, I focus on investigating arrangement changes with a different number of participants in three studies. The Main studies demonstrate the participants’ connection with the domestic products and large screen in an area of the home for socializing. Although each study has an individual plan, the main insights are based on the holistic aspects and contribution of whole studies.

Main study 1

- Reluctant to using physical user interfaces in standing position.
- In the lack of appropriate support in standing positions, the sitting position is a preferable choice for the interaction.
- Demand for using multiple user interfaces to interact with different tasks with large screens.
- Considering the privacy of a user’s account for using personal contents on the digital wall in the social gathering space.

Main study 2

- The sitting position needs to be considered for establishing eye contact between participants in their communication in the presence of the large screens.
- Current domestic products disturb the experience of audio-video contents on the screens.
- Demand for experiencing the contents in an arrangement situation with appropriate distance without physical objects in between participants and the digital wall.

Main study 3

- Physical domestic products interrupt the communication between participants as a prioritized value.
- The large screens have several characteristics; the arrangement should be in harmony with multiple performances in the presence of the large screens.
- There is a need for furniture choices to support other body positions during the experience of the digital wall.
The conducted design studies reveal some relations of participants with the digital wall in future scenarios. There are infinite possibilities of setups in regard to investigating the arrangement changes in social gathering space in homes. There are several reasons that I decided to end the exploration of design studies:

First, the seven studies provide a sufficient amount of material to show the arrangement changes and implications of the large screens at home. In addition, the findings of Main studies 2 and 3 were similar to each other with slight differences. Therefore, constructing new studies would require having other research questions. Moreover, I considered the limitation of this research for Ph–Licentiate program and thesis writing. I acknowledge that these design studies could be constructed in different formats and scenarios, or with other design research methodologies. These seven studies have been conducted as a possible study series that are achievable in the platform of Design Research Lab. In this thesis, I focus on studies to answer the research question by considering the limitations and available technologies and user interfaces in the period of conducting both groups of design studies.
End Notes

Chapter 5
Findings from Learning by Doing in the Design Studies

In this chapter, I present the various findings of the design studies and their meanings in this research. This thesis focuses on empirical studies that study the relationship between people and technology in a space, such as experiencing the digital wall in a social gathering space at home. The findings of each design study enable me to build my understanding to answer the research question; relevant findings that have been identified to answer the research question. I present several results that are relevant to this work and the design research communities; however, there are several options for reflecting these results from doing design studies: the roles of the arrangement, people’s relationships with the digital wall and the domestic products, the potential of using the Lab system as a platform to perform the design research, and in broader aspects relates to the design research methodology. In the last part of this chapter, I explain the limitations that I have encountered during this research work.

5.1 Overall results

I have engaged with multiple sources for understanding to answer the main research question: “How will the introduction of the digital wall influence the arrangement of the social gathering space in home environments, such as the space we nowadays call the living room?”. The first contribution relates to elements of the conceptual framework. In Chapter 2, I described the relations of the elements in association with the arrangement of domestic environments. Specifically, theories and examples from design history, i.e. transformation from
the parlor to the living room and television, have an essential role in framing the research approach and structuring a series of explorative design studies.

**Arrangement to make harmony**

Elements of the home are arranged to create harmony; each object contributes to the room, resulting in a feeling of unity (Henton, 1972; Nissen et al., 1994; Stepat-De Van, 1971). The satisfaction of harmony is seen with values in different historical periods; it led to creating a particular arrangement system. The results of analyzing two arrangement examples show that cultural and social values impact people’s decisions to create home spaces with a particular physical object. For instance, presenting the ‘self’ has been identified as an essential value in the American culture for arranging a parlor as a social gathering space (Halttunen, 1989). In the parlor, a social gathering space is arranged to present the owner of the home; the role of the domestic environment is not prioritized to support people’s daily needs. The function of the arrangement is related to people’s behavior. The design studies showed that objects belong together to arrange the living room in the presence of the digital wall. Although participants had different opinions, to arrange a space, the physical and social and spatial dimensions go hand in hand to make harmony.

**Using the digital wall, kitchen vs living room**

The findings of the last two Supportive studies draw insights from a connection to the arrangement. In the literature, the dining room and a kitchen have been introduced as places for social gathering space (Downey, 2013). The kitchen would be one of the places for socializing in a home but Supportive study 3 shows the Lab has limitations for simulating a kitchen space as a social gathering space. Therefore, if the kitchen is chosen as a place to accommodate the digital wall at home, several standards and safety regulations need to be introduced in this scenario. Meanwhile, participants were familiar with living room space; however, it was hard to get a sense of being in a living room if it was not an actual living room. A living room is decorated and arranged for a particular social context. In this thesis, I chose the space of a living room in Main studies.

**Arrangement to provide comfortability**

Learning about the living room demonstrates that the arrangement is planned so that it comfortably serves the participants. In the living room example, still today, the role of physical objects is significant and for casual moments in daily life. By bringing a television to the home environment, the role of the living room is the main space for a social gathering (Silverstone, 2003; Wood...
& Taylor, 2008). The living room is arranged to comfortably serve to experience the television. People lived with television as a technology, and a channel for communication (Silverstone, 2003).

I used constructive design research to frame my design research methodology. In Chapter 3, I articulated the role of constructive design research, the artistic approach in design research, and programmatic design research for investigating the probable situation of using the digital wall (Koskinen et al., 2011; Redström, 2017; Zimmerman et al., 2010). The advantage of using this methodological structure allowed me to use a combination of methods to conduct the explorative design studies. Using multiple methods creates a broad perspective from participants’ experiences with the digital wall. The methods used showed the capability of capturing both physical and imperceptible dimensions of spatial arrangements in the Lab environment.

Lab as a platform to produce knowledge
In this thesis, the Design Research Lab is considered as a platform to conduct design studies. The Lab was provided with different technologies to reveal the tangible and invisible behavior of participants during design studies. Using the space of the Lab enabled me to prototype the probable scenario of the digital wall. For instance, the technology of the media recording method provided careful observation of the study sessions, which was useful for identifying and analyzing hidden behavior (Abdipour et al., 2016).

Design studies are a significant part of the investigation of arrangement changes in this thesis which consists of two parts: Supportive studies and Main studies. The role of the supportive studies shows two parts: the primary exploration of how to use the Design Research Lab, identify the probable scenarios of learning the impacts of the arrangements. The first two Supportive studies demonstrate the emotional responses of participants in using the digital wall at home. Although this finding does not correspond with the arrangement changes, learning shows the contents on the large screens would unconsciously impact vulnerable user groups, such as people with ADHD.

Iterative studies
The tradition in Industrial Design is to go for attention to detail. Each of these design studies pays attention to pieces of findings that elaborate particular details of the relationship between the participants and the technology of the digital walls because it is technologies that show there is some connection here between people’s objects and physical space. The iterative design studies
helped me to set up “appropriate structures” to perceive the “requirements of people” (Benyon, 2012) in the space with the digital wall. The iterative studies provide the structure of the design studies and at the same time, it appropriately established the details and findings that provide the basis to construct the next scenario of design studies. In this thesis, the goal is not to interpret all details during the design studies. Iterative studies showed that design researchers have an important role in making decisions such as a plan to conduct new design studies in the inquiry process.

**The role of body position to experience the digital wall**

The comfort has been seen in the contribution of the three Main studies to provide appropriate body positions. The investigation of design studies shows that the number of participants is one of the underlying factors to understand how the arrangement impacts the social gathering space. In design studies, when one participant experiences the digital wall, the relationships are focused on the person and the artifact. Communication has a central role when two participants or more experience the digital wall. The Main studies show, when the number of participants increases, the role of the digital wall is not prioritized; instead, communication and eye contact guide the arrangement system for creating an appropriate experience with the digital wall.

**User involvement**

Users’ participation is the significant source of data acquisition to understand the arrangement changes in the design studies. The Design Research Lab has improved the possibilities of conducting different design studies with an equitable situation of participation. For Industrial Design education, students and researchers enable to simulate various types of design solutions in the Lab environment (Abdipour, 2019). The technology of the Lab enables documenting the conscious and unconscious reactions of users. This capability of the Lab is valuable when people with special needs join the design studies (Hendricks, 2007; Story, 1998; Stephanie Wilson et al., 1997). Because it allowed them to participate in the evaluation of the design solutions which were not easy to join the sessions with conventional evaluation methods. The Industrial Design students create setups and prototypes with diverse groups of participants and various design solutions such as service design, environment design, and product design in the form of physical or mixed tangible and digital context.
Value of Privacy
When several participants plan to use the digital wall at the same time, they have varied expectations of using large screens. Supportive study 4 reflects that several participants have different choices for experiencing content at the same time. The parallel use of the screens requires a wide range of interface solutions to adjust the contents for each participant separately. In this sense, the privacy of using personal information has become necessary when several participants plan to use the digital walls together.

Illustration techniques
Sketching techniques are an essential part to illustrate the complex relations between participants and the digital wall in the Lab space. Design studies reflected incalculable values of arrangement changes that were needed to be interpreted with graphic methods. I used photos of the study sessions to elaborate on the participants’ experiences, but I realized that the studies’ photos need to be more explanatory. I came up with a technique to interpret the captured photos of the sessions for the talk about spatial arrangements. That adds a sort of technique to Industrial Design where professionals use the sketch and illustrate to visualize the details and the wholeness. For instance, in the next chapter, the imperceptible arrangement has been identified as one of the main types of arrangement changes. I used the combination techniques to describe the imperceptible arrangement situation by capturing photos of gradual changes and using sketching to demonstrate the changes in each step. In this thesis, I identified a need in the role of Industrial Design to elaborate on the complex design studies by considering appropriate illustration techniques.

5.2 Limitations

Methods
The major limitation in design studies is identified in three parts. First, in Supportive study 1 and 2, physiological methods were useful to measure emotional responses, but at the same time by using this method participants remain in particular positions and cannot investigate about large screen using other body positions. In addition, the preparation and analysis of conducting studies with this method are time-consuming. Moreover, since this method addresses the particular findings, it is limited in terms of answering the main research question about arrangement changes.
Usability issues in the design study sessions

In the development of the large screens, usability is an underlying element for setting appropriate interaction between the users and the artifact. I realized two limitations concerning user interfaces with large screens.

First, the concept of the digital wall is in the conceptual stage of product development. The lack of intuitive interaction with the screens in design studies has limited the investigation and user experience. The limitation of interactions affects several aspects such as the movement of participants and connecting the digital wall with the other domestic products in homes. Second, participants preferred to change to a sitting position. There are plausible solutions to try some user interfaces (Cheng & Pulo, 2003; Hayward, 2008; Westing et al., 2011; Zhou et al., 2010). However, some of these interface solutions were not suitable during design study sessions due to the limited time duration. The granted solutions do not pull the time limitation into their arguments while in some of the design studies, I realized people were becoming tired by remaining in standing positions. Therefore, when participants chose sitting positions, they were far from the screens, and the offered haptic system was not a suitable solution to interact with the large screens. This is evidence of the limitation of the granted interface solutions and may affect probable interface solutions in a future scenario with the digital wall.
Chapter 6
Discussion and Implications

In this chapter, I discuss the plausible implications of using the digital wall within an arrangement of a social gathering space. In this thesis, arrangement implies ways that domestic products are arranged (physically) in a space in the presence of the digital wall. The following definition is useful because many elements can be included in a physical arrangement and lead to specific experiences. The domestic products are used by a diverse group of people, and as a sign system, they may affect the human senses (Kent, 1993, Chapter 1). These effects can be seen in the participants’ experiences that caused different forms of arrangement. I describe two types of arrangement implications. These implications are a reflection from observations and feedback of the participants during the design studies. In the last part of this chapter, I present the unexpected findings from the observation between the historical evidence and the last Main design study. Careful observation shows some similarities between the impact of information on walls in the parlor space and the arrangement of social gathering space with the digital wall in the Lab.

Forms of Arrangement

Based on the design studies, I present two types of implications: the tangible arrangement and the imperceptible arrangement. In the tangible part, implications can be seen in three different categories: Taken, Given, and Blended arrangements, each of them reflecting the findings from participants’ experiences in the design studies. The imperceptible arrangement provides insights into the invisible impacts of the digital wall during the design studies. I present a mock-up to visualize the imperceptible arrangement and to describe
the invisible impacts of the digital wall. It demonstrates the occupation of the space that moves from the digital wall towards a central space of the social gathering space.

### 6.1 Tangible arrangement

This implication shows visible changes that have occurred during the design study when participants experience arrangements with physical products in the presence of the digital wall. In this form of arrangement, tangible refers to changes that are visible and touchable by participants and observation methods. The tangible arrangements have been revealed in different design studies to varying degrees. For instance, participants express why they prefer making changes and why something is appropriate to preserve it for experiencing in the social gathering space. From the expression of participants, I classified the tangible arrangement into three degrees: Taken arrangement, Given arrangement, and Blended arrangement.

**Taken Arrangement**

This quality of the tangible arrangement refers to the situation in which participants decide to take out a particular physical product from the design study sessions. In this form of the arrangement, participants avoid using that particular product to have harmony with the rest of the space. For instance, in the rearrangement part of Main design studies 2 and 3, participants decided to remove the bookshelf from the environment because it created barriers for having an appropriate experience in the presence of the digital wall. In the prearrangement part of these two Main studies, the physical objects occupy space and arrange different things. Some physical objects could support the participants’ activities before the emergence of the digital wall. However, in the rearrangement part, participants needed to take several physical objects away from the space to establish a new arrangement system.

**Given Arrangement**

The characteristics of this arrangement are embedded in the suggested situation by participants to experience the large screens. In Main study 2 and 3, when several participants share the experience, eye contact is prioritized for having communication. Therefore, they suggested moving furniture to stay in a better body position to establish eye contact with each other. For instance, in Main study 3, participants decided to rearrange the domestic products to establish
appropriate eye contact. From the participants’ opinions considering the given arrangement, it was essential to provide a suitable socializing space with the other participants and to interact with the large screens.

**Blended Arrangement**

This form of tangible arrangement shows that some physical products are useful to be preserved in the social space, but it can be merged with other items. Main study 2 and 3 participants considered using the physical frames, and the television is unnecessary. These physical objects, television, and frames can be transformed into digital forms, and become part of the interactive contents that can be used on large screens. For instance, a photo of frames can be displayed on the screen. Participants emphasized they can use the television on every part of the screen with different sizes.

The results from the tangible arrangement demonstrate the relationships of people with domestic products to experience the digital wall. It presents the necessity of using conventional domestic products to create an appropriate arrangement. In the situation of using the digital wall in the home, the domestic environment will face different degrees of these three values. Consequently, accommodating the digital wall in the social gathering space will transform the system of the tangible arrangement. These forms of arrangements have been seen based on when conducting the studies in the Lab. There is some uncertainty about the range of the tangible transformation arrangement if design studies are conducted in a bigger space or a real domestic environment. In that case, the core of this learning may not change; instead, the range of changes would be different among the three values of the tangible arrangement.

### 6.2 Imperceptible arrangement

This form of arrangement presents subtle ways in which to change; invisible responses of participants were not seen during the design studies to be accompanied by tangible changes in the domestic products. The findings are revealed by reviewing the film recording after study sessions as well as noting participants’ opinions during the observation of studies. The findings expose the implication of audio-video contents from the large screen on the placement of the domestic products and location of participants in the space. This implication is seen in different studies: Supportive studies 3 and 4, and three Main studies led participants to consider a distance to experience the information on the screen.
Since the concept of the digital wall does not exist yet, there is no standard to determine the appropriate distance from the large screen user interfaces. Participants avoid placing any physical objects between the screen and their location of experience. Reviewing the observation shows when the audio-video contents are presented on the large screen, an invisible surface the size of the digital wall is pushed from the screens into the Lab space. The invisible wall might seem like a metaphoric term, but in reality, it operates like a wall that pushes domestic products and participants’ positions toward the center of the space. In the explanation of the Main study 2 and 3, I used different illustration techniques to demonstrate the users’ experiences. Here, I have created a model to illustrate the imperceptible arrangement and ways that multimedia from the digital wall occupy the space (Figures 39–45).
Figure 39: Scale model of design studies’ elements to simulate forms of imperceptible arrangement and the impacts of the invisible walls: A. The cylindrical wooden objects represent the diversity of participants. B. The cubic wooden objects represent the various domestic products in the space. C. The colorful plate represents multimedia content such as audio-video contents on the large screens; each color is considered for one type of digital content. D. Both walls of domestic space and invisible walls that can move from the place of main walls toward the center of the space. E. The ground of the domestic environment. The tracks on the wooden ground have only one function to hold the flattened surfaces i.e., invisible walls and contents on the screens. F. One probable scenario of imperceptible arrangement and the placement of elements: the main walls and a boundary of a domestic environment, the symbol of participants, and domestic products.
Figure 40: One probable scenario of experiencing two types of multimedia in a domestic environment. (Yellow and Red plates represent two multimedia sources).

Figure 41: Information from multimedia creates void space; to experience the multimedia appropriately, this space needs to be empty of physical objects.

Figure 42: In this step, participants experience multimedia content on the large screen from two sides of walls. In this situation, multimedia contents create void space from two sides, and the invisible wall from the void pushes participants and physical objects toward the middle area of space.
Figure 43: Participants experience multimedia content from three sides of the domestic environment. Participants and physical objects are pushed from three sides into the center area of space.

Figure 44: In this probable scenario, information from three sides is pushed into invisible walls. The shaped void makes a distance between the digital wall and the other elements in a space.

Figure 45: One of the significant implications of invisible walls is seen in the reduction of the number of participants and domestic products in a space. In the imperceptible arrangement, the invisible walls create a void, and this is a space that needs to be empty to experience multimedia content on the large screens.
The model is depicted to demonstrate subtle changes in the imperceptible arrangement. It comprises several elements of design studies that have been simplified to show how the imperceptible changes happen in the Lab environment (Figures 40–45). In this model, I do not plan to simulate any design study situations of this thesis; instead, the model is presented to illustrate a situation in which invisible walls influence the arrangement changes. The main elements in this model consist of the representation of the domestic environment, several user participants, a few numbers of domestic products, walls of the domestic environment, and multimedia content.

To explain this model and demonstrate these impacts, I have used visualization techniques and annotations. In this model, the colorful acrylic sheets represent multimedia, (Figure 39 C). I assume participants may play one or all forms of multimedia on large screens. The number of participants and domestic products can be varied, and the limited domestic space is an assumption space for explaining this model. In this space, I have considered that various forms of multimedia can be experienced on large screens: a static image such as photos, motion picture, i.e. movies can represent this content and sound such as music.

**The role of the Invisible wall**

The invisible wall refers to the situation when the multimedia is displayed on the screens. Although the distance between the invisible walls and the domestic walls is empty, participants cannot use domestic products in between because the physical objects cause barriers for experiencing the contents on the screen. This situation is seen in the rearrangement part of Main studies 2 and 3; participants decided to remove the physical objects, such as bookshelf from the digital wall. The invisible walls impact the location of participants and move them from the large screen toward the center of the space. It is almost inevitable to avoid these imperceptible changes since every spot on the large screen displays pieces of information. But this arrangement would be problematic, because, on one hand, participants need to establish eye contact with each other, on the other hand, the large screen pushes people and physical objects towards the center of domestic space.

A similar situation of imperceptible arrangement with the digital wall in the Lab is seen with the arrangement of the television in the home. The television also creates an invisible screen that stands far from the surface of the television display (Figure 46); it creates a distance between the display of the television. There are no physical objects within the created distance between the television
display and the invisible screen. Otherwise, the information on the television is masked by physical objects, and this distance is empty of objects. It seems this is trivial that we keep the distance far from the television screen, here, this distance is assumed as a form of arrangement that comes with the experience of the television.

**Added values in the imperceptible arrangement**

Here, the digital wall is not considered as a big television, but there are similarities between these two artifacts: both of them are considered to be used in the social gathering space in homes, and participants communicate with each other while they experience screens. The invisible wall has an essential role that is seen in the imperceptible arrangement. Findings from the impact of television on the arrangement changes in the living room, it is assumed the digital wall would
similarly impact the arrangement of the domestic environment to different degrees. As has been said earlier in this thesis in Chapter 2, the television has become the center of gravity in the living room. Based on the demonstrated mock-up of the Lab, the imperceptible arrangement is seen as the placement of the participant and the domestic environment in the center area of space.

**A careful observation- An unexpected arrangement finding**

Design studies have provided a variety of degrees of understanding of the relationships between participants and domestic products in the presence of the digital wall. For instance, Main studies 2 and 3 demonstrate the participants’ positions are crucially important to establish their communication channels between each other and at the same time experiencing contents on the large screens. Notably, in the rearrangement part of Main study 3, participants decided to sit in a circle shape to experience the information on the screen and have eye contact (Figure 47). This pattern of gathering to the center is seen similarly in the parlor example. However, the function of each period is different, but there are results gathered about arrangement through this careful observation.

In Chapter 2, the parlor space has been identified as a zone in the home to expose the character of the owner. In this space, the parlor exhibits domestic products to be shown to guests or a particular group of people. Especially, in the parlor, people used domestic walls to display various information about the owner: decorative elements, wallpaper, frames, and paintings; where the information on the walls is not interactive. At the same time, the arrangement systems are designed for communication. Figure 48 shows that there is a distance between the communication area, around the tables, with the wall of the environment. No matter the type of information on the walls, there is a specific need to appropriately experience the contents on the wall.

Moreover, the findings from the parlor demonstrate presenting multiple types of information on the wall requires a large space in front to be exposed. Taking into consideration this distance in the parlor might be useful for displaying the information on the walls to people in the space. Perhaps, the digital wall is presupposed to be installed in an ample space of a domestic environment, instead of trying to adjust this artifact to any size of home space.
Figure 47: Above: On the left, the rearrangement part of Main study 3. Participants decide to sit in a circle form to communicate with each other and simultaneously experience the information on the large screens. On the right: Top view of the experience on the left image. Content on the large screen of the left image is from YouTube (2015)\(^2\) and the photo of the study sessions by Morteza Abdipour.

Figure 48: Below: On the left: Information on walls: decoration elements, paintings in a parlor space, motives. The image takes a quote from “The Georgian Room, Royal Commission, St Louis International Exhibition 1904: The British Section compiled by Sir Isidore Spielmann, London, 1906, British Library, 7957.h.12 (c) British Library Board”(Greig & Riello, 2007). The image on the right: A top view of the parlor space from the left picture where information on walls is exhibited, and physical objects are placed in the center of the space.
Arrangements and the gravity towards the center of space

The implications of these design studies reveal the importance of the center of space as a key location for the experiences of participants. In the design studies, participants prefer a sitting position, and consequently, they maintain a distance from the digital wall; this behavior can influence designing the solutions of user interfaces. In the imperceptible arrangement, objects are pushed towards the center of space. At the same time, the digital contents occupy the peripheral space and create a void. By considering the participants’ needs and the proper operation of the digital wall, here, the center of the space becomes the most important location to construct the feeling of balance and harmony with the digital wall. Arrangement and gravity towards the center show a significant understanding of the implications of the digital wall, as a technology, to “change our space” and participants’ behavior (Wiberg, 2020). These findings are vital in Industrial Design to create appropriate solutions and frame a future, harmonic arrangement in a space.

Design studies reveal multiple forms of arrangement and some of the complex situations between participants and the digital wall. Revisiting Figure 1 at the beginning of this thesis reminds us of the possible relationships between users and the digital wall can be complex. In this thesis, the findings from the design studies bring to the surface of multiple degrees of the complex participants’ experience with the digital wall in the Lab. Findings from these design studies reflect various “complexities” (Janlert & Stolterman, 2017, pp. 73–96) at different levels. Here, the levels of complexity of experiences can be varied in each design study; however, levels of experiences are always interwoven together.
End Notes


In this thesis, I investigated the emergence of using digital walls in the home environment and the probable implications on the arrangement changes of a social gathering space nowadays called the living room. I have used the constructive design research methodology to frame my research. The design studies contributed to a deep understanding of the probable implications of the adoption of digital walls. While each chapter of this thesis focuses on particular content; the constructive design research methodology provides a way of thinking that corresponds with the whole of the thesis.

This thesis has not been constructed to prescribe particular solutions, nor does it advocate using or rejecting digital walls in our homes. However, during the design studies, I realized some essential needs that would be useful as design suggestions. Creating design suggestions is useful for the design research process, as Anthony Dunne and Fiona Raby advocate “conceptual design provides a space for doing this” (Dunne & Raby, 2013, p. 12). They have highlighted the importance of design thinking as “we are not talking about a space for experimenting with how things are now, making them better or different, but about other possibilities altogether” (p. 12). In this regard, this chapter is presented in two parts: Design suggestions and Future directions for further investigations. These two sections mainly have been shaped through conversations with participants during the design studies, reflecting the speculations of participants, reviewing the observation sessions, literature reviews, my notes from design studies, and learning from arrangement changes in this thesis.
7.1 Design Suggestions

Through this empirical work, designers can get a better understanding of how people relate to such spaces, with the digital wall, how such spaces support interactions, and how such spaces are configured through design and use. There is a growing interest (in research as well as in practice) in “interactive architecture”, “mixed reality spaces”, and a “blended physical/digital environment”, but up until this point, this is addressed through conceptual work and design explorations, i.e., (Benyon, 2012; Benyon & Mival, 2008). These are essential aspects to understand for designers aiming to support human-building interaction, or interaction with interactive architecture, physical and digital or mixed reality spaces (Alavi et al., 2019; Wiberg, 2010, Chapter 4). This thesis contributes to this as an important empirical study of interaction in such physical and digital spaces.

I am interested in what digital material does to space, arrangement changes, details of people’s behavior, and in particular the large display, as well as defining this digital material as the digital wall. In Industrial Design and product design, this attention to detail is always significant. I want to be specific about the digital wall as the object of the study. I have made decisions based on frames and preconditions of this thesis and continuing with the main scope of this Industrial design research. The findings highlight some design suggestions but not as a ready-made product solution; instead, they are presented as guidelines and suggestions for designing.

*Digital Hub for social gathering space*

The digital wall will be used, in reality, with multiple features; connecting to the internet is a given; it provides possibilities of networking of multiple devices and using them together with the digital wall. This requires a particular space for setting up this complex system. The contemporary living room might have the potential to accommodate large screens, but people might need to perform multiple digital activities in parallel. In this scenario, both in terms of the physical and digital formats, does the living room provide sufficient area for a social gathering space? This thesis suggests considering the digital hub in the home environment, rather than adjusting the modern living room to the digital wall. The digital hub can refer to a space where several digital devices are connected to each other and to the digital wall, and multiple participants can interact and socialize.
Need for redesigning domestic products

Our contemporary living rooms have been filled with domestic products. These items have reasons to be kept in this social gathering space. In this thesis, the Main studies demonstrate that if we use the digital wall in homes, the current domestic products may need to be adjusted to have an appropriate experience with the digital wall. Design studies show that there is a lack of appropriate furniture to provide appropriate body positions for experiencing large screens.

Telecommunication with the digital wall

The digital wall has a significant potential to serve as a possibility for remote communication. This characterization might be useful for moments when people need to stay in a home for a long time, i.e., during a pandemic crisis. Therefore, a social gathering space is a physical area for communicating both in physical and digital formats. During design studies, most of the participants described their ideas of using the digital wall for distance communication: playing a game with several people, using the digital wall to participate in an event, remote working and studying, and participating in social activities by distance. In one of the design studies, one participant expressed:

“I would like to try working out with other people in gyms or watching movies together with other people whom they live with somewhere else”.

These speculative ideas might provide materials for design works to improve the possibilities of the digital wall.

User interfaces

Currently, there are several interactive ways available to work with the digital wall. Designing decent user interfaces are prioritized in the development process to improve interaction mechanisms with large screens. Using a desirable interface solution has been the common demand of participants in all of the design studies.

User Involvement

A diverse group of people who have or do not have special needs will use the digital wall. It is necessary, not optional, to commit to designing a product by considering the needs of a special group, with a broad spectrum of physical and cognitive needs. Supportive study 2 demonstrates the vulnerable group of
people with cognitive disability and disorders who were influenced emotionally by experiencing the contents on large screens. This thesis has been framed with a user-centered approach, and involving a special group of users is seen as a necessary decision in the entire design development process.

The digital wall is a complex artifact that will be used by several groups of people. It is impossible to list all of the design suggestions in this limited thesis. In addition, this artifact does not exist in reality, and improvements require a holistic design thinking process before accomplishing any design solution in regard to improving the conceptual idea. Otherwise, it would be a weak strategy to improve one element of the digital wall without considering other aspects as well as people’s needs.

Optimal arrangement

The optimal arrangement is an outlook that focuses on how an arrangement develops, and it is established (materiality and socially) over time. The illustrations of the design studies show, to some extent, there are optimal arrangements when participants plan to arrange the Lab space. However, it is hard to consider an optimal arrangement, at least one that works for the participants. Here, the optimal arrangement is a relative situation, and it depends on several factors such as the size of homes, the number of people who are living in a space, the geographical place of homes, and cultural background of residents, such that answers for each individual cannot be generalized to others. From a broader perspective, living one’s life is not about optimizing, it is simply about living, and living has other qualities than just arriving at the most optimal or most efficient level.

This thesis acknowledges that the arrangement is something that develops over time, and people can feel it. For instance, if a family moves to a new place, and first they may feel the new living place is not a home without furniture or objects. In the beginning, the new place does not feel like a home, but then after a few weeks or months or years, people feel at home in the new space, even though not everything is in a perfect place. In the design studies, to some extent, the optimal arrangement was shown in Main studies 2 and 3 when the participants made quick decisions to change the arrangement. They redesigned the space based on their needs from the prearrangement to rearrangement while experiencing the digital wall in the Lab space. Now concerning the optimal arrangement, other questions might raise: who arranges us? And what? And what is the role of the designer? Can the designers design everything? Should the designer take responsibility for the whole design or to what extent is it something that is up
to the user? These questions are all potential topics for future research in these emerging areas, i.e., Industrial Design, Interaction Design, Interior Design, Architecture, and Design Anthropology when there is a clearer perception about using the digital wall in real home spaces.

7.2 Future research directions

The emergence of the digital wall should impact several aspects of human behavior. This is not synonymous with categorizing the digital wall as a good or bad product. Instead, it is essential to know more aspects of this artifact in the future. During the process of my research, I have identified some potential for further research as an important aspect of my research. But at the same time, I have become cautious to keep the focus on my research question in this dissertation. Here, I present three areas that I have identified to be investigated in the future in relation to the subject of large display user interfaces.

Sustainability

During design studies, several participants became interested in using the digital wall in their home or office environments. The attractiveness of using technology is one side of the coin; meanwhile, critical lenses are necessary to create a solution that can be useful for people and our “environment” (Papanek, 1985, p. 250) from different perspectives. I see the impacts of the digital wall from a broad perspective: interaction, architecture, furniture, behavioral, usability, emotional design, and product design. For instance, based on the findings of this research, the appropriate experience of the digital wall in the home requires suitable furniture. This means that the current furniture loses function and new types of furniture are required. In this emergent situation of our planet, humans and other creatures are challenged with multiple types of environmental problems.

The emergence of the digital wall is not only about improving one product; instead, it is essential how the other elements of the conceptual framework in this research will be changed. If the scale of changes is huge, will our planet be capable of tolerating extra production to provide the digital wall? From another point of view, presumably, the digital wall can help us to decrease some harmful production. In this case, how can the potential of digital walls improve the quality of our life in a sustainable manner? Sustainability, with several aspects, is one of the most critical challenges that need to be developed in future
research, i.e., to increase “the quality of our living contexts” (Manzini & Cau, 1989). Articulating these questions and concerns deserves further investigation to elevate awareness and to wisely plan to produce a new product despite its initial attractiveness.

**Ethics**

Thinking of the digital wall as a ‘computer processor’–‘large display’ encompasses several types of information and ways of interaction. Benyon and Mival draw our attention to the area of ethical perspectives. “There are important social and ethical issues involved if we draw people into having relationships with devices, or with a computationally enabled ambient environment” (Benyon & Mival, 2008). This is an important area for future research, for instance in relating to things. Wiltse (2020, Chapter Introduction) in her book emphasizes considerations of ethical values, i.e., “ethical significance and care” (p. 1), “ethical responsibility” (p. 7), and “rethink[ing] privacy in digital context” (p. 8). It is also essential to be aware of some of the ongoing research related to increased screen time, and it is good to keep an eye on this for further investigation (Mander, 1978; Rushton, 2015). This area can be improved with some ethical considerations, for example, the possibilities for people to relate to and configure the digital wall with respect to privacy around social interaction.

**Conducting design studies in a real situation**

This thesis acknowledges that there are many ways to conduct this research topic. I have conducted all of my design studies in the Design Research Lab; I have articulated some of the benefits of using it. Future research is required to investigate the prototype of the digital wall in a real home space with family members. It is essential to observe the interaction of family members with the digital wall for an extended period of time or experiments over the course of several days.
Epilogue

The contributions of this thesis lean toward the Industrial Design elements. (Industrial) designers design things and objects, but in between these different things, there is also empty space. For instance, what this thesis shows is the imperceptible arrangements about invisible aspects of the space. This research demonstrates how, i.e., in Main studies 2 and 3, things and people occupy space and arrange different things, parts of the interior so as to support some people’s activities. But at the same time, it is also about the empty space, and it is about the invisible dimensions of space. And this implies Industrial Design. When (Industrial) designers design an object, maybe more implicitly, they also design the empty space around the object. In this sense, the empty space affects not only human actions but also where people stand, how people stand together, or apart, influences people’s actions and people’s activities. The invisible empty space needs to be part of Industrial Design; that need adds to design theory in Industrial Design.

Studies in this thesis have this clear evidence that participants were drawn into the middle of Lab space as the study shows some sort of gravity. This adds important values to the dynamics of what the digital wall does to space. I would say that the main contributions offered in this thesis are not about technology, i.e., the digital wall. However, staying close to the technology enabled me to see these two things that have to do with the method and the theory. Having observed this has implications for design theory in Industrial Design because there is something there for people between the object and physical space.

The contributions of this research work pertain to the conceptual situation of the digital wall. In this thesis, the empirical studies in the Lab environment are something significant for the Industrial Design field in the future; it adds contributions that will be relevant in the near future. It’s research on a product that is almost but not yet here, but needs to be done before it arrives. From this perspective, I see the early design studies of this thesis as a sort of initial empirical study in this growing area of interactive large screens as well as design research.
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