Situated Abilities within Universal Design – A Theoretical Exploration

The Case of the T-ABLE – A Robotic Wooden Table

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***Abstract*—This paper investigates Universal Design (UD) through the idea of *designing for situated abilities*, rather than focusing on designing for disabled users. This shift in perspective from disabilities to abilities is explored through the design of a domestic robot that integrates into our homes, in a familiar way. We explore the concept of *designing for situated abilities* through a proof-of-concept robotic wooden table, the T-ABLE, as an alternative design for domestic robots. Finally, the paper identifies four dimensions of situated abilities.**

Keywords-robotic wooden table; design; Universal Design; situated ability; elderly.

I. Introduction

This paper reports further on our previous work [1]–[3] on investigating the use of robots in the homes of the elderly. It presents a proof-of-concept robot design, illustrating design for situated abilities. The design and the embedded concept of situated abilities represents an alternative way of thinking about, discussing, and designing with a focus on the abilities of human beings in terms of everyday situations, rather than focusing on their disabilities.

Specifically, this study presents an investigation of an alternative design for domestic robots, such as wood-based designed robots, for better integration in the home environment. Thus, we present a proof-of-concept robotic wooden table, called the T-ABLE. The name of the robotic table originates from the terms “table” and “able” or “abilities”. The design of the prototype itself is grounded in the original definition of Universal Design (UD), which addresses design which is suitable for as many individuals as possible. We move forward, in this paper, from the idea of UD associated with disabilities, and propose a shift in perspective, to a new dimension of UD, namely one focusing on designing for *situated abilities*. We argue that the abilities of individuals are strongly connected with the context and situations they find themselves in. At the same time, familiar things can represent a good point of departure for designing for abilities, rather than disabilities. Thus, the research question that we address in this paper is: *How can we shift perspective from disabilities to abilities when talking about Universal Design?* This research question can be explored in many ways. However, one approach is to explore how we can design domestic robots that fit the abilities of humans and integrate into individuals’ homes, in a familiar way.

The paper continues in Section II by presenting the background to this work. Section III includes a presentation of related work where the current research on abilities in design is discussed. Section IV focuses on the theoretical grounding for situated abilities. Section V presents our work in detail as it impacts on the elderly in terms of the Multimodal Elderly Care Systems (MECS) project leading to the proof-of-concept presented in this study. Section VI provides a discussion around the initial stated research question, the proof-of-concept design, and situated abilities. Section VII includes the conclusion and further work to close the article.

II. Background

This section presents the current state-of-the-art regarding the use of robots in the home. We continue thereafter by defining Universal Design (UD) and explaining the lack of a legal framework for UD for robots to be used in the public sector, such as healthcare or homecare services. We end the section by stating the motivation for the study, before proceeding further with related work.

A. State-of-the-Art

Several studies have developed theoretical frameworks used in studying robots in the home, such as the product ecology framework [4][5], the Domestic Robot Ecology [6], the facilitation framework [7], and the automation of work tasks framework [8]. We have learned from these studies investigating the use of domestic robots that individuals will often carry out changes inside their homes to fit a robotic product. Moreover, we have also learned from these previous studies that they focus on the use of the product, rather than on the human, or the user using the product and its abilities to handle the situation in hand [5]. Compared to these previous studies, our study proposes looking at the interaction between individuals and the robotic product, from a socio-relational perspective [9], with a focus on the experienced abilities of the individual and design of a domestic robot in the context of the abilities of the elderly (not their disabilities!) as the point of departure for our design.

Earlier studies show that once moving devices are introduced in the home, such as a robot vacuum cleaner, several fundamental changes need to be made in terms of the structure and infrastructure of the home [2][5][6]. However, if the design of a robotic product is good enough, the human should not have to adapt to the product itself: the robot should be able to integrate itself into the home environment. However, just a few of the current designs of domestic robots fit the home environment and integrate well within existing home environments. For instance, some studies have explored this idea that the aesthetics, functionality, and design of a robot should fit in with the human context. Such an example is PARO, a robot with a seal appearance used for older adults [10]–[12]. PARO seems to integrate well in home environments for the elderly, such as those suffering from Alzheimer's, giving them feelings of calm with its plush appearance. Since an animal's company has been shown to have beneficial psychological effects for relaxation, positive physiological effects, such as improving vital signs, and social effects among the elderly, PARO is proven in research to be a robotic example which fulfils these criteria [11]. It is recommended that elderly people with Alzheimer's have pets around; however, they are often not able to take care of a pet or even themselves. PARO is a good example of a robot fulfilling this need.

In addition, other previous studies focus on humanoid robots, such as Nao and Pepper. Although these robots have a humanoid look, they also have a plastic appearance. Beyond cost and other physical properties, one reason for going with a plastic look could be to avoid a user's feeling of uneasiness from the uncanny valley [13]. Studies have also shown that people assume different abilities and assign different attributes to robots depending on their appearance [14][15]. Others have suggested that a focus on the movement of the robot can turn people's attention more to the movement than the robot's appearance [16] even if the motion makes the uncanny valley effect more pronounced.

B. *Universal Design and Design of Robots*

Universal Design (UD) is described as "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" [17]. UD is based on seven core principles. These are indicated and exemplified in Table 1.

However, many people often associate UD with people with disabilities. Historically, indeed, UD was often associated with people with disabilities along with The Americans with Disability Act (ADA) [18]. These movements have had a great impact on supporting the focus of UD on designing products and services that can be used by as many people as possible. However, according to the Norwegian Digitalization Agency, UD is about designing surroundings that take into account "variation in the functional ability of inhabitants, including people with disabilities" [19]. A universally designed solution aims to reach out to as many people as possible, without the need for adapted solutions [19].

Further, certain aspects of robotics, such as Socially Assistive Robotics (SAR), aim to help people with different conditions such as Autism Spectrum Disorder (ASD), dementia, and also in the area of care for the elderly [20], but this refers specifically assistive technology for these particular groups. Aside from suggestions for incorporating UD as a way of making a robot work better in a home environment [21][22], this is an underexplored area in Human-Robot Interaction (HRI) literature. Indeed, given the limits on a robot's processing capability, poor sensors, and limited movement, robots themselves might benefit from a UD environment.

On the other hand, much of the focus of UD in ICT has been on making information accessible by applying the Web Content and Accessibility Guidelines (WCAG) [23] when building web sites and mobile applications. Typically, a robot is not presenting information the same way that a computer or mobile device would, and this means that there is not a straightforward way to apply the WCAG to a robot. For instance, Norwegian laws and regulations regarding UD in Norway [24] include aspects of the design of ATMs, payment terminals, and digital learning environments in education and training, including Higher Education. Norwegian Law, however, does not include regulations regarding the design of – and interaction with – robots, nor does it cover robots to be used, for instance, in healthcare or home care services in the public sector. In other words, the Norwegian laws and regulations relating to the Universal Design of these technologies are lacking, while the adoption of robots in health- and home-care seems to be ongoing.

Table 1. Universal Design Principles

#	UD Principle	Example from objects in everyday use
1	Equitable use	Use of a ramp for getting into a bus: it provides equal ability to step onto a bus for both people in a wheelchair and without a wheelchair, such as a woman with a stroller
2	Flexibility in use	The use of a table with an adjustable height is good for both people for abled people, people with back problems, people sitting in wheelchairs, or children
3	Simple and intuitive use	An iconic example is the iPhone design with its buttons in the same place in different versions.
4	Perceptible information	Consistency in using symbols for volume or radio buttons, send icons, or save icons on buttons
5	Tolerance for error	The undo button provides reliable feedback. Another example is the oven lock button for children's safety.
6	Low physical effort	The height of ATMs provides easy access and low physical effort for people of different heights, including children and people sitting in a wheelchair
7	Size and space for approach and use	The gates of a metro-station or security control at the airport should be large enough to accommodate individuals of different sizes, or people sitting in a wheelchair

At the same time, the elderly population (those over 65 years old), in terms of elderly the total population in Norway, is predicted to increase from 16.5% in 2016 to 17.5% in 2020, to 20.2% in 2030, and 27%, in 2070 [25] (p. 360). Moreover, life expectancy is also expected to increase in Norway, by 0.2% (ca two years) by 2070 [25]. In addition, the number of expected care recipients in Norway will increase from 367 000 in 2016, to 387 000 in 2020, to 485 000 in 2030, reaching 815 000 in 2070 [25] (p. 362). Out of these numbers, the number of home care recipients will increase from 200 000 in 2016, to 212 000 in 2020, to 263 000 in 2030, reaching 420 000 by 2070 [25]. These numbers are the highest amongst a reference scenario composed of recipients of institutional care, home care, and cash benefits (compared to institutional care that will increase from 45 000 in 2016 to 131 000 in 2070, and to cash benefits that will increase from 121 000 in 2016 to 264 000 in 2070) [25].

Moreover, the aging population seems to be the 'key driver' in the development and adoption of robots [26]. New forms of ICTs, such as robots, are being introduced into the home of the elderly to prolong their independent living [27][27][28]. The integration of robots into the homes of the elderly are argued for, on the one hand, by the statistics regarding the aging population, but also by longer life spans accompanied by corresponding disabilities due to age, by difficulties in Activities of Daily Living (ADL) experienced by the elderly, and also increased costs and a lack of (human) resources for supporting the elderly through home care services [29].

In addition, policies and political agendas are being introduced concerning the integration of robots in home care services. These usually focus on studying robots in terms of how they meet societal needs. EU Active Assistive Living (AAL) and the EU Horizon 2020 Robotics Roadmap are two of these agendas [29].

However, as earlier specified, such regulations are lacking in Norway. If such robots are to be adopted in the public sector, including the health- and home-care sectors, these robots need to be designed in such way that several users, including medical staff, care recipients (elderly or patients), informal caregivers (family members if the robots are to be used in the home), as well as technical staff are able to use them. This also means that the robots need to comply with certain standards and requirements in order to suit several types of users and/or actors (individuals, organizations, and settings). Thus, this implies that the robots need to aim to be universally designed, i.e., a minimum of requirements or standards must be fulfilled by the robot design in order for it to be able to be used by diverse users. Many of these potential future categories of users of health- or home-care robot services are not disabled people from a medical point of view. They also often lack digital or "robot" literacy.

C. Motivation

Although similar studies to this one have analyzed robot performance in homes [30]–[32], there are still many robot forms and services to explore. The elderly people in our previous studies were keen to have robots that they could understand, could manage easily, and were meaningful for the elderly [1]. In other words, robots must be designed to meet the requirements of comprehensibility, manageability, and meaningfulness, fin line with Sense-Of-Coherence (SOC) theory [33].

Thus, a table robot that can move around, and is made of wood, may feel familiar to elderly people with a design that can eventually meet these requirements. Some similar attempts have been made previously in other contexts, such as in studies investigating skeuomorphic design [34], or designing for simplicity and prolonged elderly's mastery of technology, as shown in [35]–[38]. Many of these studies, however, have a focus on static technology, i.e., technology that does not move semi-autonomously in the home. This study is different from previous studies because it explores a moving object in the home, namely a robotic table with the look of wooden furniture that is modular and supports multimodal interaction in line with human beings' situated abilities. Its design is based on the original definition of UD and its seven principles.

III. Related Work: On Abilities In Design

This section presents the related work on abilities in design. The section starts by presenting the concept of abilities in design viewed from a general UD perspective. Thereafter we continue by briefly presenting the Ability Based Design (ABD) perspective.

A. Abilities in Design

UD is studied at the micro-, mezzo-, or macro-level [39]. At the micro-level, there are often studies examining individuals or groups in UD, in order to understand human characteristics. Specifically, studies at the micro-level focus on human factors and psychology. These are usually studies in Human-Computer Interaction (HCI). At the mezzo-level, there are often studies on computer science for engineering that investigate the use of technology as a mechanism of participation. Specifically, these studies are within the fields of informatics and computer science. These are usually carried out at an organizational level. Studies at the macro-level focus on the social and legal aspects of an issue. Such studies include the use of ICTs or digital learning environments in Higher Education, and investigate laws, regulations, and legal frameworks [40]. Micro-, mezzo- or macro-level studies may include investigations on inclusion and accessibility [41][42], or diversity issues [43]. However, many of these studies focus on the dichotomic pair of abilities-disabilities. This is, indirectly, a *pathogenic view* since disabilities are a focus. A pathogenic view refers to seeing the individual in terms of what is wrong with them and regarding the disabilities as needing to be corrected.

Further, others do not enter the polemics of UD; however, they address the abilities or capabilities of people from a Participatory Design (PD) perspective. For instance, Joshi [35] wrote his Ph.D. thesis on the topic of designing for capabilities. He has co-authored several papers on designing for experienced simplicity [36] and prolonged mastery among the elderly [44].

Furthermore, Frauenberger [45] has elevated the idea of designing for abilities by talking about "designing for different abilities". However, his work focuses on designing for medically-diagnosed individuals, such as designing for the abilities of autistic children [46][47]. Thus, the dichotomy of abilities-disabilities is indirectly present when indirectly adopting a pathogenic perspective.

However, a few have adopted a *salutogenic view* in terms of designing for abilities; this view begins from the perspective that there is nothing wrong with the individual, but with the environment surrounding him. Within this salutogenic approach, some talk about Ability-Centered Design (ACD) [48], whereas others talk about Ability Based Design (ABD) [49]. Although there are nuances in these two design types, they have the same common goal: putting the individual's abilities into focus. To illustrate the idea, the concept of ABD is presented in more detail below.

B. Ability Based Design (ABD)

Wobbrock [49][50][51] introduced the idea of ABD. It refers to designing for the abilities of people, rather than their disabilities. He and his colleagues argue that one cannot have disabilities in the same way that one cannot have "dis-height" or "dis-money" [49] (p. 91). The ABD concept is described according to a set of principles that is supported by examples [49]. Specifically, ABD systems are systems that focus on the individual's abilities, on what an individual can do, where the system has some kind of awareness about the user's abilities, such that it can adapt and accommodate their abilities [49]. According to the authors, the challenge with ABD systems is that there is a high variation in the abilities of users. However, ABD systems can be regarded as ideals, where the systems themselves are able to adapt and be re-configured to users' abilities. This implies that the responsibility for being able to interact with an ABD system shifts to the designer and not the other way around, to the users [51]. This idea is similar to the one presented in this paper, which focuses on designing for situated abilities, where the individual user can interact with any system at any given time. This would require a Global Public Inclusive Infrastructure [52][53]. Finally, ABD design is centered around a disabling environment and situations, rather than around an individual's disabilities [51].

IV. Theoretical Grounding: On Situated Abilities

This section presents first the origins of the concept of "situated abilities" and its development. It continues thereafter with some examples of possible experiences of situated abilities by the user in different situations.

The term "situated abilities" was first mentioned in the work of Wobbrock and colleagues [51]. However, it was never defined, framed, explored, or further anchored. Saplacan [54] has attempted to revitalize the concept. The framing of situated abilities was inspired by the work of Antonovsky's [33] and his salutogenic perspective on the health and ease/dis-ease continuum. His work was grounded on the idea that we should study what makes people healthy, e.g., "at ease", not what gives them "dis-ease". Along the same lines, the author [54] framed situated abilities as having as a point of departure the individuals' abilities rather than his disabilities. Thus, the author framed situated abilities as the human being's ability to comprehend, manage, or find meaning in an interaction with a system or technology [54]. Further, the author [54] explains that ability, if viewed on an ability continuum (Figure 1), can be understood in terms of a lesser- or greater scale, depending on how the individual, as a

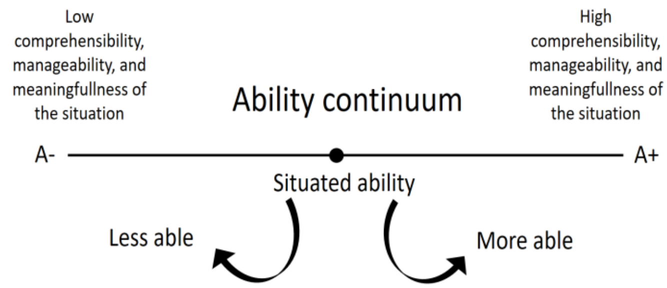

Figure 1. The ability continuum [54]

human being, experiences a situation where she interacts or uses a digital system or technology.

We present some examples of situated abilities below:

- **Example 1** on robots. The human needs to install, to understand the technicalities and feedback from "autonomous things", to facilitate and adapt to them, and to divide and share their work tasks with them [3]. Examples illustrating this type of situated abilities can be found in studies on the use of a semi-autonomous robot, such as a vacuum cleaner robot [2][3], or a robot lawnmower [8]. These studies illustrate situations where the human's abilities are situated, i.e., they have lower or higher abilities to interact with the robot, depending on their familiarity with the respective robot. However, in many of the situations presented, it seems that humans need to adapt to the robot's work to make it work, and not the other way around.

- **Example 2** on Digital Learning Environments used in Higher Education. Although there is a regulation in Norwegian law in The Discrimination and Disability Act, Chapter 3, on universal design [55], the law addresses UD only from the perspective of the single-use of individual websites. This, however, does not cover the user's experience as a whole, when, for instance, using several websites or platforms, such as in the case of the cross-use of digital learning environments [56]. Examples of such situations have been illustrated in several studies [54][56].

- **Example 3** on chatbots. An example of experienced situated ability is when the human user interacts with a chatbot, but the chatbot does not understand what the user wants even though the user knows what the user needs help with. This situation often occurs not because of the design of the chatbot itself, and not because of the user's disabilities. The user would solve the problem much more easily by talking directly to a human instead of using the chatbot. The use of the chatbot, however, lowers the situated abilities of the human user, in that situation. Several studies on chatbot design have been undertaken, with both people without any disabilities, and people with disabilities (see for instance [57][58].

- **Example 4** on the use of a different operating system: Another example is when a Microsoft user is asked to use a Mac computer. The human user will encounter lower situated abilities when using the Mac computer, but higher situated abilities when using the Microsoft computer, if the user has mainly used earlier Microsoft computers.
- **Example 5** on ordering a book via the e-library system. Another example is when an old person without ICT literacy is asked to order a book via the e-library system. The person will encounter lower situated abilities in the interaction and use of the e-library system, whereas they will experience higher situated abilities if they place an order at the library's desk. This example was also presented in [54].

V. Case and Proof-of-Concept Design

This section starts with the case brief. Thereafter, it continues with a presentation of the initial findings from the research project that led us to propose the current design for T-ABLE. The design of the T-ABLE is then presented, followed by our initial tests.

A. *Case brief*

The study is part of the Multimodal Elderly Care Systems (MECS) Research Project. MECS investigates the requirements, specifications and design of a safety alarm robot for elderly people living independently in specially designed accommodation facilities dedicated to the elderly (≥ 65 years old).

B. *Initial Findings*

From 2016-2019, the authors (DS, TS, JH) conducted a series of studies with the elderly on domestic robots to be used in their homes. Through workshops, user studies, individual interviews and group interviews [1][3][59], we learned that a robot's functionality is the most important aspect for the elderly, although appearance and aesthetics are also important, especially for female users.

Throughout our investigation, we were interested in developing knowledge about the preferences of elderly people in terms of a safety alarm robot, how the safety alarm robot should be designed, and what functionalities it should have. Although the research interest was in a safety alarm robot which ultimately had mounted sensors and perhaps an RGB or an infrared camera that could detect and track the health state of the elderly user, it was soon noticed that the elderly were not familiar with this kind of advanced technology. Although we tried to talk about safety alarm robots with the elderly, as this was the main goal of the MECS project, the elderly indicated that they were more in need of assistive or servant robots. They explained that they needed a robot that could help them with moving things around in the home, a robot that could bring them objects, or a robot that could help them with household activities. At the same time, the elderly people wished for a robot that did not occupy too much space since their apartments were generally limited in size, usually composed of a kitchen space joined to a living room, and a bedroom, a bathroom, and a small entrance hall. Many of the home spaces were cluttered with furniture, personal items, art objects, books, walking-chairs, or wheelchairs that occupied a lot of space. In 2018, vacuum cleaner robots were placed in the homes of the elderly and participants were given a block-note and a pen and asked to write down notes each time they ran the robot, in the form of diary notes, inspired by Gaver et al.'s [60] idea on probes. During this phase of the study, we found that many of the elderly participants encountered challenges with interacting with the robot. For instance, the technical feedback which displayed errors as digits were often indecipherable even for the non-elderly participants. One participant complained about an error message that she received when she used the app to control the robot, which said that it "cannot connect to the cloud services" – she did not understand what the "cloud" was [59]. This is a specific situation where the abilities of human beings cannot handle the design of a technology: either because of the English language or because of the technical language the device used for giving informative feedback.

During our initial investigations for the MECS project [3][7][59][61]–[66] several challenges and requirements were encountered relating to what a robot being used in the home should look like, how it should behave, what size it should be, or what it should do. However, one particular participant posed the question: "What if a table could be called upon and bring me the telephone and carry a cup of tea? What if it could keep the telephone always charged and in reach?". The robotic wooden table was created in response to this request. We took up this challenge, and are currently in the process of designing, making, engineering, and evaluating such a table – as well as listening and talking to home dwellers, and observing their use of the table. To illustrate the use of the T-ABLE, a persona and a scenario has been developed together with elderly participants. This is illustrated in Figure 2.

Eve

Eve is almost 100 years (born in November 1938), in good spirits, and able to walk when he uses a walker for support. She is living independently at home.

Eve has had a fixed telephone from 1960 to 2009 at home. The fixed telephone was previously placed in the hall, fixed to the wall with a cable and placed on a telephone table. In other words, the telephone table was stationary, always in the same place, albeit with a long cord so it could be used in the region near the hall.

In 1999 she got a mobile phone. After ten years of using the mobile phone, she ended the subscription for the fixed telephone, and at the same time, reconfigured the hall by removing the telephone set. In other words, Eve currently owns only a mobile phone, and does not have the fixed telephone anymore.

Issues such as: "where is the phone?" or "is the phone charged?" did not previously pose any problem for Eve, since the fixed phone was situated in its permanent position, in the hallway.

In 2012, Eve got a safety alarm from her children, a wristband device with a red emergency button. She wears it when her son is visiting, otherwise it is placed in the bathroom. The mobile phone is indeed vital for safety for Eve. It can be and is used for contacting family, friends and others in case there is a problem. However, the problem of finding the phone and making sure it is charged are challenging.

She imagines the use of the t-able. The mobile phone now has a telephone table to rest on, and is always charged there. The way Eve imagines using the t-able is to let it sit by her bedside during the night, and then have it set up to move to the hall during the day. If she needs assistance, the t-able will move to where she is and assist her.

Figure 2. Scenario designed together with the elderly

C. *Design of T-ABLE*

The design of the T-ABLE was inspired by the modular design of a stool (*krakk* in Norwegian). The stool is a versatile object; it is a jack-of-all-trades of homes and can be used as a chair, side table, telephone table, footrest – and to reach the top of the shelf by standing on it. The stool has proved useful for all age groups, genders, and people with varied abilities, in different stages of life, and a variety of situations. In contrast to other specialized objects, such as chairs, dining tables, and ladders, the stool, with its smaller size, is flexible and adaptable to more users and use situations. The stool design is versatile and, as such, it may fit many different uses and situations. Inspired by the design of a stool, the T-ABLE, the robotic wooden table, is designed to hold small items and transport them around the home, as a servant robot would do. In addition, it can reconfigure the home on the fly, keeping the same natural look of the home, with its wooden appearance: similar to the old TV-sets, in wood, that were part of the furniture of a home. The T-ABLE has a horizontal, flat top surface. It is made in three iterations, illustrated in Figure 3. All the prototypes are made from various types of wood, wheels, and control mechanisms. The top surface is 40×40 cm, and the height is about 40 cm. It is ruggedly made so that it is also possible to sit on top of it (maximum weight 200 kg). The maximum speed is set to 1.3 m/s in order to keep it safe. A prototype is given in Figure 3 (a-d). The prototype was fitted with a specific point for charging the telephone. The T-ABLE is equipped with a battery that both powers the engines for driving the table, and charging the telephone on top. The battery is then charged when the T-ABLE is connected to the central power system in the home at the charging station, for example, at one of the locations where it sits for a reasonably long period. One version of the prototype was modular, with an extra tabletop that could be removed. This gives double the tablespace and can work as a scriptorium.

Further development is needed to work both on the ways in which the control and steering of the table are achieved. Technically, the controllers for the motor system are both interfaced with an RF remote control, with Arduino hardware. Plans are in place to run the Robot Operating System (ROS) via a PC. This would allow the user to interact with the table in various ways (voice, buttons, gestures); additionally, fitting sensors to the table would allow for input to the navigation, wayfinding, and obstacle detection functions of the table.

D. *Initial Tests*

What is "new" with the T-ABLE is that it can move by itself. Instead of the table having to be lifted or pushed to the preferred position in the room, this can be done by way of command in a remote-control fashion – or it can be programmed to move based on input from the environment, for example the time of day, following the person when the person gives that command, or in other ways.

The current prototype has been tested only in two homes so far, as COVID-19 has limited further testing. No systematic testing or evaluation has been done so far, but informal sessions have been conducted where joy and excitement were expressed when the robotic T-ABLE was moving around in the home. The initial tests have demonstrated that our participants are positive about the domestic servant robot, the T-ABLE. Figure 4 (a, b, c) shows an illustration from our early tests with participants.

Further, the initial testing showed that the users needed to understand the world of the T-ABLE to be able to negotiate with it and feel comfortable with it. Three themes emerged. First, the participants wished to know what information was sensed by the T-ABLE or what kind of input it gets. The second theme related to the movement of the T-ABLE itself. The participants wondered how they could best attempt to move the table along – in a “follow-me” fashion, or how the T-ABLE moves while they are sitting still themselves. The third emerging theme was about the relationship a user, as a human being, may develop with such an object, and how this relationship could potentially inform the UD and a diversity of uses and individuals in their everyday life.

In this paper, the discussion and reflection upon the last theme which emerged is of particular interest since it is well aligned with our theoretical approach.

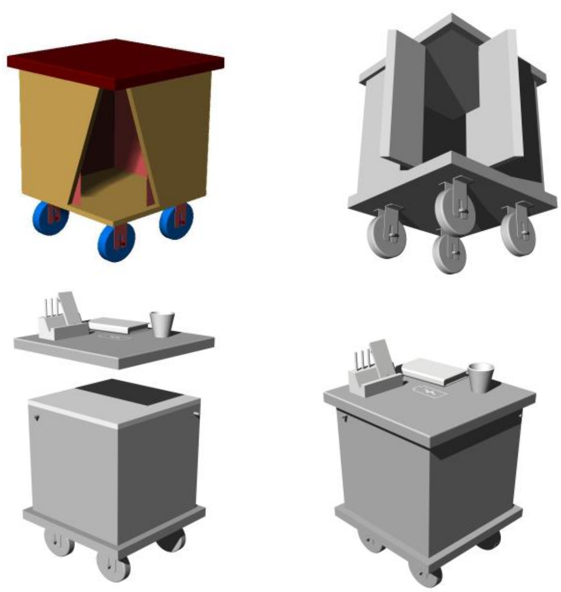

Figure 3 a) Iteration 1 – T-ABLE drawing by Nicholas Ibicheta; b) T-ABLE with telephone and charger; c) T-ABLE with an extra tabletop extending the horizontal surface; d) version of the T-ABLE with a place for depositing items.

Figure 4 a) and b) Prototype of T-ABLE transporting things in the home c) Prototype of T-ABLE where an elderly participant uses it to bring the home fixed phone and the mobile phone closer to her

VI. A THEORETICAL EXPLORATION OF EVERYDAY SITUATED ABILITIES

The MECS research project's original idea was to create a safety alarm robot for elderly people (≥65 years old) who are living independently . However, this was an attempt at a pathogenic design, i.e., designing for their disabilities. In other words, the idea of having a safety alarm robot in the home was in line with a medical model with the premise that older people at home need a device to track and detect them so that they can get help when something bad happens, such as if they fall. This approach neglected, however, their situated abilities. It seems they needed or wanted something that could help them at home, e.g. a servant robot to help them with household chores or a robot that could bring or carry things, or keep the phone in a standard place and always charged. This is in line with a salutogenic approach, where the design of the robot is in line with what the user, as a human being with his abilities, can do or a need the user has.

Thus, to understand the human experience, a phenomenological approach was adopted and the focus was on the first-person experience [67]. In other words, the human experience in a situation with a vacuum cleaner robot based on our earlier work was taken into account, as well as some insights from the human experience with the T-ABLE robot. At the same time, the T-ABLE was designed with UD in mind. To understand and go beyond the design of the T-ABLE as a robotic wooden table, the discussion around UD and the T-ABLE design is elevated to a theoretical level, in the next three sections, where the initial stated research question is answered.

A. *T-ABLE from a Universal Design Perspective*

The T-ABLE takes into account situated abilities and attempts to blend in with the home environment. For instance, the T-ABLE was designed to fulfill Eve's situated abilities, but it can also fit other users. In other words, the T-ABLE fulfills at least some of the UD principles. We explain how below.

1. **Equitable use**. The robotic wooden table can be used by young and old users, children, or people sitting in wheelchairs.

2. **Flexibility in use.** The robotic wooden table has a modular design and can be used for multiple purposes: for carrying items, for charging the mobile phone, or for depositing things.

3. **Simple and intuitive use.** The robotic T-ABLE has the familiar look of a piece of furniture – a wooden table.

4. **Perceptible information.** The form of the robotic wooden table indicates how it is to be used.

5. **Tolerance for error**. It does not have buttons or interfaces that display error messages that may confuse the user. The robotic T-ABLE instead is based on an intuitive use similar to the use of habituated objects such as a table.

6. **Low physical effort.** The height and size of the T-ABLE provide easy access and low physical effort for people of different heights, including children and people sitting in a wheelchair.

7. **Size and space for approach and use.** The T-ABLE blends in with the home environment with its natural material-look. It fits better than, for instance, other robots that have a plastic appearance.

While the creation of a prototype for the safety alarm robot is still being worked on, the T-ABLE has already generated joy for those who have experienced it and we are interested in seeing what a future investigation can turn up.

B. *Shifting Perspective from Disabilities to Situated Abilities*

The research question addressed was: *How can we shift the perspective from disabilities to abilities when talking about Universal Design?*

UD is about making technology accessible, understandable, useful, and usable for as many people as possible. Ideally, UD includes people of all ages, sizes, and abilities. UD is increasingly important for the HCI community, in more and more areas of everyday life, and involves the use of digital technology. UD is about social equity on the macro-level [39]; it is about human diversity, accessibility and usability of things and the environment, and it is about a participatory process – acknowledging and respecting human autonomy, its dignity, and integrity. According to Lazar [68], deaf people who use sign language do not see themselves as disabled people, but as people who use sign language. This reminds us that we humans as users wish to keep our dignity and integrity – we do not want to see ourselves or for others to see us as disabled. For instance, we as researchers of design or designers often forget that some users lack digital literacy or do not know how to interact with advanced technologies, such as robots, although they are not medically diagnosed as disabled.

However, the diversity of humans as a starting point for developing technologies which include all users is very often a challenge. According to Trevanius, there is an optimization process in which the edges, extremes, and diversity are lost [69]. Along the same lines, several models on UD are known that address the (dis)abilities of people from different perspectives. Amongst these UD models are the medical-, social-, relational-, expert-, empowering-, charity- and economic models. However, many of these models are strongly connected to disability studies, although UD, at its core, does not focus on disabilities, but on designing for as many people as possible.

If we shift focus from disabilities to abilities, albeit using some of these existing UD models, situated abilities could be talked about as having several dimensions. Thus, situated abilities can be identified as being at the cross point of several of these models, however with a focus on abilities instead of disabilities. Four dimensions of situated abilities have been identified, through the T-ABLE proof-of-concept design.

a) A social dimension – the user can place the technology within his understanding of the environment surrounding him

The social dimension refers to the fact that the environment must be corrected because it disables and oppresses the individual [9][70]. For instance, in the T-ABLE design, the social dimension is represented through the design of the T-ABLE itself: the robotic wooden table is designed to fit into the home environment of elderly people, rather than being designed with a robotic zoomorphic or anthropomorphic look. Thus, the T-ABLE fits into the home environment of the users in the way it is designed, most notably in that it is a piece of furniture designed in wood. In other words, the user can place the technology in his understanding of the environment surrounding him.

b) A relational dimension – the user can relate to the design of the technology through its embedded familiar elements

The relational dimension is inherited from the Scandinavian or GAP model [70]. This dimension focuses on the relationship between the human and the environment. The Scandinavian or GAP model is against the categorization of humans between abled and disabled individuals, acknowledging human diversity and individual experiences [70]. Thus, situated abilities look at individuals as abled individuals who may have lower or higher situated abilities in their everyday interaction and use of digital technologies or systems. In addition, the idea of designing for situated abilities is incorporated in the T-ABLE design through the familiar elements of a table, with a natural look. The users, including elderly people, are more used to having tables in their homes than navigating robots. In this way, their relationship with the T-ABLE is assumed to be more familiar than with robots that don't necessarily have a natural look. In other words, the user can relate to the design of the technology through its embedded familiar elements.

c) A socio-relational dimension – the user sees the technology as a habituated object

The socio-relational dimension assumes that the abilities are theorized, subscribing to the socio-relational model. The socio-relational model talks about disabling mechanisms as part of the environment that can be avoided or removed through different measures, including physical ones (Carol Thomas, 1999 in [9]). This dimension indicates both a social and a relational dimension, namely that the abilities are experienced by the individual as an embodied experience in the environment the individual is part of. Thus, the socio-relational dimension in the T-ABLE design refers to removing some of the physically "disabling" mechanisms, such as interacting with an unfamiliar robot, through buttons, displays, or interfaces. The design of the T-ABLE itself as a robot removes some of these barriers since the majority of users are usually able to interact with tables and are familiar with this kind of habituated object [71].

d) An empowering dimension – the user feels in control of his or her abilities to interact with the technology

The empowering dimension focuses on the abilities of the individual, by empowering the individual through the design of technology. This dimension subscribes to the UD empowering model that trusts the individuals' autonomy, decision-making power, and control, and the professionals are regarded only as advisors rather than experts [72]. The model instead regards the individual as the expert on his own body [72]. This implies that the design of the technology respects the autonomy, dignity, and integrity of the user. The user knows how to interact with an object. In the case of the T-ABLE, this dimension was taken into account by the inquiry of one elderly participant who posed the original question: "What if a table could be called upon and bring me the telephone and carry a cup of tea? What if it could keep the telephone always charged and in reach?"

C. The T-ABLE from a Heideggerian Perspective

It was stated at the start of the paper that one of the researchers' consideration was how to design domestic robots that fit the abilities of humans and integrate into individuals' homes, in a familiar way, rather than designing robots for their disabilities. This statement regards the human being as an abled individual in terms of what she can do, rather than what she cannot do. Similarly, the everyday life of humans that Heidegger examined and described had tables, chairs, writing equipment, radios, hammers, rooms, and many other examples of man-made things, but also nature and trees. The relationship between Heidegger's Dasein (human being) and this equipment is best understood through the use of and engagement with the "in-order-to" as Heidegger describes it, in addition to what such items are used for. There are different levels of this in-order-to towards a final cause, the for-the-sake-of-which. Another central premise for Heidegger was that the man-made things, primordially, are not understood as detached, isolated objects for use in everyday life. Furthermore, there is no such thing as "equipment" (Zeug), but a totality of equipment, and equipment nexus. A table does not primordially exist in everyday life as an isolated object, but together with chairs, table-legs, a tablecloth – all of these represent in one form or another an equipmental nexus.

Further, in the lectures before Being and Time [73][73], Heidegger did a phenomenological analysis of how the home dwellers oriented to and around the table, and how the table was oriented in the room. The way they placed the table in the room, the way they oriented themselves towards the table, and how the table was part of the daily life at home with his family and friends were used to flesh out the central role that objects and equipment played, and the reciprocity between the table and the dwellers. Only later, was the well-known example of ways of various ways relating to the hammer-in-use used.

Thus, T-ABLE is an example of familiar technology. In the German language of Heidegger, the familiar is described as *vertraut* or *bekannt*, that which we are used to or that which we know. The early writing of Heidegger is not concerned with inclusive design or UD specifically, but it addresses the question of being-here. Heidegger claims that the basis for the understanding of "being-in-the-world" lies in the everyday lives that we all live and understanding of our familiarity with it. Our behavior in our everyday life activities with each other and the equipment surrounding us give insight into everyday living with familiar things. Familiarity is, hence, about what is well-known, what is familiar to us. This knowledge is not primordially theoretical, but essentially a skill related to our situated ability to act, to do something, or to interact with a robotic device. Furthermore, involvement or engagement is a condition for the possibility of being familiar with something. Interacting or engaging with a robotic product is conditioned on the design of the product itself, first and foremost, and the skills of the individual user.

Further, designing for situated abilities seems to be strongly linked to designing with familiarity in mind. For instance, previous research has also examined how a relation to moving things in the home can be classified based on the type of movement the human or robot is doing [25].

This research has also suggested that finding familiar movement relationships with things could help in designing human-robot interaction in the home. More recent research on more natural-looking motion, using the idea of slow in-slow out can be found in Schulz et al. [64][65].

Furthermore, an extensive body of research exploring UD and familiarity is available [74][75][75]–[77]. Moreover, several studies on familiarity focus on the appropriation of technology through making their design familiar to the user [75][78][79][79]–[81]. The authors, inspired by the work of Heidegger, argue that familiarity might be used as a concept when working with inclusion and UD.

Thus, we have illustrated the idea of designing for situated abilities through the design of a domestic robot, the T-ABLE. The T-ABLE prototype incorporates some familiar elements. First, the robot is designed with the look of a table, rather than having a humanoid appearance that may lead to the uncanny valley phenomenon [13]. Second, the wooden appearance of the domestic robot is a design that fits better in the existing home environment, appropriating its design to the existent furniture in the home, rather than the appearance of a machine with a plastic look. Last, the design of the robotic T-ABLE is modular, allowing for multiples uses.

Finally, designing for situated abilities is not only about UD. It goes beyond the design of a product or service. It is an abstract concept, a theoretical approach that begins with the abilities of the human being. UD is rather focused on service products that serve the human. In other words, designing for situated abilities to increase the individual's abilities on the ability continuum, in a given context or situation, involves incorporating familiar elements in the design of the product (or service).

VII. Conclusion and Future Work

This study proposes the idea of designing for situated abilities, rather than disabilities, adopting a salutogenic, e.g., a positive-laden approach, to design. The initially stated research questions were answered by presenting an alternative design to domestic robots, wooden-based robots that fit naturally into our home environments, and are based on a theoretical elevation of everyday situated abilities. The idea of situated abilities anchored in a UD approach was then introduced; however, it was different from existing UD studies, which have emerged from disability studies. The idea that was proposed in this paper was the idea of designing for abilities, rather than disabilities. The definition of situated abilities as indicated in Saplacan [54] was used: "Situated ability is the ability to comprehend, manage, or find the meaning in the interaction with a digital system." (p. 9). This design approach is close to the relational models, such as the Scandinavian or GAP models [70], however with a twist on the disability perspective – focusing instead on abilities and enabling environments. In other words, the disabled environment or a disabling design is recognized as being part of the problem. These arguments were based on our previous research, as described in the Background Section of the paper. Further, it was argued that a good design for a product, be it a domestic robotic product or another type of product, is good if the product fits the individuals' environment AND the individuals' abilities and needs, rather than the individual fitting the product. Thus, four dimensions of designing for situated abilities were identified: 1) a social one, 2) a relational one, 3) a socio-relational one, and 4) an empowering one.

However, this work could be further explored in the context of the HCI debate in several ways. Further, aging and the need to create a global infrastructure which involves inclusion- and ability-based design have been on the UD agenda for a while [52][53]. This could be explored further. Moreover, indirectly through this paper, a debate on the ethics and responsibilities of design is introduced, along with the relationship between humans and (digital) things seen from the UD perspective, specifically in terms of the idea of designing for situated abilities, and the idea that our abilities are situated on an ability continuum. This perspective fits well with the ideas discussed in Frauenberger [82], and those discussed in his earlier work [45] on designing for different abilities, rather than designing for different disabilities. Finally, this work can catalyze discussions in the debate explored in Ashby et al. [83] on the fourth HCI wave, on value ethics and activism for positive change within HCI.

Other possible open research questions to be explored are:

a) How can the challenges posed by the design of robots concerning UD, i.e., robots that are designed to be usable by a diversity of users (care recipients, informal and formal caregivers, medical staff, and technical staff) be addressed?

b) What legal implications does this have concerning the UD of products to be used in the public sector, including the healthcare sector?

b) How can UD set a regulatory ethical framework to ensure adequate development of AI in robots?

c) What are the technical benefits and challenges set by a UD framework when developing robots to be used in healthcare or the public sector?

It is hoped that our approach to designing for situated abilities may help to result in a shift in the perspectives of current UD studies focusing on disabilities, though the importance of such studies is acknowledged. Finally, we argue that a salutogenic approach to design, such as designing for situated abilities, rather than disabilities, can be beneficial in finding new alternative designs.

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