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 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 by designing a domestic robot that familiarly integrates into our homes. 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][2][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 represent an alternative way of thinking about, discussing, and designing with a focus on human beings' abilities in terms of everyday situations, rather than focusing on their disabilities.

Specifically, this study investigates 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 that is suitable for as many individuals as possible. In this paper, we move beyond 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 individuals' abilities 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 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. One approach is to explore how we can design domestic robots that fit humans' abilities and integrate into individuals' homes in a familiar way.

The paper continues in Section II by presenting the background of 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 the elderly in terms of the Multimodal Elderly Care Systems (MECS) project, leading to this study's proof-of-concept. 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 domestic robots' use that individuals will often carry out changes inside their homes to fit a robotic product.

At the same time, Dautenhahn [9] argues that the Human-Robot Interaction (HRI) community's current focus should be on user studies, along with HRI design, theory, and methods. She argues that the HRI community has moved forward from the classification of robots and "variation" in robots. She says that the HRI communities should focus instead on long-term interaction with robots in "real-world environments" with "real people" (p. 4:2). She says that this shift in focus from the use of robots in the labs or living labs to the use of robots in real environments with real people move also focus from studies on investigating short-term interactions to long-term interaction between the human and the robot. She argues that researchers should study and learn from real people's use and engagement in real situations.

Moreover, we have also learned from the previous studies that the studies focus on using the product, rather than on the human, or the user using the product and its abilities to handle the situation at 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 [10]. Our study also focuses on the individual's experienced abilities and the 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]. If the design of a robotic product is good enough, however, the human should not have to adapt to the product itself: the robot should 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 the idea that aesthetics, functionality, and robot design should fit in with the human context. Such an example is PARO, a robot with a seal appearance used for older adults [11][12][13]. PARO seems to integrate well in home environments for the elderly, such as those who have 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 that fulfills these criteria [12]. It is recommended that elderly people with Alzheimer's have pets around, but the people with Alzheimer's are often unable 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 [14]. 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 robot's movement can turn people's attention more to the movement than the robot's appearance [17] even if the motion has the potential to make the uncanny valley effect more pronounced.

B. *Universal Design and Design of Robots*

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" [18]. UD is based on seven core principles. These are indicated and exemplified in TABLE .

Many people often associate UD with people with disabilities. Historically indeed, UD was often related to people with disabilities along with The Americans with Disability Act (ADA) [19]. These movements have greatly impacted the focus of UD on designing products and services that can be used by as many people as possible. According to the Norwegian Digitalization Agency, however, UD is about designing surroundings that consider "variation in the functional ability of inhabitants, including people with disabilities" [20]. A universally designed solution aims to reach out to as many people as possible without the need for adapted solutions [20].

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 [21], but this refers specifically to 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 [22][23], UD 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 UD's perspective.

TABLE I. Universal Design Principles.

#	UD Principle	Example 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 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- 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

On the other hand, much of UD's focus in ICT has been on making information accessible by applying the Web Content and Accessibility Guidelines (WCAG) [24] when building web sites and mobile applications. Typically, a robot is not presenting information the same way that a computer or mobile device would. Therefore, there is no straightforward way to apply the WCAG to a robot. For instance, Norwegian laws and regulations regarding UD in Norway [25] 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 homecare seems to be ongoing.

At the same time, the elderly population (those over 65 years old) is increasing. The elderly 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 [26] (p. 360). Moreover, expectancy is also expected to increase in Norway by 0.2% (around two years) by 2070 [26]. 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 [26, p. 362]. Out of this population, 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 [26]. 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) [26].

Moreover, the aging population seems to be the *key driver* in developing and adopting robots [27]. 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 is argued for 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 even increased costs and a lack of (human) resources for supporting the elderly through home care services [30].

In addition, policies and political agendas are being introduced concerning integrating 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 [30].

If such robots are to be adopted in the public sector, including the health- and homecare sectors, these robots need to be designed in such a 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, can use them. This also means that robots need to comply with specific standards and requirements to suit several types of users and/or actors (individuals, organizations, and settings). Thus, this implies that the robots need to be universally designed, i.e., a minimum of requirements or standards must be fulfilled by the robot design for it to be used by diverse users. Many of these potential future categories of users of health- or homecare 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 have analyzed robot performance in homes [31][32][33], 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 [34].

Thus, a table robot that can move around, and is made of wood, may feel more 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 [35], or designing for simplicity and prolonged elderly’s mastery of technology, as shown in [36][37][38][39]. Many of these studies, however, have a focus on static technology, i.e., the technology that does not move semi-autonomously in the home. 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 [40]. At the micro-level, there are often studies examining individuals or groups in UD 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 using ICTs or digital learning environments in Higher Education and investigating laws, regulations, and legal frameworks [41]. Micro-, mezzo- or macro-level studies may include investigations on inclusion and accessibility [41][42] or diversity issues [44]. 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 people’s abilities or capabilities from a Participatory Design (PD) perspective. For instance, Joshi [36] wrote his Ph.D. thesis on the topic of designing for capabilities. He has co-authored several papers on designing for experienced simplicity [37] and prolonged mastery among the elderly [45].

Furthermore, Frauenberger [46] 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 rather with the environment surrounding him. Within this salutogenic approach, some talk about Ability-Centered Design (ACD) [49], whereas others talk about Ability Based Design (ABD) [50]. 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.

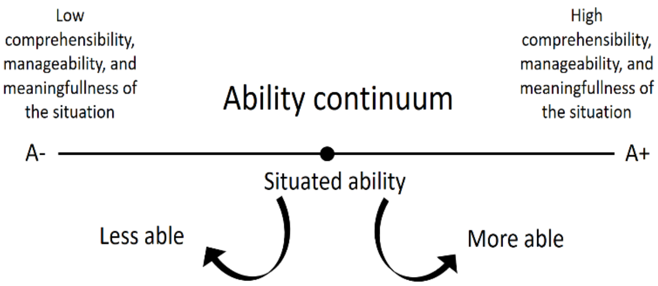

Figure 1. The ability continuum [51].

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" [50] (p. 91). The ABD concept is described according to a set of principles supported by examples [50]. Specifically, ABD systems 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 [50].

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 reconfigured 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 [53]. 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 [53].

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 [53]. However, it was never defined, framed, explored, or further anchored. Saplacan [51] has attempted to revitalize the concept. The framing of situated abilities was inspired by the work of Antonovsky's [34] 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 [51] framed situated abilities as a point of departure for 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 [51]. Further, the author [51] 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 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, understand the technicalities and feedback from "autonomous things," facilitate and adapt to them and 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, humans need to adapt to the robot's work to make it work, 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 [56], the law addresses UD only from 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 [57]. 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 chatbot design itself and not because of the user's disabilities. The user would solve the problem much more quickly by talking directly to a human instead of using the chatbot. However, the use of the chatbot lowers the situated abilities of the human user in that situation. Several studies on chatbot design have been undertaken with people without any disabilities and people with disabilities (see for instance [57][58]).
- **Example 4** on using 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 Apple's operating system, but higher situated abilities when using Microsoft's operating system.
- **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 [51].

These examples indicate that the situated abilities are contingent and highly specific to both the person using the technology and the situation in which it is used.

V. Case and Proof-of-Concept Design

This section starts with the case brief. Thereafter, it continues by presenting 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 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, 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 move things around in the home, a robot that could bring them objects, or a robot that could help them with household activities. Simultaneously, 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, rollators, or wheelchairs that occupied much space. In 2018, vacuum cleaner robots were placed in the homes of the elderly, and participants were given a notebook 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 [61] idea on probes. During this phase of the study, we found that many 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 [60]. This is a specific situation where human beings' abilities 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][60][62][63][64][65][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 designing, making, engineering, evaluating such a table and 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 have been developed together with elderly participants. This is illustrated in Figure 2.

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, similarly to the mechanical ottoman from Sirkin et al. [67], 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. It can also re-configure the home on the fly, keeping the same natural look of the home, with its wooden appearance: like the old TV-sets, in wood, that was part of a home's furniture. 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 T-ABLE prototypes have three or four wheels where two of the wheels are hub motor wheels (Electric Wheel Hub Motor). The wheels' diameter is 12 cm, which makes it possible for the table to travel over carpets and uneven surfaces. Furthermore, the wheel and the way they are fastened to the table is rugged, so that it is possible to, for example, sit on top of the table (maximum 150 kg). An on-board LiPro battery powers the wheels' motors and the ECR (Electronic Speed Control). The speed of the two wheels is regulated with an RF (radio frequency remote control) directly, and in one prototype with an Arduino box between the RF and the ECR. The two hub motors wheels make skid steering possible for the table, and hence it can be controlled to move accurately around at the command of the person with the RF. 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 powers the engines for driving the table and charges the phone on top. The battery is then charged when the T-ABLE is connected to the home's central power system 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 table space 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 motor system controllers 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

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 proof-of-concept was tested through the Wizard of Oz (WoZ) techniques, similar to the tests carried out by Sirkin and colleagues with their mechanical ottoman [see 67]. Both voice and the use of a bell-button were used to give commands and steer the T-ABLE. The person operating the RF controller, the Wizard, listened to the voice commands and recognized the user's key presses. Based on the commands such as come here, follow me, go there, she steered the T-ABLE in the correct direction and position. During these WoZ tests, an external button to T-ABLE acted as the command button that executed different commands at the user's request. Four motion design commands were simulated through WoZ: COME_HERE, FOLLOW_ME, DOCK, and UNDOCK. Specifically, if the user pressed the button once, the T-ABLE performed the COME_HERE task. If the user pressed the button twice; consequently, the T-ABLE will perform the FOLLOW_ME task. The DOCK and UNDOCK command accompanied the other commands. Another simulated order was fetching a cup of coffee or dishes.

Eve

Eve is 92 years old (born in November 1928), in good spirits, and able to walk when she 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. That is, 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. That is, 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

The current prototype has been tested only in two homes so far. The tests were performed in one home with one senior adult (≥65 years old) and another home with two adults, two children, and one cat. The tests were documented through photos and videos. However, 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. There are two reasons why systematic testing has not occurred yet. First, The COVID-19 pandemic does not allow easy access in the homes of the elderly and non-elderly people and has limited further testing. Second, this paper focuses mainly on the proof-of-concept design of robots for everyday domestic use regarding their UD dimensions. Therefore, this is outside of the scope of this paper.

However, the initial tests have demonstrated that our participants are positive about the domestic table robot. 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 T-ABLE world 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 was 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 that emerged are of particular interest since it aligns with our theoretical approach.

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) living independently. This was an attempt at a pathogenic design (designing for their disabilities). That is, the idea of having a safety alarm robot in the home was in line with a medical model’s 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 robot’s design is in line with what the user, as a human being with his abilities, can do or a need the user has.

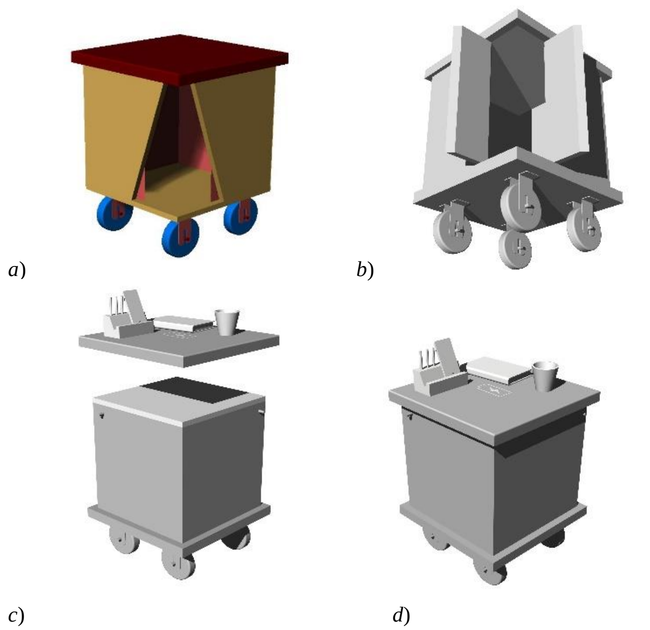

Figure 3. *a*) Iteration 1 – T-ABLE drawing by Nicholas Ibicheta; *b*) T-ABLE with telephone and charger; *c*) T-ABLE with an extra tabletop extending the horizontal surface; *d*) version of the T-ABLE with a place for depositing items.

Thus, to understand the human experience, a phenomenological approach was adopted, and the focus was on the first-person experience [68]. That is, 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 T-ABLE design 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 design considers 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. 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.

a)

b)

c)

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

5. **Tolerance for error**. It does not have buttons or interfaces that display error messages that may confuse the user. Instead, the robotic T-ABLE is based on 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 creating 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 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 vital for the HCI community in more and more everyday life areas and involves the use of digital technology. UD is about social equity on the macro-level [40]; 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 [69], deaf people who use sign language do not see themselves as disabled people, but rather 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.

Human diversity as a starting point for developing technologies that include all users is often a challenge. According to Trevanius, there is an optimization process in which the edges, extremes, and diversity are lost [70]. Along the same lines, several UD models 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 discussed as having several dimensions. Thus, situated abilities can be identified as being at the cross point of several of these models, however focusing 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 users' home environment 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 [71]. This dimension focuses on the relationship between humans and the environment. The Scandinavian or GAP model is against humans' categorization between abled and disabled individuals, acknowledging human diversity and individual experiences [71]. 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 do not necessarily have a natural look. That is, 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 [10]). This dimension indicates both a social and a relational dimension, namely that the individual experiences the abilities as an embodied experience in the environment the individual is part of. Thus, the T-ABLE design's socio-relational dimension refers to removing some of the physically "disabling" mechanisms, such as interacting with an unfamiliar robot, through buttons, displays, or interfaces. The T-ABLE design itself as a robot removes some of these barriers since the majority of users can interact with tables and are familiar with this kind of habituated object [72].

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 individual's abilities 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 [73]. The model instead assumes the individual as the expert on his own body [73]. This implies that the design of the technology respects the user's autonomy, dignity, and integrity. 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 Phenomenological Perspective anchored in Heidegger's work

At the start of the paper, one of the authors' consideration was how to design domestic robots that fit humans' abilities 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, humans' everyday life that Heidegger examined and described had tables, chairs, writing equipment, radios, hammers, rooms, and many other examples of human-made things and 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. Heidegger's central premise was that the human-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], Heidegger did a phenomenological analysis of how the home dwellers were 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 a well-known example of various ways relating to the hammer-in-use was employed.

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. Heidegger's early writing is not concerned with inclusive design or UD specifically, but it addresses the question of being-here. Heidegger claims that the basis for understanding "being-in-the-world" lies in the everyday lives that we all live and understand 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, do something, or 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.

D. Discussion through the lenses of the existing HRI literature

Designing for situated abilities seems to be strongly linked to designing with familiarity in mind. Our findings are confirmed and supported by several earlier studies. We start the discussion in this sub-section by first presenting a few other examples of robotic furniture, such as the mechanical ottoman [67], the Roombots [75], and the PEIS robotic table [76]. Thereafter, we continue with reflections and discussion on long-term interaction with robots in the home by bringing for- and contrasting arguments for the T-ABLE study.

For instance, a robot similar to T-ABLE was first developed by Sirkin and colleagues [67], namely the mechanical ottoman. The mechanical ottoman is a robotic footstool where the participants engage with the robot by placing their feet on the footstool or taking them off. The robot is also able to adjust its cushion and to navigate the plane environment. However, it does not have an anthropomorphic look; thus, the participants are encouraged to engage with the robotic footstool through a joint, at times, negotiated action between the human and the robot.

A second example is given by the study from Sproewits et al. (2009) [75] on Roombots. Roombots are described as self-reconfiguring modular robots acting as adaptive furniture [75]. The Roombots are a combination of Information Technology (IT), roomware, and robotics. They started from the idea that humans and technology will co-habit future working and living environments seamlessly [75] (p. 4259). Their building blocks are made of attachable/detachable simple robotic modules with connectors in-between these.

A third similar proposal to T-ABLE is the PEIS robotic table [76]. The PEIS robotic table is designed as a robotic service table used in domestic settings as part of a smart home environment. Like the T-ABLE, the PEIS table is envisioned to be a robot butler that can move around the home, carry objects on top of it, bring objects at the command, and be able to dock/undock itself [76]. The authors' vision is that many such autonomous robots as PEIS may orchestrate their actions and ecologically fulfill the users' requirements – this view is rather opposed to having one robot "doing it all." The study argues that besides the robots' functionality, the robot should adopt a furniture-like design [76]. According to the authors [76], the design of such artifacts will not be perceived as "foreign bodies" by the human, "but rather as a natural extension of their usual, familiar environment" (p. 245). The authors also argue for the familiarity of movement that should both be perceived as safe and safe for the human user, with a high predictability rate of the robot's behavior [76]. This robotic motion is also explored in previous research: the current literature includes studies on 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]. The current research also suggests ways of finding familiar movement relationships that contribute to the design of robot motion. A such example is the more recent research on natural-looking motion, using the idea of slow in-slow out from Schulz et al. [64][65].

Further, current studies also argue for the robot's non-invasive wooden appearance to increase its ecological familiarity-look similar to a piece of furniture [76].

However, a contrasting study to ours and the ones described above on furniture robots is the study from [78]. Although the study from [78] does not talk about robotic furniture to be used in the home, but rather about robots to be used in public spaces, such as museums, the study's arguments still support our study. The main argument is that robots, in general, are designed to either be used in the lab, living labs, or non-real world environments, or they are designed to be used in public spaces, with a short-term interaction in mind [9]. A few examples of such robots are receptionist robots in hotels, greeting robots in shopping centers, or robots in a museum [9]. Minerva and Rhino [78] are examples of such robots used in museums as tour-guides. They are service robots that assist people in everyday life; however, they are designed for short-term and spontaneous interactions, where people spend only a limited amount of time with the robot, e.g., around 15 minutes. They were designed with some humanoid features, such as avatars displaying different moods, e.g., happy, serious, sad; however, they are not considered humanoid robots.

One essential aspect of their design is that this avatar moods feature was chosen to enable a representation of human emotions that the people would easily recognize. This, in its turn, enables the humans to easier relate to already familiar social aspects to them, according to [78]. In addition, the physical features, such as legs and arms, were not emulated as humans specific characteristics, i.e., these were not designed as real human legs, arms, heads, or faces. However, this kept the robot design simplified, still giving familiar physical aspects that are easily recognizable by human users. Further, the authors [78] argue that incorporating familiar features in robot design, however, without anthro- or zoomorphizing the robots, is essential to enabling smooth interaction between the human and the robot and a higher acceptance of the robot amongst the human users. This is also in line with our view and arguments in this paper, confirming that familiar features embedded in the design of robot facilitate the integration of robots in domestic settings, and may support long-term interaction.

Compared to the authors investigating Minerva and Rhino robots [78], the authors of the study on Roombots design [75] focused on the robots' function rather than their appearance. The authors envision that such robots can be useful when they autonomously can orchestrate themselves into different types of static or dynamic structures, such as into different pieces of furniture, i.e., from stools and chairs to sofas and tables, and from robotic arms picking up objects to servants robots transporting the objects, depending on the users' needs and requirements [75].

Further, the authors insist [67] that long-term interaction with such robots, to be used in the home, is needed. The authors also argue that such work has not been done so far. Instead, the focus on human-robot joint action was so far on task handover, similar to when robotic vacuum cleaners are used in the home or when a robot is part of a distributed system, such as a smart home ecology, e.g., see the study from [76]. They also confirm that people tend to usually show more acceptance of robotic furniture and their use in their homes. Similarly, Sirkin and colleagues [67] argue that it would be great if robotic vacuum cleaners, such as Roomba, would have a humble look of the furniture, such as a stool. This look challenges the HRI community to shift the focus from mechanical-, anthropomorphized-, zoomorphized- or biologically inspired robots' appearances to furniture-like robots.

Moreover, several studies on familiarity focus on the appropriation of technology by making their design familiar to the user [75][78]–[81]. At the same time, an extensive body of research exploring UD and familiarity is available [81]–[85]; however, none of these explore familiarity and UD in robot design.

All in all, although the studies from [78] on Minerva and Rhino, the study from [75] on Roombots, and the study from [76] on the PEIS table are very contrasting, all studies agree that incorporating familiar features in the robots to enable long-term interaction. Thus, this confirms our theoretical findings and discussions on this initial study on T-ABLE. However, none of these studies focus on how the robotic piece of furniture can be designed with UD in mind to enable as many users as possible to use. This aspect both argues for our own positioning of this study, as well as catalyzes further our motivation for continuing this investigation in more rich empirical settings.

Thus, the authors inspired by the work of Heidegger, argue that familiarity might be used as a concept when working with inclusion and UD. Hence, we have illustrated the idea of designing for situated abilities through a domestic robot's design. The T-ABLE prototype incorporates some familiar elements. First, the robot is designed with a table's look, rather than having a humanoid appearance that may lead to the uncanny valley phenomenon [14]. Second, the domestic robot's wooden appearance 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 proposed in this paper is the idea of designing for abilities rather than disabilities. The definition of situated abilities as indicated in Saplacan [51] was used: "Situated ability is the ability to comprehend, manage, or find the meaning in the interaction with a digital system." (p. 9). However, this design approach is close to the relational models, such as the Scandinavian or GAP models [72], 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.

This work could be further explored in the context of the HCI/HRI debate in several ways, including responsible robotics, AI, and new paradigms of HCI and HRI.

For instance, Boden et al. discuss the importance of responsible robotics, especially now when more and more robots leave the research lab [86]. In this sense, the authors have developed a set of principles that regulate robots in the real world. Amongst the designed principles, they describe principle 2, saying that the robots should comply with the existing law, including privacy. Principle 4 says that robots should not include the "illusion of emotion and intent" and be used with vulnerable users (p. 127). Further, principle 5 refers to being able to identify who is responsible for any robot.

Further, aging and the need to create a global infrastructure that 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 [87] and those discussed in his earlier work [46] 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. [88] on the fourth HCI wave, on value ethics and activism for positive change within HCI.

Other possible open research questions aligned with the future directions to be explored are:

a) How can the challenges posed by the design of robots concerning UD, i.e., robots 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 used in the public sector, including the healthcare sector?

b) How can UD set an ethical regulatory 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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