Preserving safety, dignity and autonomy through multi-modal interactions: An exploration into a preferred future of design for accessible dressing technology and e-textiles

by

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Abstract

Ready-to-wear clothing is often designed for individuals without disabilities, which can create dressing barriers and challenges for individuals with disabilities, especially those with motor coordination, cognitive challenges sensory and self-regulation issues. In two studies we explored the visions of occupational therapists for the future of dressing through smart clothing and dressing technology. Using co-design and design fiction online workshops, we were able to gather a rich data set that included interview data, virtual sticky notes, creative writing exercises and storyboards. We coded and used thematic and abductive analysis to explore the data and created design fictions to explore the future of dressing technology. Occupational therapists identified challenges that impact dressing tasks, and requirements for the design of technology situated in the near future that would support the autonomy of disabled people. They identified that instructional technology (such as clothing that provides sequencing cues and task instructions) could offer people with disabilities support for dressing challenges. According to the OTs, dressing technologies of the future should be multi-modal, preserve the dignity of the individual, be discreet, washable and durable, encourage autonomy, maintain safety and security, be customizable and be funded by governments or social groups.

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A Note on Language, Terminology and Inclusion

Throughout this document you will note that I use varying terms to refer to people with disabilities or the disabled. I purposely alternate between these terms for a number of reasons, the first being with respect to preferred language in the disability community. Although in many circles disability first language is preferred and accepted, in other communities or individuals in the disability community person first language is preferred. In an attempt to be inclusive of both of these points of view, I use both person first and disability first language. I recognize that my own bias as a human computer interaction (HCI) researcher who is also an occupational therapist (OT) practicing for the last fifteen years in the clinical community with various disability groups impacts my use of language. Educated as an OT in a time when person first language was largely the accepted means of referring to disabled people, I often unconsciously default to person first language. In an effort to recognize the evolving landscape of disability and the impacts of ableism on people with disabilities, I attempt to be as inclusive as possible in my use of language. I implore the reader to bear with me as I am always learning new ways to recognize my own implicit biases.

Chapter 1: Introduction

Getting dressed (donning) and taking off clothing and footwear (doffing) are essential parts of our daily routine. However, because most ready-to-wear clothes and clothing patterns are designed for individuals without disabilities, this task can become particularly complex or pose barriers to individuals with disabilities. Clothes are rarely designed for limitations of motor control or coordination, cognitive challenges (for instance, not understanding or remembering sequential tasks of dressing [90], sensory and self-regulation issues, or factors related to using adaptive equipment (e.g., wheelchairs or orthoses)). As a result, ready-to-wear clothes can become inaccessible for individuals with, for example, development coordination disorders [80], stroke [90], Parkinson's disease [60], multiple sclerosis [36], autism [10], and cerebral palsy.

When faced with inaccessible clothing options, many disabled people will rely on caregivers or others to complete dressing tasks for them [52]. This is often due to difficulty initiating the dressing task, or the inability to complete the task altogether, and it allows them to save energy for other meaningful tasks. To solve dressing challenges, people with disabilities work with occupational therapists (OTs) on a variety of strategies. Occupational therapists are rehabilitation professionals who assess and treat functional difficulties that impact daily activities including dressing [77]. Occupational therapists assess the whole person, including their physical, cognitive and emotional abilities that may be impacting occupational performance issues such as dressing [77]. Occupational therapists are uniquely positioned to comment on the future of technology that might assist with dressing challenges. Occupational therapists work with disabled people to create solutions to difficulties with dressing. In treating difficulties with

dressing, they leverage low tech solutions such as assistive devices and behavioural/adaptive strategies. Additionally, occupational therapists have a unique contribution to directing visions of future technology in that they are a profession that is guided by a shared set of values and ethics surrounding the treatment and support of people with disabilities that is not simply market driven. It is through these shared values and ethics that occupational therapists can give voice to a preferred future for adaptive technology, while critically evaluating the utility of devices and potential social outcomes of changes to how we think about dressing in the future.

When used appropriately, technology has the potential to support the independence of people with dressing challenges. In the field of human computer interaction (HCI), researchers have explored how computer-aided dressing assisted disabled people with both environmental factors (for example, wearing warmer clothes in colder weather) [67] and robotic assistance [14]. However, there is limited research that explores the potential of electronic textiles (e-textiles) for dressing challenges. E-textiles, a subset of wearable computing, are fabrics that have electronic components such as sensors and actuators sewn into them [26]. Though e-textiles have many uses, some of the more prominent ways they are used in health is to monitor body systems [23] track physiological signals [23] and create prostheses or exoskeletons [61]. While there has been some research on improving independent dressing for challenges such as motor coordination [49], few researchers have looked at the potential of e-textiles used to support dressing challenges of people with disabilities. In the first study of this thesis, we explored how e-textiles might assist with dressing challenges in the future.

Design for disability is a popular area of research. However well intended, many projects that are focused on designing to assist people with disabilities fail to be adopted [46]. Adoption of assistive technologies has been shown to have many barriers [47] and, in many cases, devices can lack evidence for the effectiveness of their use [19]. Often researchers do not consider the potential implications of their design for use in the real world, only seeking feedback after the prototype has already been developed. The reasons for technology adoption issues are many and include lack of consultation with people for whom the technology is intended, solving a problem that does not truly exist [7], perceived or real privacy or safety issues [8], or failing to see the potential drawbacks of the technology developed such as creation of dependency/reduced autonomy [8], cost or difficulty setting up the technology [19]. There are areas of research that seek to explore the implications of technology before it has been developed. For example, speculative design [20], critical design [20]and design fiction [5]. I utilize design fiction in the second study of this thesis to provide insight into how dressing technologies might be used by disabled people in the near future, while exploring their implications situated in a social context.

Design fiction is an area of human computer interaction research, in which participants and researchers are asked to imagine a future oriented scenario, set in a social context and to develop a prototype that explores how it may be used in the set social context. The purpose of which is to create a discussion or discursive around the phenomenon described. Design fiction is an emerging field that allows researchers to explore the impacts of new technology while placing it in a social and political context. By engaging participants to explore possible futures, they open the discussion for how

technology may both help and hinder. Through design fiction we can find "ways in which we may resist the urge to present slick solutions or criticisms, and instead acknowledge the complexity of the problems we seek to address and the fragility of our own ideas and approaches" [7:4977]. Design fiction can bridge the gap between HCI researchers and people who have day-to-day experience working with people who have dressing challenges, such as OTs. I used design fiction as a research method in the second study of this thesis to explore the potential uses, drawbacks and social implications of technologies for dressing challenges with OTs.

We conducted two studies with occupational therapists to gain insight into first (study one) defining the issues related to dressing challenges, exploring how occupational therapists envision the future of dressing and how technology might support accessible dressing for individuals with disabilities. Secondly, we developed design fictions (study two) to more deeply explore the potential use of dressing technology situated in the near future, which allowed us to examine the possible social, political, ethical and practical issues that might arise with the solutions proposed. In study one a remote co-design method was used to ground the research in the lived experiences of occupational therapists, as it leverages the combined creativity and collaboration of designers and non-designers [65]. Informed by Voros' [88] model of future visioning, "problems oriented future work" [88:3], this method allowed for an exploration of many possible futures through the lens of occupational therapists. This concept was introduced by asking OTs to imagine a future without limitations of current technology and financial resources to allow for unique visions of the future. Remote workshops allowed for the inclusion of therapists from all over North America as well as adhered to COVID 19 safety protocols.

The first study provided an insight into what technologies might be useful for people with disabilities, however it did not allow for a full exploration of how the technology might work, or whether or not these technologies would fully address the needs of people with disabilities. After conducting the first study, it became clear that to fully understand how dressing technology might support people with disabilities in the future it was necessary to explore more thoroughly how the proposed technologies would be situated in the day-to-day experiences of disabled people. Design fiction was used to consider how dressing technology could be situated in a future world while exploring the practical, ethical and social implications of the technology. Design fiction is a method that allows participants to envision the future of technology, provides a tool to communicate those visions and explores design requirements [82]. By incorporating design fiction into the second study it allowed me to gain a deeper understanding of the implications of future dressing technologies and how they should be designed to avoid providing solutions that do not address the daily needs of people with disabilities.

The first study (Chapter 3) centers on visions about smart textiles that may assist people with dressing challenges from the perspective of occupational therapists. Visions of the future are integral to developing the direction of new technologies and stand to inspire research communities in HCI [62]. Visions also offer a view of preferred futures of technology [62]. With a team of three HCI researchers, one PhD candidate, one post-doctoral fellow and myself an OT and HCI researcher, we ran 2-hour workshops consisting of brainstorming and storyboarding activities with eight occupational therapists on how we might integrate e-textiles in the future to support people with disabilities. The PhD candidate assisted with study design and technical support during

the workshops and the post-doctoral fellow provided technical support during with workshops and guidance on writing and interpreting the results of the study. I recruited participants, conducted the workshops, collected the results and completed the data analysis and writing of the study. Drawing from the participation and insight of these OTs, I discuss future directions for how e-textiles may further aid disabled people to improve their independence and autonomy in dressing. In this first study, I asked the following research questions (RQ):

- RQ 1: What do occupational therapists envision the future of e-textiles could be to support people with disabilities?
- RQ 2: In what ways might e-textiles assist disabled people to become more independent with dressing?

In workshops, my team collected a rich dataset derived from interviews, co-design brainstorming and storyboarding. Using affinity diagrams, we identified several themes including discussion on current challenges related to the person, environment, and clothing that hinder independence in dressing. The workshops also included an ideation session to explore e-textiles around self-mechanized clothing, regulating clothing, and corresponding clothing. Corresponding clothing teaches the wearer to dress using technology cues without dressing ‘for' them. This offers a new direction for HCI exploration to assist people with disabilities to participate more fully without intervening to ‘do things for' the user, thus preserving the human need for self-determination. While the OTs were able to provide insight into what preferrable futures might exist for e-textiles and people with disabilities, there was limited exploration in this study into the implications of how these technologies might be situated in real world use. Additionally,

as a result of discussions in this study, it became clear that e-textiles may not be the only technology solution that could aid with dressing challenges.

The second study (Chapter 4) centered around creating participatory design fictions with 6 occupational therapists to further elucidate visions of the future and situate technology that supports disabled people to manage dressing challenges. By using the design fiction methodology, it allowed me to delve deeper into how the OTs proposed dressing technologies were situated in the near future. This included exploring social-political and ethical implications of the technology and the society in which dressing technologies existed. It provided a means to explore how disabled people would live day to day with dressing technologies. Informed by the results of study one, I opened up the discussions to include any technology proposed by the OTs, not limiting solutions to e-textiles. In this study I asked the following research questions (RQ):

- RQ 1: What do occupational therapists envision the future of technology could be to support people with disabilities with dressing?
- RQ 2: In what ways might technology assist disabled people to become more independent with dressing?
- RQ 3: What are the benefits and draw backs of future technologies in supporting people with disabilities and their dressing needs?

In this study I asked, six occupational therapists to imagine a future oriented scenario in the context of a person experiencing a disability that would impact on their ability to dress. I asked the occupational therapists to complete a future oriented creative writing exercise guided by probing questions around a dressing disability to set the scene for the prototype. I then asked the OTs to assist in a storyboarding activity where they explored a

new technology of their choosing in the context of the fictional world to develop an understanding and discussion regarding how this technology might assist a disabled person to complete dressing tasks. I then asked OTs to share any concerns regarding the use of the technology. The results of this study revealed that occupational therapists envision technology that assists with task sequencing in various forms. They identified that instructional technology (such as clothing that provides sequencing cues and task instructions) could offer people with disabilities support for dressing challenges. According to the OTs dressing technologies of the future should be multi-modal, preserve the dignity of the individual, be discreet, washable and durable, encourage autonomy, maintain safety and security, be customizable and be funded by governments or social groups. They expressed concerns regarding how societies of the future might balance the needs of people with disabilities with potential climate and planetary crises. They also provided insight into the anxieties that people may feel related to faulty or nefarious technology in the future. Participants developed stories and explored how technology could assist people with brain injury, multiple sclerosis, mild dementia, and the cognitive sequelae of viruses in dressing. In each scenario participants were able to explore how technology could function as a guide for the sequencing of dressing. Informed by the themes and interaction recommendations elicited in the co-design workshops, creative writing exercises and interview with the occupational therapists, we created two design fictions which are presented here. In two studies using first co-design followed by participatory design fiction we were able to explore what dressing challenges currently exist and what possible and desirable futures e-textiles and technology might have for supporting people with disabilities.

Chapter 2: Literature Review

The following literature review examines the contributions of occupational therapy to HCI research, the role of occupational therapy in dressing rehabilitation, as well as how disability impacts dressing. Further, this literature review examines the role of e-textiles in rehabilitation and the current technology available to support dressing challenges. Finally, this literature explores the importance of future visioning and the recent literature on design fiction, its use in health care and co-design.

2.1 Occupational Therapy and HCI

Human computer interaction researchers are increasingly leveraging the unique expertise of OTs to design more accessible technologies. Occupational therapists evaluate tasks and tools from a holistic perspective including the person, the environment and the activity [1]. Previous HCI researchers have found that OTs are makers in how they adapt tools and activities to support their clients' needs, but rather than using iteration (like HCI researchers) they focus on solutions that can be re-used across clients and that are customizable [33]. Though do-it-yourself (DIY) assistive technologies are increasingly studied within HCI, consulting with OTs can help ensure that solutions are also safe due to the field's prioritization of client safety [33], [71]. For example, in co-design sessions with individuals with disabilities, including OTs helped to capture insights and details on how an individual moved and worked with tools that design researchers missed [1], [37]. Consulting with OTs can also be beneficial when designing disabled people to ensure that solutions are customizable to the breadth of individual needs [39].

2.2 The Role of Occupational Therapy in Dressing Rehabilitation

Occupational therapists are involved in the rehabilitation of those with dressing challenges. Occupational therapists use strategies which might include backward chaining techniques [48], overlearning, video training [32], [81] or other forms of functional retraining such as a problem-solving approach [91]. Backward chaining is a behaviour training method used since at least the 1960s to teach people with disabilities daily living skills such as dressing. It involves the teacher or therapist completing all of the steps up to the last step prior to the completion of the task. The person being taught the skill then completes the last task. Once they have mastered the last task, the next task is left undone until they are able to complete the entire task (in this case donning the entire piece of clothing [48]. Overlearning involves practicing a skill over and over until it becomes automatic. Video training involves demonstrating the skill step by step on video and demonstrating the skill to the learner to teach the task [32], [81]. Video training is often combined with another technique to teach the skill. Problem solving approach involves training person specific strategies to address physical challenges such as placing a motor impaired arm into the sleeve of a shirt first as in the case of stroke retraining [91]. Often these four strategies are tailored to the individual and focus heavily on one-to-one interaction between a therapist and the disabled person. Occupational therapists have indicated that teaching dressing strategies in their practice can be limited by time, staffing or the environment in which they work [91]. Additionally, teaching strategies can be limited by the client's own abilities or priorities for dressing tasks [91].

Although OTs are skilled at teaching strategies to aid in dressing rehabilitation, they also leverage low-tech assistive technology to support the independent completion

of dressing tasks. For example, button hooks, sock aids, long handled shoehorns, dressing hooks, Velcro shoes and adaptive clothing are commonly used items [52]. In many cases low-tech assistive technology is discarded by the user due to perceptions that they are not needed, the aids do not work well, or they are too difficult to use [52]. High-tech solutions, including e-textiles, to my knowledge have not been explored in the OT literature or practice, however this is an emerging field in HCI research where they offer potential to support independent dressing for people with disabilities [49], [13]. E-textiles have been used in other areas of rehabilitation to support people with disabilities, which opens the possibility that they may be useful for dressing challenges.

2.3 E-textiles and Rehabilitation for People with Disabilities

E-textiles are fabrics that have electronic components such as sensors and actuators sewn into them [26]. They have been used in art, technology, and fashion for "playful and serious applications" [29:1]. E-textiles range from commercial grade applications, such as the Levi's jacket by Google Jacquard (Figure 1) that connects to your smart phone [28], to maker creations used in teaching applications [41]. E-textile research spans health applications [34], [6], [85], material science [43], fashion and educational tool kits among many other areas.

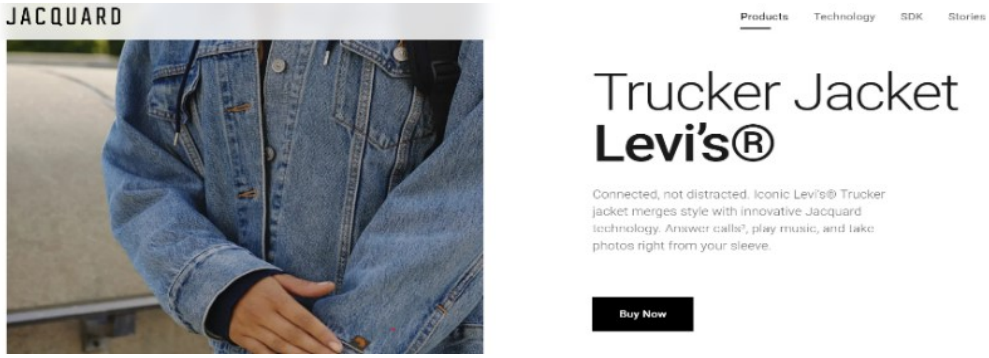

Figure 1: Levi's Jacquard Connected Jacket

E-textiles have been used in research to assist in rehabilitation in numerous ways, including monitoring health [34], [6], [85] assisting with self-regulation [21], [27] and as tools for communication [45]. Each of these areas show promising ways of aiding disabled people to manage their health and participate in the community.

2.4 Importance of health monitoring for people with disabilities

Monitoring body systems has been shown to be important to support the overall health of people with disabilities, to impact their health and make informed decisions which can improve their wellbeing. In the case of spinal cord injury, monitoring for blood pressure has been essential to recognizing cerebrovascular disease [34]. Monitoring physical activity can predict the risk of falling for people with neurological diseases such as Parkinson's disease and multiple sclerosis [6]. Monitoring the number of steps taken by stroke survivors can predict their risk of a secondary stroke [44], and monitoring of daily life activities of the individual can guide the optimal use of rehabilitation programs for them [84]. E-textiles have been used to monitor electrocardiogram signals, heart rate, blood pressure and body position [42], [23]. They have also been used to monitor sensation [42]. These capabilities offer disabled people solutions for body systems monitoring that could provide safe home-based opportunities to closely guard their health. Many studies have discussed the importance of these capabilities, however little research has focused on a vision of how these solutions might be functionally incorporated into the daily lives of people with disabilities.

2.5 Importance of self-regulation for people with disabilities

Self-regulation, which refers to the ability to regulate emotions and thoughts for "goal directed behaviour, controlling impulses and solving problems constructively" [55], is

essential for disabled people. Self-regulation ensures that people are at the right state for learning [4], relating and participating in daily life. When a person is able to self-regulate, they can fully engage in activities. When a child is able to self-regulate, they have better academic success, relationship satisfaction and psychological well-being [18]. This also holds true for children with developmental disabilities [18].

E-textiles have been used as tools for self-regulation. For example, in the case of Calm Wear [27] smart clothing (Figure 2) was used to actuate calming tactile stimuli in response to heart rate variability and respiration as signs of anxiety. Additionally, this has been used for people with disabilities as in the case of the "hugging" vest (Figure 3), a deep pressure vest designed to help calm the nervous system of autistic children and assist with wireless nervous system regulation [21]. In this design, the system was actuated remotely by a therapist or parent for the autistic child. Despite increasing research into rehabilitation applications including health monitoring and self-regulation, e-textiles and smart clothing have not been fully explored in the area of dressing assistance for people with disabilities.

Figure 2: CalmWear: Smart Clothing for People with Autism

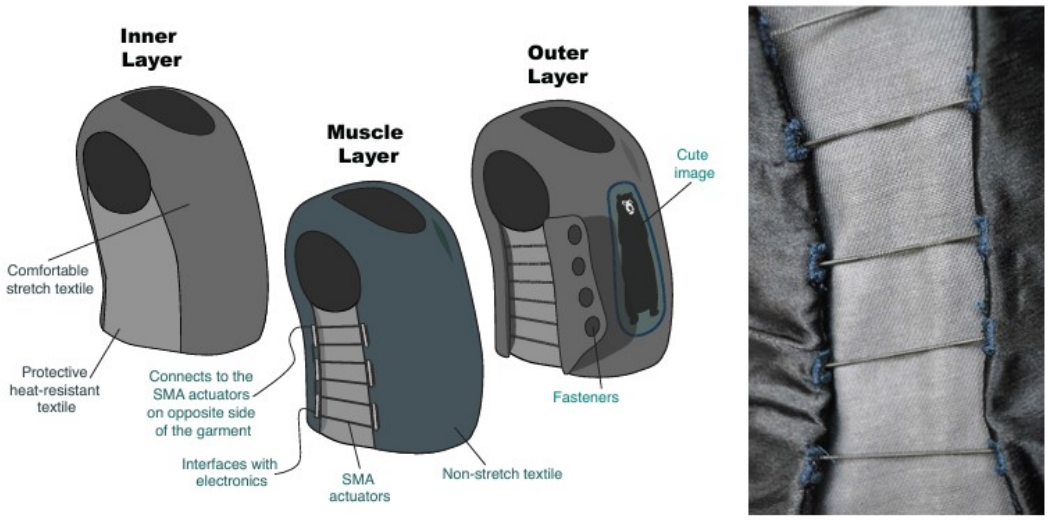

Figure 3: The "hugging vest" for Remote Calming of Children with Autism

2.6 Importance of independence in dressing for people with disabilities

Dressing independently is an important aspect of community participation. It has been shown that participation in dressing for people with disabilities has been impacted by the mechanical aspects of dressing, cultural aspects of dressing, as well as sensory aspects of dressing [40]. The ability to select clothes to wear is an aspect of self-determination for disabled children [22].

Based on a review of the literature, there appears to be limited research on e-textiles or smart clothing used to assist people with disabilities to increase their independence in dressing. Schaad et al. [67] developed a system to assist people with mild dementia to dress using sensors which detected the weather, displayed appropriate clothing on a screen and used an LED strip that lit up compartments of clothing to aid in the selection of weather appropriate clothing (Figure 4). However, it did not aid in the actual physical task of dressing itself or the cognitive task of sequencing the dressing

task.

Figure 3. On the display the sweater is marked in green as well in the wardrobe.

Figure 4: Dressing App with LED Strips to Assist with Clothing Selection

Chu et al. [14] proposed a system in which smart clothing and an assistive robot aided cognitively impaired users to know when their clothes were worn correctly, partially worn, or worn inside out (Figure 5). However, this system did not instruct the wearer on how to correct the issue.

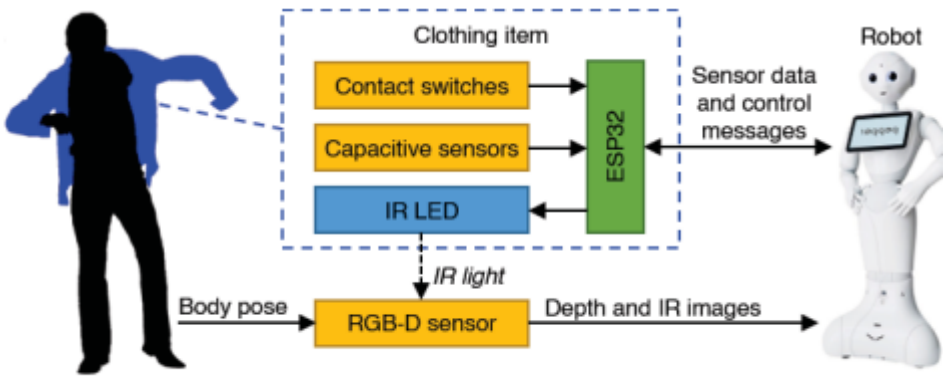

Figure 1. Architecture of the Clothing Perception System for Dressing.

Figure 5: Robot Aided Dressing System

In terms of assisting with dressing, Enfold [49] is a jacket using shape memory alloy (SMA) and origami folds developed to help people with cerebral palsy to wrap the

garment around their body without outside help (Figure 6). This garment did not, however, instruct the user on how they might increase their ability with dressing.

Figure 3. 'Enfold' jacket

Figure 6: Enfold: Smart memory alloy to assist people with cerebral palsy to dress

Computer-aided dressing technology and e-textiles have the potential to provide people with disabilities more options and independence in dressing, however explorations into their use have been limited and lack a fulsome discussion of how these technologies would be used and implemented in daily life for disabled people. Further definition of the challenges for dressing accessibility needs to be explored in order to first define the problem and to identify if, and how, e-textiles or technology might address these issues. Future visioning is one possible way to explore challenges and propose solutions to dressing problems.

2.7 Future Visioning

'Future visioning' has a long history in HCI research [62]. Some researchers have used design fiction, speculative design or other techniques to elicit the future of technology from the participants' perspective. In the first study conducted for this thesis, future visioning was centred on the principal of "problem oriented futures work" [88:3] as

described by Voros in 2001, where "it is often concerned with how organizations and society might, or ought to, respond to challenges lying in the nearer-term future" [88:3]. Voros describes four types of futures: 1) possible futures, 2) plausible futures, 3) probably futures (also called probable futures by Voros in 2017 [89]) and 4) preferable futures (Figure 7). Future visioning in this manner allows for an exploration of many possible futures and situates ideas into categories of how likely they are to occur based on what is currently possible and known. By introducing the possibility of preposterous futures (seemingly impossible futures) it allows an exploration of outside the box thinking [89]. In the first study presented in this thesis, this concept was introduced by asking OTs to imagine a future without limitations of current technology and financial resources to allow for unique visions of the future.

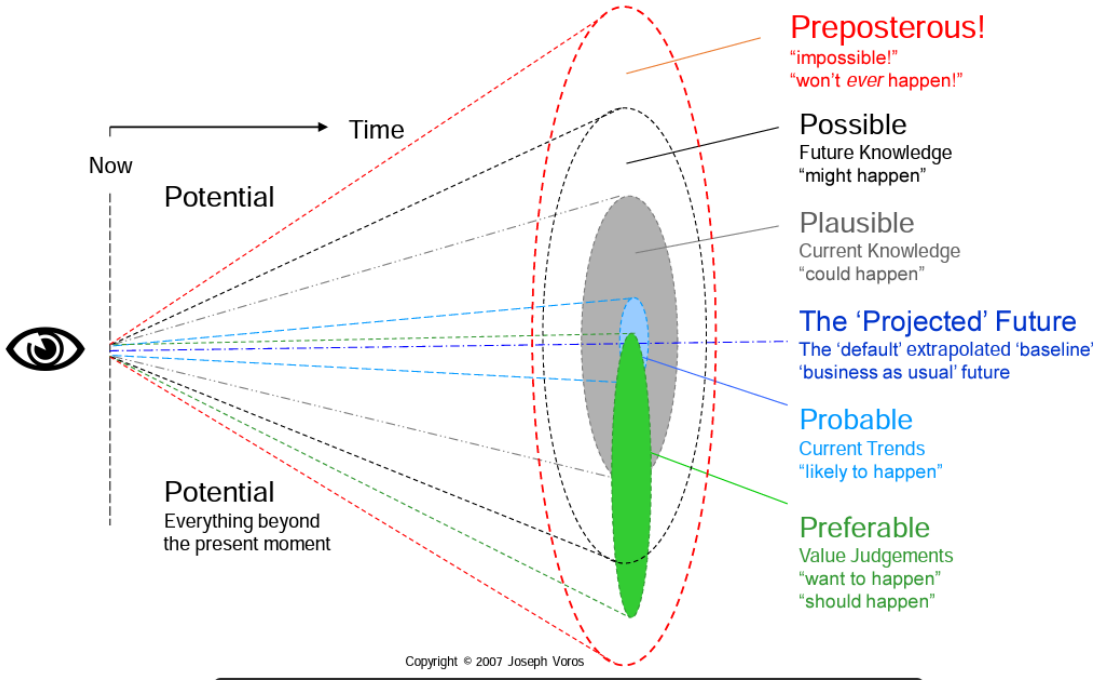

Figure 7: Voros' Future Cones diagram

Reves [63:1] describes “envisioning” which includes "projections into the future regarding implications of existing technology trends" [63:1]. Quigley asserts that "traits common to all visions are an aspirational future." [62:2547] and states that "visions have proven to have the power of shaping communities in Human Computer-Interaction and guiding research efforts over many years, or even many decades" [62:2547]. There are several methods of 'future visioning' that are used to elicit participants’ views of novel technologies and plans for the use of future technology. Human computer interaction researchers have used sketching, drawing and cartooning as a means to explore possible futures and novel technologies [79]. In particular, storyboarding as a means of co-creation is used to develop a communication tool regarding future visions [79]. Storyboards can be used as part of co-design methods which honors participants expertise allowing them to collaborate with other professionals to share ideas. I employed this method in the first study of this thesis to develop a common understanding with the OT participants.

2.8 Remote Co-design

Co-design in this case refers to "the creativity of designers and people not trained in design working together in the design development process" [65:6]. Steen states that co-design "can be understood and organized as a process of collaborative design thinking... as a process of joint inquiry and imagination"[74:27]. Co-design can be used to ensure that participants were valued as experts in their experience. Steen outlined 5 phases which included Phase 1 and 2 - Exploring and Defining the Problem; Phase 3 - Conceiving the Problem and Possible Solutions; and Phase 4 and 5 - Trying out and Evaluating Possible Solutions. Study one roughly follows these stages.

Researchers have used remote co-design in HCI to elicit perspectives on the future of technology in young black adults [31] in light of the COVID-19 pandemic. They successfully used Zoom as a platform to conduct speculative design sessions. Researchers have also used remote co-design with children [66]. The children completed co-design projects asynchronously, then sent in pictures to researchers of their robots and story boards followed by an interview with their parents online. Remote co-design offers a method for engaging OTs who may not be able to attend in-person workshops due to distance or COVID-19 protocols. Remote co-design was used in both study one and two of this thesis. In the second study participatory design fiction was explored as a methodology to further clarify how dressing technology might be used in daily life in the near future.

2.9 Design Fiction

Design fiction for the purposes of this study is defined as a world building activity [15] in which an artefact is created to provoke discussion about the future use of that technology. Compared to future visioning, design fiction has a more recent history in the HCI literature, based on a 2009 paper by Bleeker [5] who created research methods to engage in design fiction. Lindley et al. [50:210] defines design fiction as "1) something that creates a story world, 2) has something being prototyped within that story world, 3) does so in order to create a discursive space.". Sturdee et al. [78:376] state that “design fiction is not a means to directly evaluate a particular user interaction but rather consider a world in which that interaction makes sense to the prospective user.” Design fiction is also used to consider the ethical and social implications of a new technology. Tannenbaum [82:22] states that “situating a new technology within a narrative, forces us to grapple with

questions of ethics, values, social perspectives, causality, politics, psychology, and emotions.”. Tanenbaum [82] posits that design fiction has three potential purposes, 1) a method for envisioning new technologies, 2) tools for communicating innovations to other researchers or the general public and 3) inspiration and motivation for design by exploring design requirements.

Bruce Sterling the originator of design fiction defined the approach as “the deliberate use of diegetic prototypes to suspend disbelief about change” [9]. Diegetic prototypes can be defined as a combination of artefacts to describe a possible technology situated within a story or future world. Diegetic prototypes can take many forms such as film, user manuals, posters or website designs. The main function of the diegetic prototype is the creation of a ‘story world’ in which the new technology exists. The ‘story world’ must follow its own rules as outlined by the creator of the world and create plausible solutions within that world. Bleecker [5:7] states “A design fiction practice creates these conversation pieces, with the conversations being stories about the kinds of experiences and social rituals that might surround the designed object”. Coulton et al. [16:5] argue that “creating the world is the principal task of the designer when creating a Design Fiction.”. Storyboards and cartoons have been used as a means to create design fiction [78], [56] by creating a story world as well as discussing the implications of the technology proposed within the story world. For example, in the case of Sturdee et al. [78] a cartoon story board was used to describe the social impacts of a Voight-Kampff machine based on a machine described in the film Blade Runner [69] which measured physiological signals to determine the ability of a person or android to exhibit empathy.

The creation of these cartoon story boards allowed the authors to explore potential uses and misuses of the proposed technology within a near future scenario.

2.10 Design Fiction and Health Care

Design fiction has been used to generate discussion and visions of the future in healthcare, with examples like HawkEye by Noortman et al. [59] where a design fiction probe simulated remote monitoring for people with dementia. In Noortman et al.'s study [59] a researcher designed probe was deployed to participants homes with instructions for its use, including a description of the method with which the probe could be used to monitor a fictitious person with dementia. Participants perceptions of the proposed technology were then gathered. In this case, the probe was designed by the researchers prior to discussion with the participants and not co-designed with participants. Another example of design fiction used in health care is by Stead at al. [73], where participants were asked to envision a future in which DIY healthcare technologies are possible and common. Stead and colleagues [73] presented 3 design fiction scenarios that surround a device called HealthBand. Shulte [68] developed a design fiction related to dementia care, where they explored the implications of smart wearable technology on people with dementia. In this case, they commented on what might happen if the wearable technology went wrong. The design fiction was not presented to any participants for comment, rather was crafted as a standalone scenario. Finally, Tsekleves et al. [87] explored the potential for design fiction to act as a tool for determining the plausibility and acceptance of health care technology and services. The authors co-created the design fictions with older adults,

which created a discussion around assisted dying and around the use of smart technologies for an aging population.

2.11 Co-Design and Design Fiction

Often design fiction research involves the researchers developing a prototype themselves and then requesting feedback from participants. This approach can create a power imbalance between the designer and the intended audience. Strachan et al. [76:e17] states that "when speculative design is combined with participatory and co-design methodologies, it can help people-non-designers-to consider and visualize the future, not as some abstract, scary and oppressive concept, but as something inevitable that we can help to shape." [76]. There are, however, some examples of co-design and design fiction employed together, where the participants are involved in the creation of the story world and the eventual prototype. In the project by Sondergaard and Hansen [72], three groups of participants, Danish high school students, international and Japanese design students and Japanese people with disabilities were asked to imagine how digital personal assistants (DPAs) might interact with them in the future through co-design workshops. Two design fiction scenarios were created out of the results, the first presenting a DPA with a female voice who responds to sexual harassment in various ways, the second presenting a digital personal assistant being used for female health in the bathroom. These two design fictions explored the impact of gender stereotypes and solutionism on DPAs and the importance of varied perspectives when determining how we should live with DPAs in the future. Another study where this was employed was by Nagele et al. [56] where they requested that participants with recurrent bladder infections create a near future story world in a creative writing exercise. The researcher then worked with the

participants to create storyboards of the story world and technologies that they proposed to address the issue of recurrent bladder infections. It is on the study of Nagel et al. [56] that the methods for my second study are based, modified for use with occupational therapists and remote co-design. Nagele et al.'s method was shown to be effective for addressing the needs of vulnerable users and allowed for an exploration of intimate needs which closely relates to my study on the needs of people with disabilities for addressing dressing challenges.

2.12 Summary of Background

Occupational therapists have contributed to HCI research, including using their maker skills to create customizable solutions for the needs of their clients, providing input into ensuring that assistive technologies are implemented safely and assisting in the design of tools for disabled people. Occupational therapists also contribute to support people with disabilities to address dressing challenges through the use of strategies such as backward chaining, overlearning, video training and problem-solving approaches. These strategies are limited by time, staffing and client's abilities. Occupational therapists often rely on low tech adaptive technology to assist with increasing independence in dressing for their clients, however there are difficulties with adoption of this technology such as aids that are not well suited to the task. E-textiles have the potential to support people with dressing challenges. E-textiles have been used in research in many areas of rehabilitation for people with disabilities including health monitoring, self-regulation and as tools for communication. well as how disability impacts dressing. Few studies have explored the potential for e-textiles to assist with dressing challenges. Through future visioning we can explore the potential for new and not yet existent technologies to address dressing

challenges. Engaging in future visioning with OTs can lead to possible solutions to dressing challenges. Co-design offers one method to engage in collaborative ideation with OTs to support the generation of new e-textile solutions, Co-design and future visioning is applied in study one (Chapter 3). These methods alone do not fully situate dressing solutions in daily use and cannot anticipate drawbacks or social impacts of the proposed solutions. Through design fiction we can explore further the implications of these solutions on the day to day lives of people with disabilities within a social context. Participatory design fiction allows for the voices of OTs to contribute their expertise in disability and dressing challenges to the vision of how assistive dressing technology of the future should be designed and situated in society, Participatory design fiction, based on the work of Nagele et al. is used in study two to delve more deeply into the implications of future dressing technology.

Chapter 3: Smart Textile Visions: Occupational Therapists' Visions for the Future of E-Textiles

In this first study, we were interested in (1) understanding what occupational therapists envision the future of e-textiles could be to support people with disabilities, and (2) brainstorming in what ways might e-textiles assist disabled people to become more independent with dressing. We asked OTs to consider the future of e-textiles and people with disabilities. In so doing we encouraged OTs not to think of current technology limitations and be open to possibilities beyond what is currently possible and instead to consider e-textile solutions that may not yet exist. Our research team consisted of myself (a Masters candidate in HCI and OT), a PhD candidate in the School of Information Technology and a post-doctoral fellow in HCI. We explored these questions using remote co-design workshops, where we collected data using brainstorming, interviews and storyboarding activities. We obtained clearance from our institution's research ethics board.

3.1 Participants

Participants included 8 OTs, seven female and one male between the ages of 25 and 50. The OTs indicated their area of practice included 7 pediatric therapists, 1 seating and mobility, 1 neurology and ergonomics, and 1 indicated low vision care in their area of practice. Five of the OTs indicated that they had experience with wearables and 2 OTs owned wearable devices. Three of OTs indicated they had experience with e-textiles. We recruited participants in the United States and Canada via social media on professional networking sites, via professional association newsletters and direct email invitation. We

collected consent and demographic information via online Qualtrics questionnaires in advance of the workshops.

3.2 Workshops

We held 7 workshops consisting of 1-2 OTs per workshop via Zoom. Three researchers were present for each session, where I facilitated the co-design session while the second (PhD student) and third (post-doctoral fellow) researchers provided scribing and technical support as needed. We used a co-design approach, which included having participants take part in a 2-hour video conferencing session on Zoom while using a collaborative white board application on the Miro platform [54]. The data collected included interview transcripts, brainstorming via virtual sticky notes and narratives captured in story boards.

We conducted these sessions remotely in the context of the COVID-19 pandemic, as it allowed us to continue to conduct the study despite the need for physical distancing. Additionally, remote co-design allowed for the inclusion of multiple perspectives of OTs from across Canada and the United States without limiting the sample selection to those in close proximity to Carleton University.

Phase 1 and 2: Exploring and Defining the Problem

Following 'get to know you' activities (Figure 8) we led participants through a series of questions, which included: *What dressing challenges do you (where you refers to the OT participant) face in your practice/life? What are some areas where people you work withhave difficulty getting dressed?* They were encouraged to think widely from the point of view of clients with motor, cognitive and regulation needs and to not limit themselves to particular diagnoses or disabilities. Although participants were primarily pediatric therapists, the participants explored these challenges from across the age span.

Participants answered these questions verbally as well as using virtual sticky notes or icons provided. We recorded their answers in the virtual whiteboard (Figure 9) and audio recorded using Zoom.

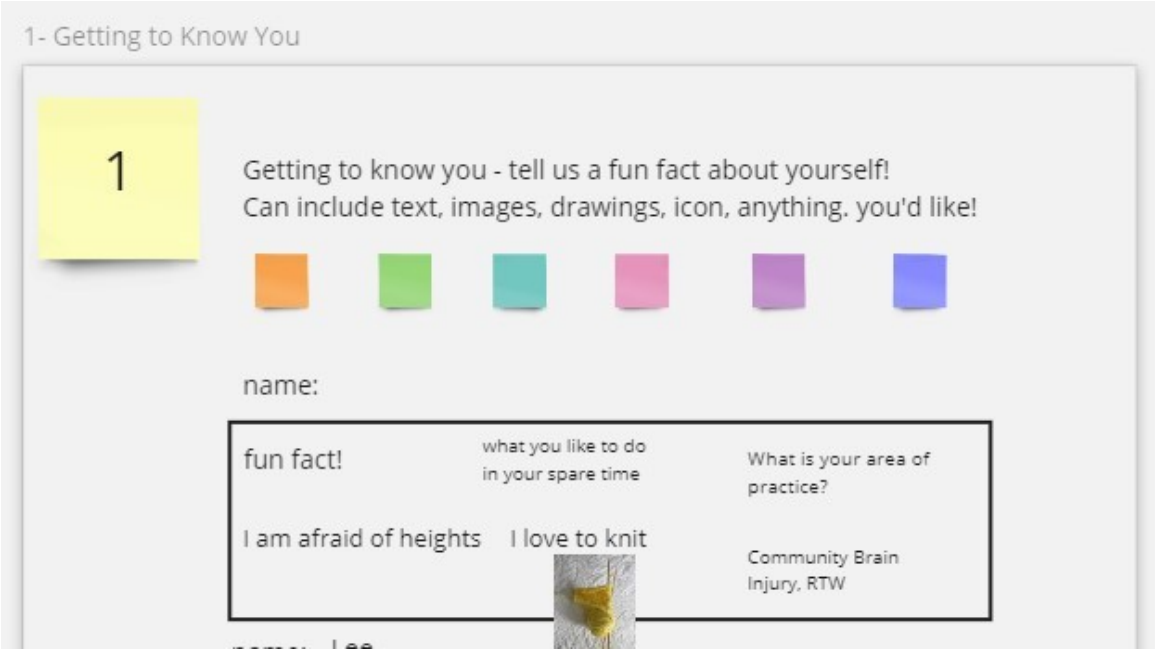

Figure 8: Getting to Know You Exercises, including telling a fun fact

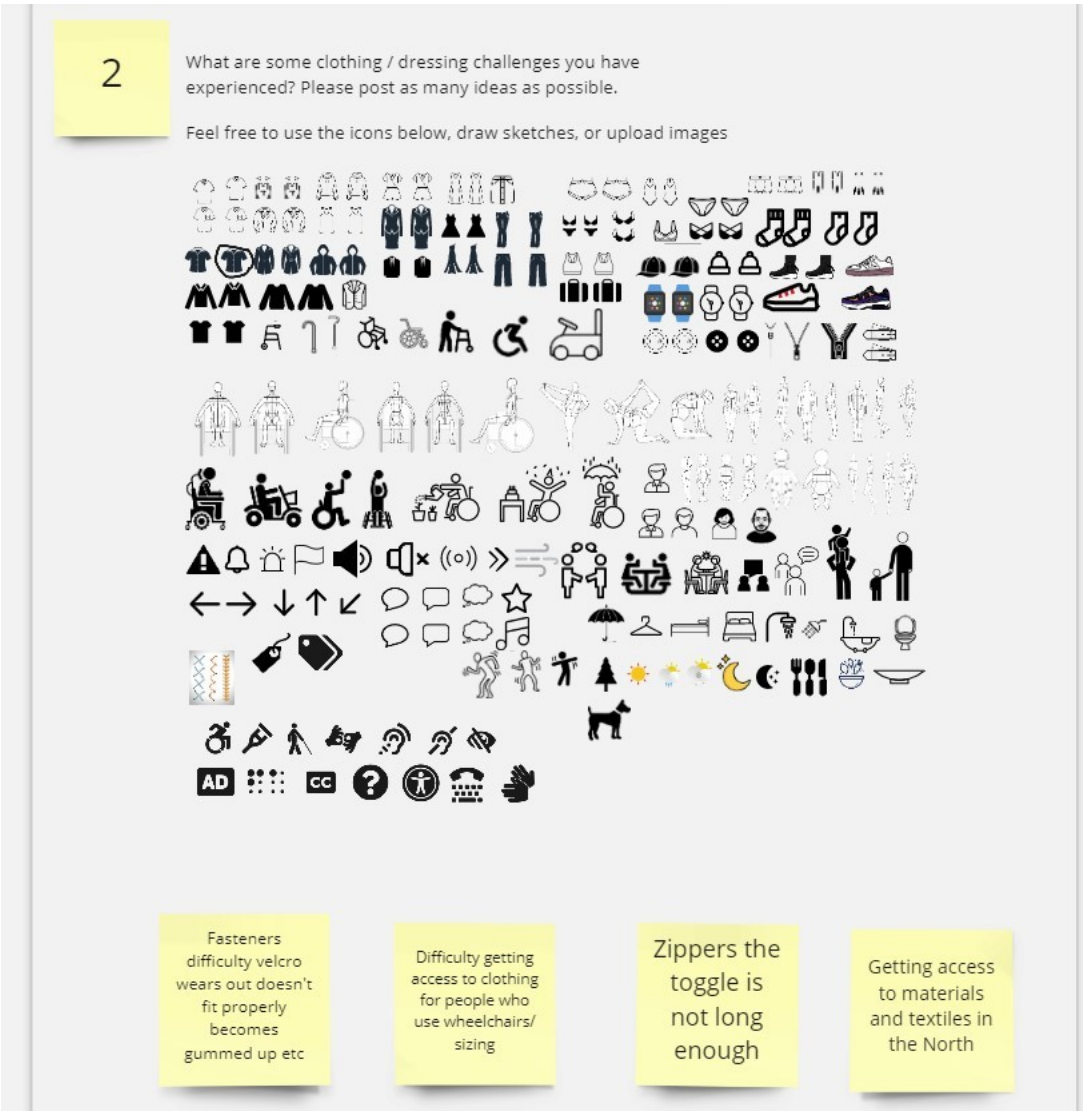

Figure 9: Dressing Challenges Exercise

Ideation Exercises

We led participants through ideation activities that included a learning module about e-textiles and a drawing activity called "wearable crazy eights" [38]. In the "wearable crazy eights" activity participants draw eight pictures in eight minutes of wearable concepts automatically generated by an online ideation deck. The purpose of the deck is to encourage “outside the box” design ideas. The concepts are presented as a string of words

describing a garment followed by a situation for use and adverb. For example: “leg warmers for fear, patiently!”. During the ideation activities, participants drew or verbally described the garment generated by the online ideation deck. At the end of the activity participants were asked to select their favorite concept or drawing and then present it to the researchers.

Phase 3: Conceive the Problem and Possible Solutions

We then asked participants to answer the question: *If there were no technology limitations what solutions would you create for the problems you identify?* Participants used virtual sticky notes, icons (the same ones as in Figure 9) or verbally described their answers. Some participants described their answers while researchers scribed their answers on sticky notes.

Phase 4 and 5: Trying Out and Evaluating Possible Solution

Finally, we asked participants to choose their favourite solution/vision for the future and to create a storyboard describing their vision (Figure 10). The OTs were first taught what should be included in the story board and then were assisted to select pictures to add to their story board. Some OTs required more support than others, this included support to operate the Miro board software and support to find images that described their proposed idea. We then asked them to consider the following questions regarding their design:

- *What would you like the garment to feel like?*
- *What would you like it to look like?*
- *What is the context you would use it in (when/ where)?*
- *How would you describe someone's experience with it? How often would the disabled person wear it (e.g., daily or on specific occasions?*

- *What could it offer the caregiver, what could it offer the individual with the disability?*
- *Is it discrete or public?*

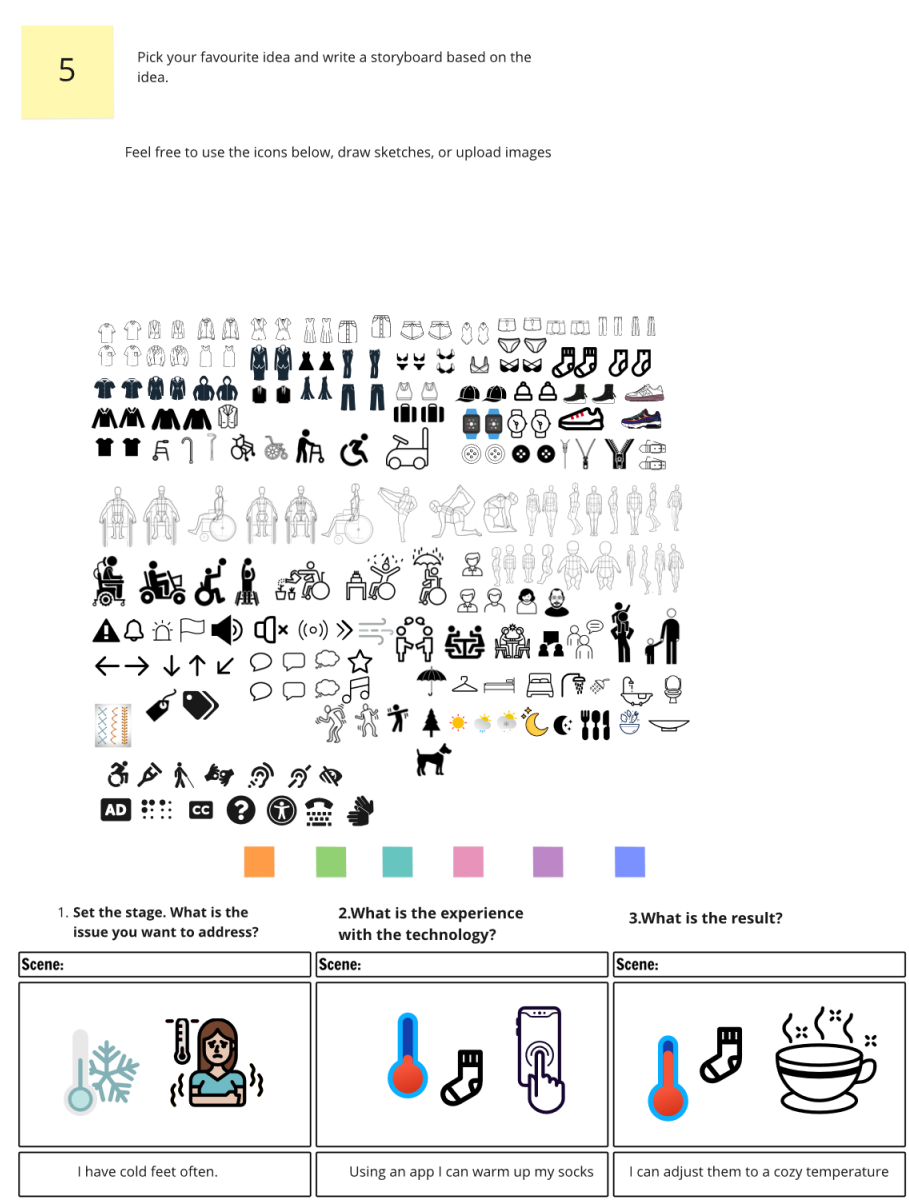

Figure 10: Storyboard Activity

3.3 Analysis

We analyzed the data using a triangulation approach with four phases that included overall review, followed by coding the virtual sticky notes using affinity diagramming, concept coding and axial coding, coding the interviews and finally coding the story boards.

The first step in analysis included the first author reviewing all aspects of the data from a high level by reading over the transcripts, looking at the virtual sticky notes and story boards to gain an understanding of the data. Next, we arranged the virtual sticky notes using affinity diagramming [51] (Figure 11 and 12) to develop codes. Affinity diagramming is a process by which large amounts of data/notes are organized into hierarchical representations of data [51]. The coding process was informed by the work of Johnny Saldana [64] in the Coding Manual for Qualitative Researchers. Saldana describes "concept coding", whereby the researcher "extracts and labels the big picture ideas suggested by the data" [64]. We divided codes into two major categories and then arranged the sticky notes under each concept code. The concept codes were then arranged, as in axial coding [64], into higher level themes. Saldana describes "axial coding" as a process to "compare, reorganize and focus the codes into categories" [64].

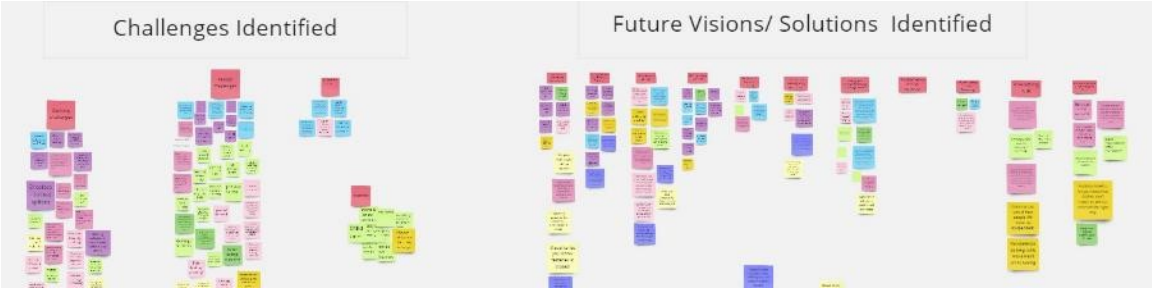

Figure 11: Affinity Diagram

Figure 12: Close up of Smart Textile Visions Affinity Diagram

The third phase of analysis involved transcribing the audio recordings of the workshops using Trint and then coding and de-identifying the data. The coding structure was based on the codes and codebook developed through concept coding of the sticky notes. The interviews were coded twice (2 cycles) to build confidence that the coding strategy was capturing the concepts appropriately. I coded only the portions of the interview responding to the questions, not the ideation activities. Finally, the storyboards were gathered together on a Miro board and coded for the overall concept and proposed solution using the codes previously determined when concept coding the sticky notes.

3.4 Results

The following section presents the codes, categories, and themes that were developed from the data following concept coding and axial coding the sticky notes and deductively coding the interview transcripts and story boards. As a result of concept coding the sticky notes 2 preliminary categories were developed with concept codes that support each category shown below (Figure 13 and 14):

Dressing Challenges

- *Personal Challenges*

- *Social and Environmental Challenges*
- *Clothing Challenges*

Future Visions/Solutions Identified

- *Automatic Opening and Closing Items*
- *Clothing that Helps with Emotional Regulation*
- *Shape Changing Clothing*
- *Self-Managing Clothing*
- *Temperature Regulating Clothing*
- *Instructional Clothing Using Technology*
- *Clothing that Leverages Technology to Manage Health*
- *Stylish Clothing through Technology*
- *Positioning Aids*
- *E-Textile/Clothing as Communication Device*

These concept codes for Future Visions/Solutions were then arranged more conceptually using a process of axial coding into higher level themes to illustrate the main ideas OTs brought to these sessions:

1) **Self-Mechanized/Self Moving Clothes**
2) **Regulating Clothing**
3) **Corresponding Clothing**

The same concept codes listed above were used to deductively code the interview transcripts and story boards.

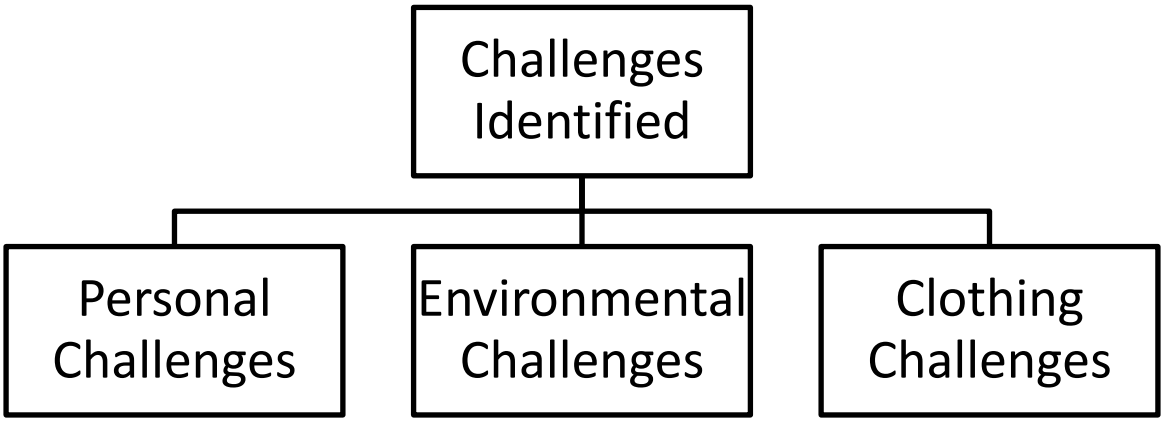

Figure 13: Dressing Challenges Concept Coding Structure

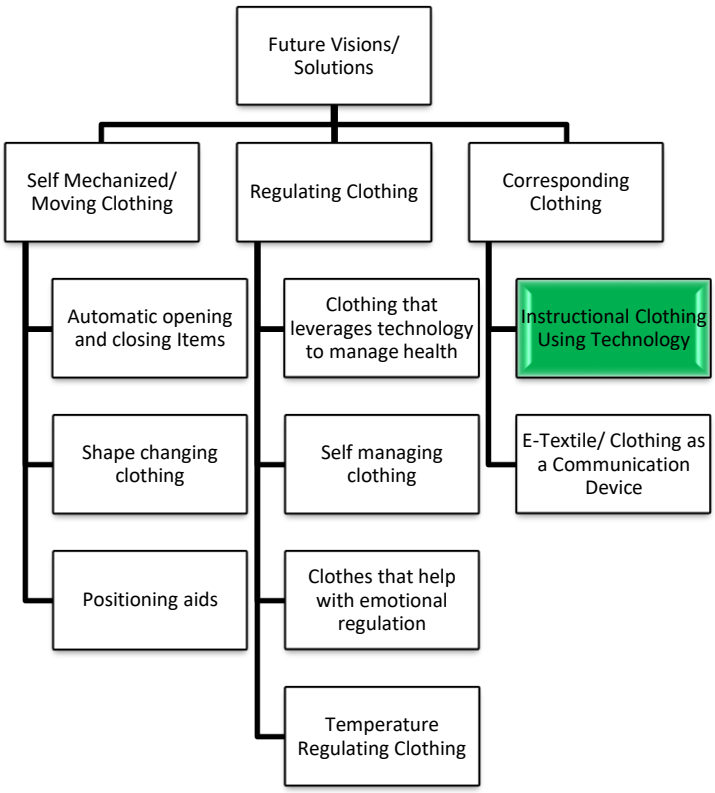

Figure 14: Smart Textile Solutions Concept and Axial Coding Structure

3.4.1 Dressing Challenges

When asked to identify dressing challenges that people with disabilities face, the participants identified three types of challenges that ranged from within the person, to the environment, to the design of clothing itself. I elaborate on the codes related to dressing challenges below to illustrate the barriers discussed by OTs.

***Personal Challenges*:** All eight OTs identified that personal factors created dressing challenges. They also indicated that fine motor abilities would hinder an individual's ability to manage dressing. This would lead to functional difficulties such as managing buttons or snaps or donning and doffing items of clothing. One participant described some ways in which fine motor abilities impact on dressing: *"It's the fine motor*

and the motor planning areas that are most difficult, so knowing where to place fingers to hold the right tension and following next steps and putting together like all the different perception." (Participant 7). Another type of challenge that 5 OTs noted included cognitive challenges such as sequencing the tasks of dressing or comprehending the task. They stated that this would lead to functional challenges such as knowing what steps to take next when putting on an item of clothing. For example, one participant described that cognitive abilities can impact on this: *"So, there are certain cognitive abilities or limitations that come along with the amount of damage that she had in their brain. And so, one of those components was really being able to follow steps."* (Participant 6).

Social and Environmental Design Challenges: Two OTs identified dressing challenges that included the design of the social or built environment. The two OTs identified social constraints to dressing such as others not valuing independence in dressing or costs of adaptive clothing being prohibitive. This would lead to functional difficulties such as not learning to dress oneself or not having access to clothing that one could wear that would be properly adaptive. *"I think the generic things, anything that's adapted or medical is four or five times the cost, and a lot of our clientele can't afford that."* (Participant 2).

***Clothing Challenges*:** Finally, all 8 OTs identified difficulties with how clothing is designed that impairs individuals' abilities to manage dressing tasks. One participant described that *"closures can be too small and require the use of both hands to manage".* (Participant 2). Another participant described that clothing requires assistance to don due to complicated dressing steps such as shoe tying (Participant 1). The OT's stated that this could lead to functional difficulties such as requiring the assistance of another person to

don or doff these items of clothing. Other design flaws that were noted included clothing that was not adaptable to weather conditions when used with assistive devices such as wheelchairs. This would lead to functional difficulties such as getting wet when out on a rainy day or cold when out on a snowy day. For example, one person described the difficulties of maneuvering clothing when it is cold outside: *"...maneuver putting clothes around and all of that so needing specialized clothes to accommodate the wheelchair and accommodate being warm inside when it's* cold..." (Participant 7).

3.4.2 Future Visions Solutions Identified

The OTs shared future visions, through brainstorming and creating story boards, which they felt would solve the challenges they identified in the first half of the study. These included a range of solutions using e-textiles or future technologies, which led to the development of these central themes 1) Self-Moving/Mechanized Clothes, 2) Regulating Clothing and 3) Corresponding Clothing.

Theme 1: Self-Moving/Mechanized Clothes

This style of smart clothing discussed by OTs includes clothing that leverages technology to move itself to assist with managing fasteners, positioning for health or acts as a way to don or doff clothing for someone who is unable to do so themselves. In the case of clothing that can move itself to manage fasteners, 8 OTs suggested that these would be used to open and close zippers or buttons automatically. All the OTs indicated that fasteners of this type could assist people who do not have the physical dexterity or cognitive ability to manage them themselves. One participant described the mechanism of automatic fasteners: *"So just the idea of buttons that when they came close to each other*

would magnetically be completed without any sort of fine dexterous movement of individual digits in terms of what it would feel like." (Participant 2).

Clothing that can position for health was described by 6 OTs. They described those pieces of clothing that would position the body to improve posture, manage spasticity (abnormal muscle tightness due to contraction of the muscle) or otherwise position the body in a way that supports improved health. They also envisioned clothing that would manage swelling, measure heart rate or sense pressure. Smart clothing was also imagined by the therapists, that can assist with donning and doffing including pieces that can change shape to assist with either tightening or maneuvering clothing on or off.

Theme 2: Regulating Clothing

Occupational therapists identified several types of clothing that could assist with regulation in various ways. The clothing suggestions fell into the categories of regulating emotion, regulating temperature, regulating or managing health, and regulating/self-managing the clothing itself.

In the case of regulating emotion, 4 OTs suggested that e-textiles could be used to assist with self-regulation. They stated that smart clothes could be used to assist a person to identify various states such as anxiety or sensory overload. The 4 OTs suggested that the clothing then would react in a certain way to assist with regulating these emotional/physiological states. For example, one participant designed a hoodie that included relaxing music as a means of regulating emotional state. *"My concept was kind of like incorporating like a big giant hoodie type thing that once you're in a panic zone or you're having a panic attack or anxiety, then you can kind of shut out the world and have controls in your pockets for things like music and relaxing breathing cues and whatever*

else." (Participant 7). See Figure 15 which shows the storyboard developed by this participant related to this concept:

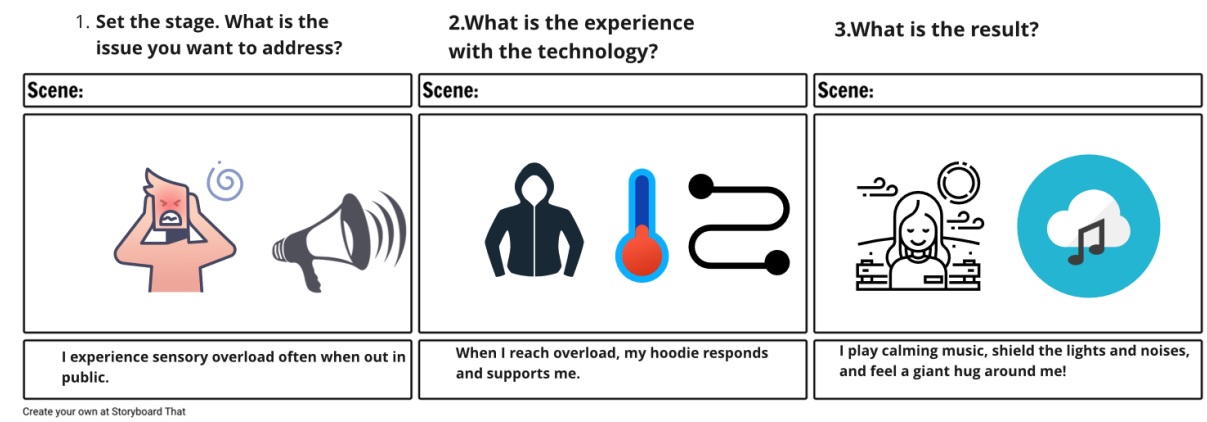

Figure 15: Calm Hoodie Story Board Participant 7

Four OT's described temperature regulating clothing which included clothing that might sense temperature either outside or within the body and then act accordingly to cool or heat the body. One example of this was a *"heat sensing jacket with cooling fan built in for temp regulation"* (Participant 1). Another participant noted this to be especially useful for people who lacked sensation such as in the case of spinal cord injury. *"So, I think that if there's a way for the fabric or the threads to have a temperature regulation to be useful especially because I feel like with certain individuals, for a spinal cord injury..."* (Participant 6). With respect to managing or regulating health OTs suggested these types of smart clothing could use sensors to monitor a person's health and provide some way of managing a health condition. An example might include a piece of clothing that monitors skin integrity for someone who lacks sensation, alerting them when they have put too much pressure on a certain area of their body, thus the clothing would assist in reducing

the risk for pressure sores. Lastly, clothing that could manage itself included clothing that could assist the wearer to manage the care of the clothing itself. For example, clothing that would assist with folding or hanging itself was suggested.

Theme 3: Corresponding Clothing

This type of smart clothing discussed by OTs included clothing that aided in communication in some way, either by communicating instruction or by allowing the user to communicate.

Instructional clothing could provide the user with some sort of cue either auditory, visual or tactile on how to use or operate the clothing. One participant described shoes that cue the steps to tying shoelaces. *"So when they're trying to learn shoe tying, oftentimes like they're fine motor, their fingers get so like jumbled up that they are really frustrated and their fingers don't do what they want them to do, so they don't know which ones to use to pull through. Like pull this. Crying and all of that. So instructions. But these would be like following these would cue and support the instructions, if that makes sense. So cue the kids to use like their pinky there, which fingers to use when leg for the next step of the task or something like that?"* (Participant 7).

Wearable technology was suggested by 4 OTs that allows the user to communicate verbally or visually communicate with others. This included shirts that demonstrate the emotion of the wearer, or when the wearer is unable to verbally communicate this. One participant described a shirt that speaks on behalf of the user, eliminating the need to communicate verbally themselves. See Figure 16, which

describes how communicating clothing would help a disabled person express their needs and emotions.

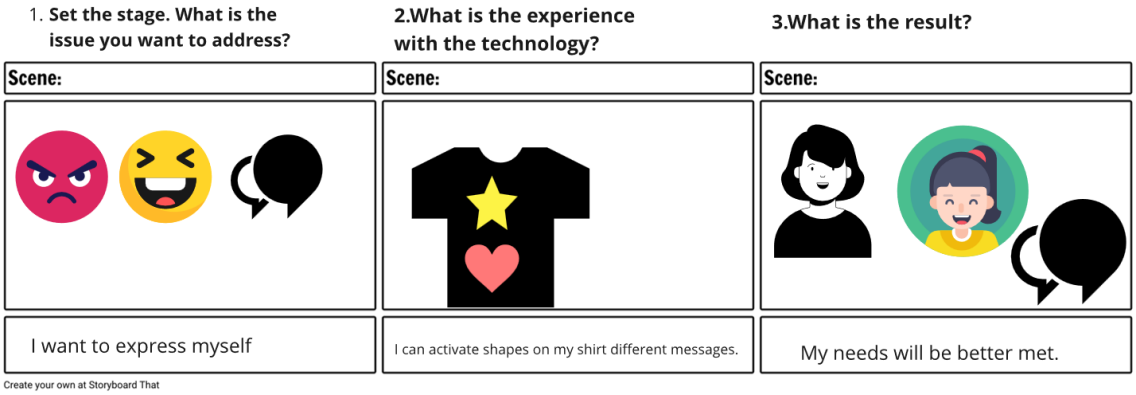

Figure 16: Communicating Clothing that Speaks the Users Mind by Participant 5

Occupational therapists suggested corresponding clothing could also be used to communicate information about the environment to the user, for example, communicating about obstacles in the environment for blind or partially sighted users. A participant described these types of clothing as *"...clothing that could...motion detect obstacles..."* (Participant 7).

3.5 Summary of Study 1

This remote co-design study of 8 occupational therapists and their future visions for smart adaptive clothing for people with disabilities offers a new direction for HCI research. Occupational therapists identified dressing challenges for disabled people that included *Person Challenges, Clothing Challenges* and *Social and Environmental Challenges*. They then envisioned solutions to these challenges which were clustered into 3 major design themes. They identified 1) Self-Moving/Mechanized Clothing, 2) Regulating Clothing and 2) Corresponding Clothing as unique solutions to dressing

challenges. Although some of these types of e-textiles already exist today, one key finding from this engagement with OTs is that clothing that can instruct the user how to dress, move or interact with clothing to use it is a new area for study. This vision offers people with disabilities not only the opportunity for increased independence in dressing in the face of *Clothing, Personal, Social and Environmental Challenges*, it also offers opportunities for self-determination using technology that does not disable further, but rather empowers and enables. HCI researchers can benefit from learning from OT practice and visions when designing assistive technology. Through the lens of empowering independence without 'doing for' the user, HCI researchers can develop relevant assistive technology.

The next step in exploring this area of study was to develop design fictions and diegetic prototypes using the challenges and technologies identified in this first study to further explore how the technologies proposed by the occupational therapists may impact on the users in a more fulsome manner using the method of developing more comprehensive ‘design fictions’. This stage of the work also allowed for further exploration of how prototypes or initial plausible designs could be developed from the original ideas that were suggested.

Chapter 4: Designing for the Future of Adaptive Clothing: A Design Fiction Study

Building on the results of the first study, we chose to explore the dressing challenges and possible solutions identified further. In this second study, informed by the results and discussions of the first study I opened the potential solutions to include technology as a whole instead of limiting the discussion to e-textiles. In this study, I asked 6 OTs to imagine a future oriented scenario that explored the following questions: *What is the future of technology envisioned by occupational therapists to support people with disabilities with dressing? In what ways might technology assist disabled people to become more independent with dressing? And what are the benefits and draw backs of future technologies in supporting people with disabilities and their dressing needs?*

We explored these questions using design fiction scenarios and story boarding. We asked the OTs to participate in a three-step process which included:

1) First, I asked participants to write (on their own time before the session) a future oriented scenario where they described how a predetermined occupational performance issue for a person with a disability is impacted by new technology and future socio-political circumstance.

2) I held a co-design workshop via Zoom with the participants to explore design fiction and to create storyboard scenarios envisioning their fictitious world and technology solutions.

3) I then analyzed the scenarios using abductive analysis and story boards. I then created diegetic prototypes (storyboards and a fictious website) based on those themes identified.

4.1 Participants

Participants included 6 OTs and their areas of practice included pediatrics (3 participants), community therapy (1 participant), assistive technology (1 participant), acute inpatient rehabilitation (1 participant). The participants ranged in years of experience from 2 years to 18 years of experience practicing as an occupational therapist. All 6 participants were female ranging in age from 26 to 42. Five out of 6 participants were familiar with wearable devices, 2 participants owned wearable devices, 3 participants were familiar with e-textiles. Four participants had participated in study one as well. We recruited participants in the United States and Canada via social media on professional networking sites and direct email invitation.

We collected consent and demographic information via online Qualtrics questionnaires in advance of the workshops.

4.2 Creative Writing Exercise

I first sent participants a creative writing exercise that consisted of creating a personal narrative from the perspective of a disabled person in the future. This exercise is closely modelled after Nagle et al. [56] in their participatory design fiction protocol. I asked the OTs to select an occupational performance issue on which to base their scenario. Below in Figure 17 is the exercise as presented to the OTs.

FUTURE YOU:

It is year 2032-2052 (select one, choose any day in this timeframe)
Write a personal narrative from the perspective of someone with a disability, diary entry or describe an ordinary scene in which you are the main character in this future.

The narrative should revolve around one of the following three occupational performance issues on which to base your narrative:

1) *You have developmental coordination disorder and difficulty managing your shoes.*
2) *You have a cognitive impairment and have difficulty sequencing your dressing tasks.*
3) *You have sensation issues as a result of an injury and have difficulty managing dressing task.*

Think SCIENCE FICTION and be creative

Set The Scene – The creativity of your world is entirely up to you. This is NOT about predicting the future. Anything you create, no matter how magical, dismal or realistic, is more than okay.
Some questions that you can use to guide your Narrative:

- *Where are you?*
- *When are you?*
- *What might you be doing?*
- *How does your occupational performance issue effect you?*
- *What might be happening on a larger scale in this world? Politically? Socially?*
- *What fears, concerns, or desires have manifested in this world?*
- *What technologies are present or absent in this world?*
- *What are your values?*
- *How do you feel?*
- *How do people around you in this world feel or act?*
- *What has changed for better or for worse with your condition? how? why?*

Length and Format are entirely up to you

Figure 17: Creative Writing Exercise Prompt

Once the writing exercise was completed the OTs sent it back and I then collected the narratives and included them on the Miro board. Following this I invited the OTs to participate in workshops via Zoom.

4.3 Workshops and Storyboards

I held 6 individual workshops via Zoom. I facilitated the participatory design session which included having participants take part in a 1-hour video conferencing sessions on Zoom while using a collaborative white board application on the Miro platform [54].

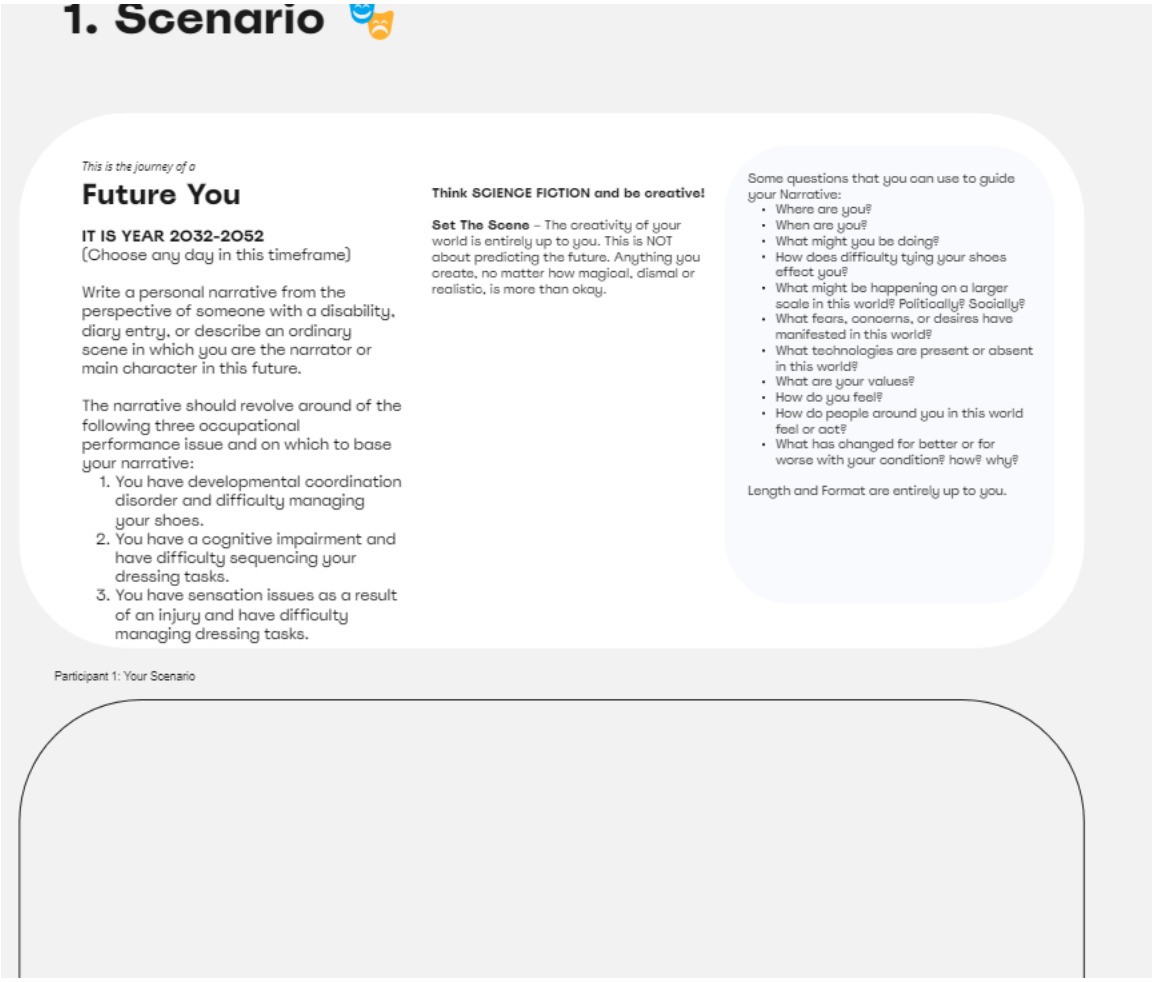

Figure 18: Miro Board activity reviewing the creative writing exercise presented to participants.

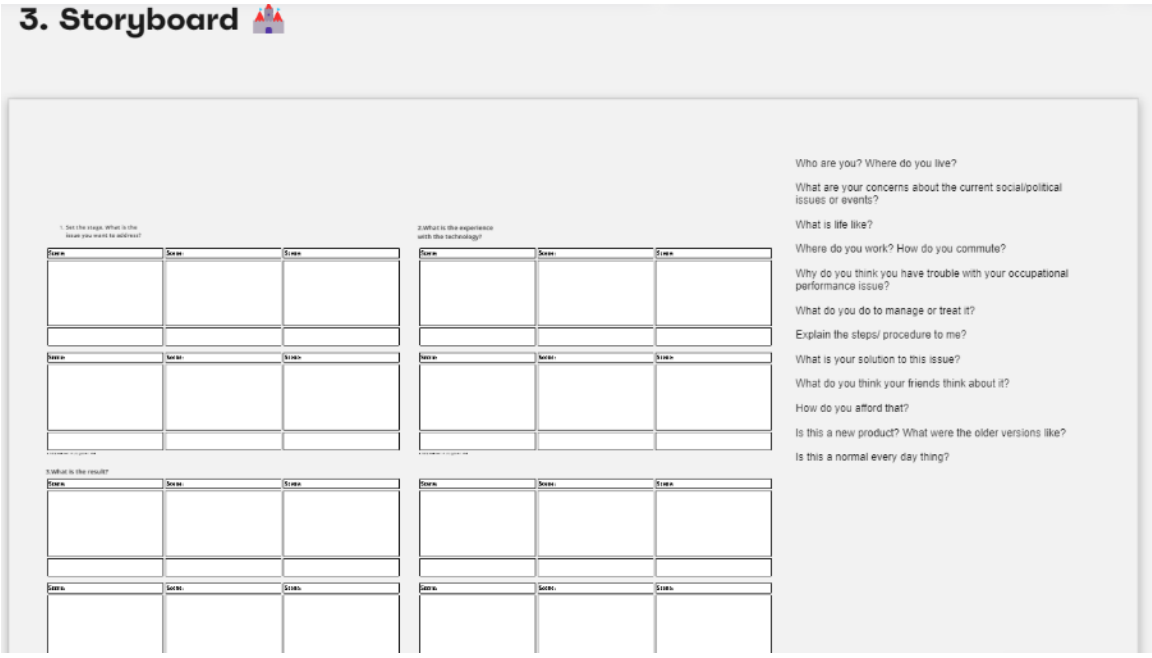

Figure 19: Miro Board activity co-designing a storyboard based on the participant's scenario.

Data collected included interview transcripts and the storyboarding activity using verbal descriptions, sticky notes and icons. In the co-design sessions, after reviewing the creative writing exercises with participants (Figure 18), I invited participants to explore e-textiles and design fiction to support their ideation. I showed participants a slide show describing e-textiles and how they can currently be used in design and medical applications. I then provided them a definition of design fiction and showed a video of a speculative design fiction entitled Uninvited Guests [35] that was created by SuperFlux. Following the video, I guided participants through interview questions based on the study by Nagele et al. [56]. The questions were aimed at exploring the story world in more depth and creating a deeper understanding of the main character, their daily life and the proposed technology. The interview consisted of the following questions:

- *Who are you? Where do you live?*
- *What are your concerns about the current social/political issues or events?*

- *What is life like?*
- *Where do you work? How do you commute?*
- *Why do you think you have trouble with your occupational performance issue?*
- *What do you do to manage or treat it?*
- *Explain the steps/ procedure to me?*
- *What is your solution to this issue?*
- *What do you think your friends think about it?*
- *How do you afford that?*
- *Is this a new product? What were the older versions like?*
- *Is this a normal everyday thing?"*

I asked participants to verbally describe their answers and I summarize their answers using sticky notes on the story board (Figure 19). I then encouraged them to select icons or pictures that might help them describe their proposed technology solution.

Following the workshop storyboards and fictional websites to create a fictional experience of the technologies and worlds proposed by the occupational therapists. The storyboards were developed using Storyboard That software [75] and the scenarios created by the occupational therapists. The storyboards included a visual depiction of the scenarios described by the participants and a representation of the proposed solution. The fictional websites were created using Figma and photographs from iStock.com. Together the story boards and websites explore the design ideas embedded in a near future scenario as presented by the occupational therapists.

4.4 Analysis

We analyzed the data using a triangulation approach with 4 phases that included my overall review of the data, followed by coding the interviews using a process of thematic analysis, abductive analysis of the creative writing activities and finally creating the story boards and fictional websites based on the themes identified in the previous phases. I read over all of the transcripts, creative writing activities, sticky notes and storyboards to

familiarize myself with the data. Next, I transcribed the audio recordings of the workshops using Trint. I first de-identified the data and then one interview transcript was coded by myself and another researcher (a postdoctoral fellow in Human computer interaction) to create consensus on coding. I coded the interview transcripts twice to increase my confidence that the coding was capturing the agreed upon concepts.

Following interview transcript coding, I analysed the creative writing exercises by following the steps outlined by Nagele et al.[56] their use of Brinkman's [12] abductive analysis. Brinkman [11:720] describes abductive analysis as "neither data-driven (induction) nor hypothesis-driven (deduction) but driven by astonishment, mystery, and breakdowns in one's understanding (abduction)". These steps included reading the narratives over seeing them as "instances". Noting "matters of concern" and anything that surprised us. An Excel sheet was created with each narrative and three columns were created with the following headings: Matters of Concern, Surprising Items and Themes. For each column I made a note regarding what the story raised for me. Following the review of all of the writing exercises, I named themes that resonated throughout the group of narratives and then each writing exercise was labelled with its corresponding theme.

1	Participant	Narrative	Matters of Concern	Surprises	Themes
	Participant 1	sensation issues: difficulty with dressing I am lying in bed at home while my family are out and about....It's 9am on a winter day, getting close to Christmas I am trying to muster up my energy, taking my meds, getting into a cold shower to get ready to go Christmas shopping as a hot shower flares up my MS symptoms (achy body, fatigue) My body needs time to get	Power shortages, health care shortages, people with disabilities left behind, dystopic	No major advances in treatment for MS	1) Variation in Treatment Advances. 2) Balancing Clim

Figure 20: Abductive Analysis Example

Finally, I created storyboards to explore the themes identified in analysis of the study data. First using pen and paper drawing to conceptualize the story world, followed by creating digital story boards using Storyboard That software [75], with the creative writing exercises and verbal descriptions of the occupational therapists woven through the scenes. Finally, I created fictional website landing pages to assist with world building and bringing the technology to life.

4.5 Results

In the following section I present the results of the co-design design fiction exercises completed with the occupational therapists, specifically the storyboards and world building activities. I also present the results of the thematic analysis of the interview transcripts and abductive analysis of the creative writing exercises. This is followed by the presentation of a design fiction Wonder Wear, through storyboards and a fictional website.

4.5.1 Abductive Analysis of Creative Writing Exercises

Creative writing exercises were completed by each participant following the suggested questions to guide the exercise. I then developed story boards guided by the story worlds created by the participants to present the proposed technologies and imagined futures. Themes that emerged from the creative writing exercises included 1) balancing climate/planetary emergencies with the technology needs of people with disabilities, 2) the prevalence of assistive robots, 3) variation in advances related to treatment.

Theme 1: Balancing Climate/Planetary Emergencies with the Technology Needs of People with Disabilities

This theme was present in 4 of the 6 creative writing exercises. Each of the 4 OTs presented scenarios where climate change and extreme weather has had an impact on how society is organized. They commented on how these changes impacted the availability of technology for people with disabilities. For example, one participant brought up the issue of energy conservation and its impact on society: *"Yet again, gearing up for the booster clinics, health care shortages of people and boosters, more and more people are becoming depressed with all the stressors and pressures to work. There is such a large demand on electricity that there are communities with rolling black outs to conserve energy."* (Participant 1). Another participant explored this concept, although presented a more optimistic view of how climate change might impact society. *"I'm happy that things are more sustainable these days - it makes me feel more connected with the world around me that plants and plastics can be harvested into fibers, so all these clothes don't end up in landfills and hurting our environment or the way we live. I know that I'm lucky to live in the Midwest where there aren't as many natural disasters of forest fires, tornadoes or hurricanes but hopefully nature can heal itself so we all can keep enjoying the national parks."* (Participant 3). Another participant discussed how the consumption of technology and focus of technology will change: *"As natural disasters and disease became more prevalent, somehow, we managed to come to some hybrid world where essential technology was allowed to thrive, but some unessential consumption began to be less tolerated."* (Participant 4). She goes on to clarify how these changes have impacted people with dressing challenges: *"I wish my wardrobe was self-*

intuitive, and I didn't have to spend time thinking about it, but dressing seems to be considered less essential to invest in these days." (Participant 4).

These comments reflect some of the concerns we face today, reflecting how we must consider how often the needs of people with disabilities are pushed aside in favour of other issues.

One participant had a more positive view of how society will treat the vulnerable in the future: *"The people were fed up with the monarchy and we now have sold off all of their assets and divided them amongst the people of Britain. We have made strides in lessening poverty, and people care for the less fortunate."* (Participant 2). In exploring these issues OTs bring to light the possibility of multiple possible ways forward encouraging us to reflect on whether or not technology will be available or prioritized as a solution to dressing challenges in the future.

Theme 2: Prevalence of Assistive Robots

Three of the 6 OTs discussed how prevalent robots will be in the future. They incorporated robots as a visible part of the regular everyday routine in the future. For example, one participant stated: *"We use robots for a lot of manual labour."* (Participant 2). Another discussed robots, who complete manual labour tasks. *"Like on the one hand, it's nice we have these robots that can sort out our garbage into compost, landfill and recycling once I put my trash into the single bin, that I can just sit in my car and it'll bring me to where I want to go, that robots can cook for me and robots that can put my shoes on for me but sometimes it feels like if these things are being done by robots, what can I do for myself?"* (Participant 3). Participant 3 also commented on her ambivalence towards the use of robots for everyday tasks and explored the potential benefits of robots

for people with disabilities: *"I feel torn in everyone having robots because I don't want to feel lazy but at the same time, if everyone has robots doing these things for them, then it makes me feel better that I'm not the only one who needs help getting dressed. I wonder how people with disabilities felt in the times before robots because it might have been more noticeable those who were able and those who were unable..."* (Participant 3).

An alternative view shared by one participant focused on how future world robots will become back up technology to newer more ubiquitous solutions. She explained that should her brain computer interface fail; she can rely on her robot: *"I also have even bought my dressing robot that hangs on my door and holds up any clothes for me so I can just stand in the right spot and it tells me to raise my arms or turn around or anything to help me get dressed every day."* (Participant 6).

Theme 3: Variation in Treatment Advances

In the creative writing activities, there were descriptions of how treatment has progressed for people with disabilities. There was variation in how the OTs presented treatment. In 3 cases, treatment had progressed and improved. For example, one participant stated: *"Now, they have made strides in the treatment of dementia, so that it never progresses past the mild stage, which is comforting."* (Participant 2). Another described advancement in arresting the aging process: *"It is year 2050 and I am 60 years old but look 25 thanks to substances found in outer space."* (Participant 5). Another participant discussed advancements in emerging technologies such as brain computer interfaces to treat sensation loss. *"Now, I wake up and I am able to not worry about that anymore. I wake up every day and once I put on my sensation implant, my senses are almost back to complete normal. It works similar to a cochlear implant. I had surgery about 2 years ago*

where they input sensors into my hands and feet to help restore my sensation. Over time, my brain plasticity has adapted to the implants and once I attach my outside implant on the back of my head when I wake up, everything is back to normal." (Participant 6).

The other 3 OTs were more pessimistic about treatment advances. For example, one person described that finding the right treatment regime for MS remains a struggle in the future: *"Looking at different medications to treat my MS and hoping that I will be able to cope with working through the pain."* (Participant 1). Another described how new diseases will challenge the development of new treatments: *" It was determined that I had been infected with a new strain of mosquito which had recently emerged in my region in North America, it was a hybrid species between a mosquito from somewhere in South America and one from North America as their territories began to overlap, the new mosquito was named NiZik and was known to cause various cognitive challenges. This continues to be a new disease and therefore not much is known about the trajectory, I seem to be in the 25% of people who continue to suffer cognitive effects of NiZik, the other 75% of people had no symptoms."* (Participant 4). One participant provided insight into some reasons why there might not be a desire for technology to advance the treatment of dressing challenges: *"I'm glad that there aren't yet robots that get someone dressed because I feel weird a robot watching me in a way."* (Participant 3)

4.5.2 Thematic Analysis of Interview Transcripts

In the co-design workshops, I also interviewed the OTs to deepen my understanding of their proposed future worlds and solutions to the dressing challenges identified in the creative writing exercises. A focus of the interviews was on how the interactions would support people with disabilities, however our discussions also touched on the possible

emotions of the user and how society may have changed to support people with disabilities overall. The OTs were viewing an empty storyboard where I added sticky notes to capture their answer to each question (Figure 20). They later added icons to assist with explaining their ideas.

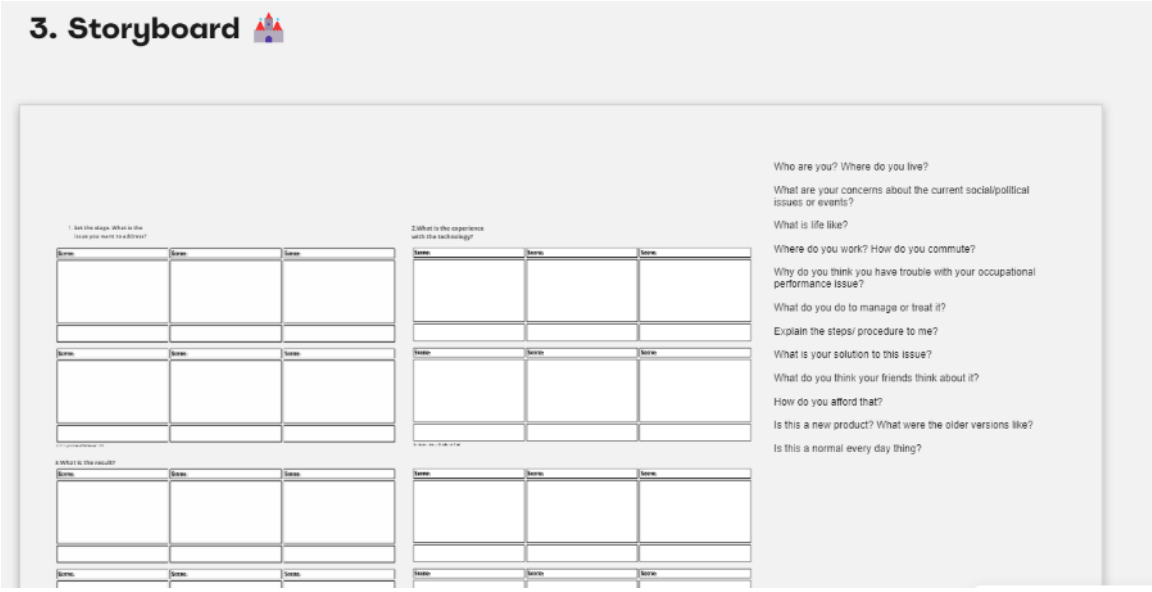

Figure 21: Storyboard as viewed by the OTs during the interview

The interviews were transcribed and coded using thematic analysis which I present below as continuation of the themes I have already outlined that emerged from the creative writing and storyboard exercises.

Theme 4: Interaction and Usability Requirements

When describing potential technologies that would assist with dressing challenges in the future, the OTs provided insight into how the technology could be designed to improve someone's experience with dressing and could compensate for challenges. The OTs described multi-modal and discreet interactions, that could protect the privacy and security of the user, while providing sequencing cues/task instructions to also preserve their autonomy.

Multi-Modal Interaction

Before I elaborate on the perspective of OTs, it's important so describe what multi-modal interaction means, namely, it refers to the interaction or mechanism of the clothing that uses a variety of methods to communicate with the user to assist them with dressing (e.g., sensation/vibration, auditory, visual and shape changes).

Four OTs described multi-modal interactions as a preferred method of design for dressing technologies of the future. For example, one participant described multiple ways in which the clothing would alert the user to any errors: *"it could be connected to her smartphone or a device that can give you alerts. So, let's say she missed something. There could be sensors in the clothing that can sense [that] you miss this layer. Did you need this layer? The alarm will not shut off until you put it on in the correct order."* (Participant 5). She went on to describe other methods of alerting the user to mistakes in how the clothing was put on. For example: *"So in case, she's not on her phone, she can get through. It could be sound; it could be a light. It could even be some sort of screen on some of her clothing, something that is universally working with devices in the home and within her clothes."* (Participant 5). Another participant also described multi-modal interactions to assist with initiating dressing tasks, describing that the user would give the garment a verbal cue or create scheduled tasks. "*I guess it might be a verbal cue or happening at a certain time in the day. So, I'm not sure it would happen spontaneously at like a certain time where she would normally get dressed think Monday to Friday. Like for a working person, if it was Monday to Friday at six or 7 a.m. or if in her day she wanted to set it up around what time she woke up, or if there could be like a verbal*

prompt where you're like, okay, I'd like to get dressed now. And it kind of happened. So, I hadn't really thought too much about that initiation sequence, but I thought either verbally or via some sort of schedule was kind of how I thought [sic] happening." (Participant 4). One person indicated that a preferred method of interaction would be through shape changing clothing mixed with alerts through temperature or noise. "*Maybe the shirt could kind of like pop up or like lift up so that she knew, oh, this part is lifted. Maybe I should do the sleeve first. Or let's say it would happen maybe after like 2 minutes if she was like kind sat on her bed and she's okay. What do I do? I'm just staring at the shirt. Then it would start popping up. But if she had just went to her closet and got the shirt out of, let's say she put on this sleeve part over her head instead of the head part, then it would kind of alert her. I don't want to make it tighter because the sleeve it's already tight, but. maybe kind of like heat up a little bit, like, oh, that's an error…. And I think too is like over time, the shirt would kind of learn from just Samantha putting it on what her actual routine is so that hopefully it would give her life less alarms and less triggers."* (Participant 3).

Participant 1 described multi-modal interactions that could be tailored to the specific context in which the clothing was used. *"I think, you know, because she's a teacher, you probably want different types of feedback at different times. So, you don't want to sensation feedback during a classroom session…. you want feedback at a time where she can actually focus. So, the feedback should be visual and sensational, but it should be also timed, you know, whether it's, at lunchtime or during breaks or times what she can control or at this point when I have downtime, I'll be able to look at it versus like during a peak period of time."* (Participant 1).

Discreet Interactions

Discreet interactions refer to interactions that are hidden or less noticeable to others to help maintain the privacy of the user. Three OTs described that the interaction style of dressing technology should be discreet and not obvious to others that it is assisting someone with dressing challenges. For example, one participant described an interaction where the technology could be activated or interacted with using traditional looking buttons. *"So, a lot of the technologies are embedded in buttons because that's a common tool and buttons allow easily electronics to be attached to clothing. So that is a way that it could be readily available. But a part of that garment, which is really important to her, because while she relies heavily on technologies, she doesn't want to look like a robot. She works with robots, but she is not a robot. So, I think those things are really important. But these buttons can also have screens like an Apple Watch because now they can make screens more efficiently and smaller."* (Participant 5). The purpose of these interactions was to integrate the technology *"seamlessly into her life and in terms of how she interacts with it."* (Participant 5). Another participant described reducing the reliance on traditional devices which might make a user's disability more obvious and instead creating an intuitive discreet interaction. *"And I think she also is looking to not necessarily rely on the obvious device being a tablet or some sort of application, but having it be a semblance of what her old life was, which is something just more automatically intuitive without the reminder that you're using this compensatory strategy to achieve dressing."* (Participant 4). One person shared several options for interaction styles that might discreetly integrate into jewellery, fingernails or make up to reduce the

stigma associated with assistive devices: "*on and off buttons for your earrings where you can pull it and change … it's part of your jewelry versus, you know, this long neck with this big button that you have to call when you're in distress. Yeah. You know, I always laugh because, you know, when we when we give those things, you're like, oh, you're a fall risk. Let's get you. A big dog collar that you got to walk around with it. Most people don't like that." (Participant 1). "The makeup, you know, maybe color sensitive or again, you see lots of people will even put like decals or kind of jewelry on their skin, you know, as ways of decoration. But could they be utilized as… just points of light on and off or, control volume or whatever that you wish to use it for. Less conspicuous. I do like the jewelry option, like things on the rings, things on the earrings, like a bracelet or something like that.*" (Participant 1) "*It would be nice to be able to control some of the actions, maybe through her nails. So, if you had decals or stickers on her nails, then she could add a touch of her nails. And she could do that. And then she had fancy decals for her nails.*" (Participant 1).

Need for Privacy and Security

Need for privacy and security refers to the OT expressing that the technology should have controls surrounding privacy and also ensure that the safety of the user is prioritized. Three OTs brought up concerns regarding whether the device would be safe or lead to breaches in privacy. One participant discussed having alerts to other carers to determine if a device is functioning properly to ensure safety of the user: "*what if it does fail? And I don't know that it's failing because that could potentially be a safety issue if I'm, like, cutting vegetables… I guess there would have to be some type of alarm on it or*

something. If it's short circuiting or maybe like my doctor gets a notification and if it's not going well or something, and then they call me and say you have to come in." (Participant 6). Another participant discussed how privacy might be impacted by devices that collect data about cognitive functioning: "*concerns about privacy. Yeah. I guess in her case, if it was mapping out things and cognitive deficits, you might want to have data as far as algorithm [sic] goes to figure out, you know, are there times that she's faster, slower at this? Is there a time where the cognitive fatigue, especially in her case from a virus, there could be times a day that she's more affected or times in her week or monthly period where she's more fatigued. So, it could be, you know, collecting some of that data, which means that absolutely there could be privacy breaches*" (Participant 4). One person echoed this concern and felt that there should be some safe guards to protect people from feeling that they are being surveilled by the technology: "*basically helping somebody get dressed was helping to maintain a level of scrutiny, some privacy, ethical side, I guess that people don't feel like they're being watched by like a robot or computer or just technology in general, that it wasn't always like listening to everything or like watching everything that they're doing."* (Participant 3). She went on to describe ways in which users could feel that their privacy was protected: "*As it's been important if it could have the feature that you could just turn all the technology off all completely. So, if anyone ever felt like that their privacy was being violated in any way, they could just, it would just be a regular no technology shirt, but you could still wear it."* (Participant 3). "*I think with the different features that it has, people might think, oh, like if Alexa can hear me say [sic] know everything, like, what is my clothes going to know about me?"* (Participant 3).

Sequencing Cues/ Task Instructions

Sequencing cues/task instructions refers to instances where 4 of the OTs described how the proposed technology provided cues to the user to assist with completing dressing tasks, as opposed to completing the task for them. One participant described a technology solution that would assist the user to get dressed in an errorless way: "*This problem that she has, she needs something that can provide, like an errorless way to get dressed. Which could be having confirmation through her clothing that she put them on in the correct way."* (Participant 5). She provided further description as to how the device might provide instructions to the user: "*And so it could be connected to her smartphone or a device that can give you alerts. So, let's say she missed something. There could be to be sensors in the clothing that can sense like you missed this layer. Did you need this layer? This alarm will not shut off until you put it on in the correct order."* (Participant 5). Another participant described a similar interaction where technology might be used to sequence clothing: "*they sequence ideas, you know, like, you know, to wear a t-shirt in a sweater with, you know, long pants or something. And so, she's tried a few of those, but…they haven't felt right for her*" (Participant 4). One person also described personal robots that assisted with sequencing clothing in the correct order: "*everyone has like their personal robot. And so, they could buy a robot that could, tell me if things match. Or tell me I'm putting something on in the wrong order…. And then she would tell me what goes next, and don't forget your stockings, wear sensible shoes*." (Participant 2). Another participant described ways in which a garment could assist with sequencing without the use of verbal instructions, by shape changing: "*Maybe the shirt could kind of like pop up*

or like lift up so that she knew, oh, like, this part is lifted. Maybe I should do the sleeve first." (Participant 3).

Maintaining Autonomy of the User

This refers to instances where 3 OTs discussed how the proposed technology would support the autonomy of the user to maintain their ability to make decisions and maintain their skills. One participant described an interaction in which the user can choose clothing with support to ensure that the clothing is appropriate: "*And I, you know, her having the choice to sort of say, okay, yes, I like this or no, yes or no kind of thing. And then the clothing that's left kind of, it each moves forward one at a time, allowing her to dress herself with that piece*." (Participant 4). Another participant also described how a user might be able to maintain autonomy in clothing selection with the support of a robot: "*And then she would, I guess, indicate to me and then I would say, I hate that shirt. Pick another one. And then yeah. And then I guess I would try them on, and then she would look at me with her robot eyes and say, you look so good, and then I would feel good*." (Participant 2). One person described how technology might assist a user to work on their dressing skills but still be able to maintain their autonomy: "*Work on their skills. Right. But then also, like they can help themselves, too*." (Participant 3).

Theme 5: Emotional Impact of Dressing Technology Anxiety Regarding Faulty Technology

Anxiety regarding faulty technology refers to instances where 3 OTs described their or their imagined character's anxiety regarding the potential downfalls or failures of the proposed technology to address dressing challenges. One participant expressed concerns

regarding dressing technology that might rely on algorithms to learn the user's needs and preferences: "*There's an algorithm, I suppose. I always think of concerns just in terms of, I always feel like there's things we can't predict, you know, things that we just really didn't see. So, I do think that any time you give things too much intelligence in the virtual world, they do find that there could be concerns. Like what if, what if it reinforces behavior we don't want, like we're seeing with sort of some of the downsides of the Facebook algorithm issues*." (Participant 4). Other concerns brought forward by Participant 4 included what might happen if the clothing could be hacked: "*if it was clothing that could somehow move on its own, I think I wondered to what degree you'd be able to maybe control somebody that was inside it or have it moved as a person, you know. So, if you couldn't hack it and get it to come to life, could it pick things up? Could it, you know, mobilize itself? Could it find a way to like, I don't know, lock doors, open doors? So, I guess in the worst-case scenario, could it be used as [a weapon] where I, you know, I always think of like that with automatic driving cars. I'm like, can you hack them? And then would it just take the next terrorist event to like hack all the cars and make everyone drive into each other like, you know, so. So, I don't know if there could be the potential for that, if it's potentially hackable*." (Participant 4). Participant 6 described a brain computer interface that could be placed on the outside of the brain in order to ensure safety: "*Just so it is experimental and, hopefully, it would get like progressed in the future so that you don't need the implant thing but may not mean like the outside thing, but maybe the outside thing can be a part of the safety procedures with it. So, like each day, like you check it, that it's good, and then that's like your, like physical check to make sure everything is still good*." (Participant 6). Participant 4 expressed multiple

concerns about the safety of dressing technology in the future: "*So I think, yeah, I guess there could also be potential for there to be malfunctions, too. I don't know if there's, I don't know, where there's electrical impulsive people ever go electric. You know, if there's any shock that can happen from devices malfunctioning or, yeah. Or if it could ever malfunction and potentially hurt the person while they're wearing it, you know, if it is designed to sort of be able to kind of come to life in some degree, could that backfire while the person's wearing it? ...Is there ever a way to bypass it if this is being, you know, maybe imposed on someone for some reason?...But I do wonder if there is a potential way to somehow hack it, or triggered, or you know, infiltrate it.*" (Participant 4).

4.5.3 World Building Exercise

As a synthesis of the results of the abductive and thematic analyses I present the following design fiction Wonder Wear which attempts to incorporate the OT identified design requirements for future dressing technology into a situated fictional near future world. This is achieved through the development of a fictional website and storyboard highlighting the social context in which this technology exists (Figures 21 and 22). The purpose of this design fiction was to creatively synthesize the findings but also develop a diegetic prototype that could be presented to people with disabilities for their feedback. By creating a 'story world' with an artefact (fictional website) informed by the creative writing exercises and interviews with OTs, it opens up possible discussions regarding disabled peoples' perceptions of instructional dressing technology situated in the future.

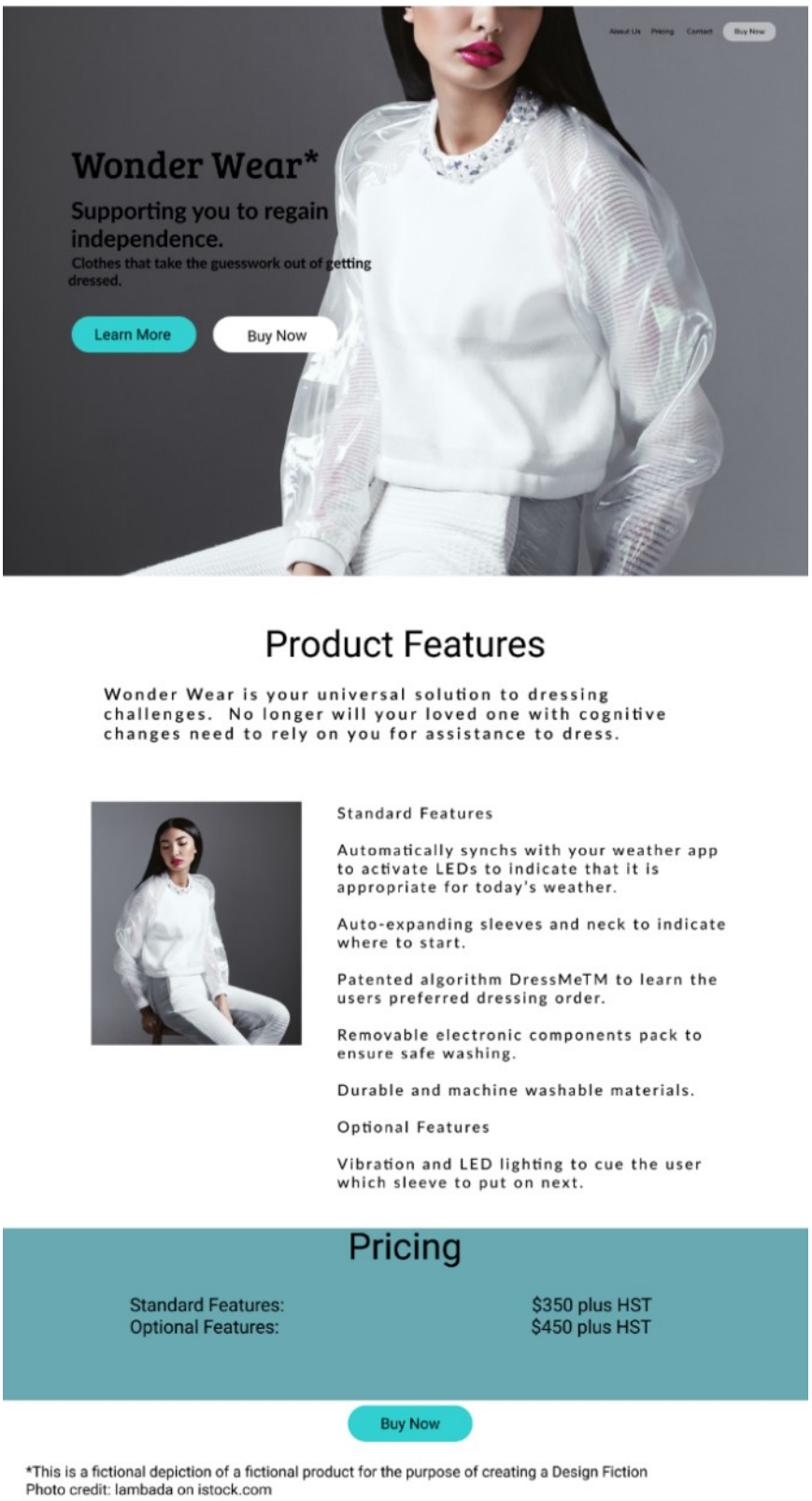

Figure 22: Fictional website for Wonder Wear

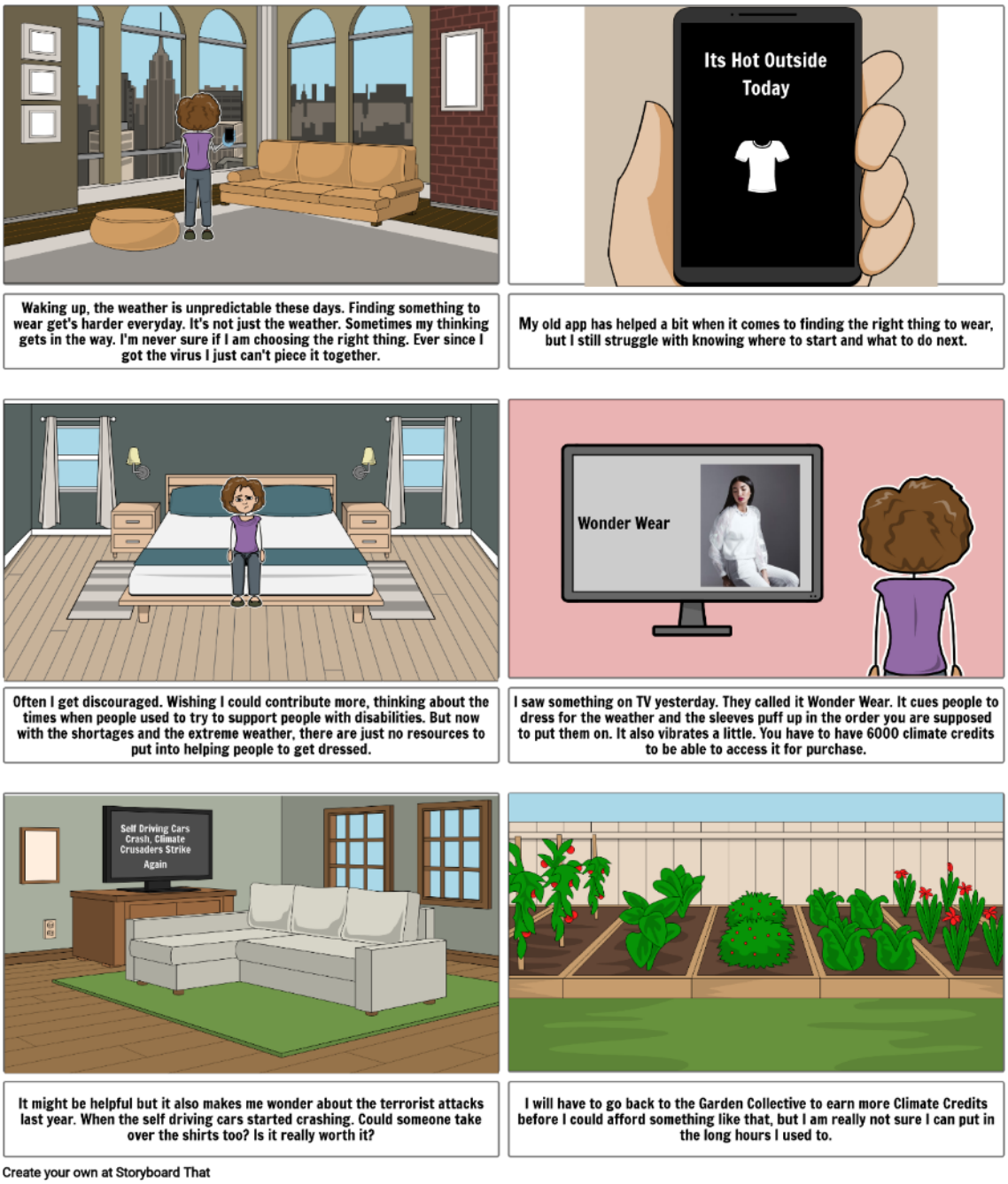

Figure 23: Design fiction storyboard

4.6 Summary of Study 2

Creating design fictions through the practice of co-design with OTs allowed us to explore the potential design of future technologies to support dressing challenges. Design fiction offers a creative and an informative method for exploring how in the near future new technology might impact users with disabilities through both the action of the technology itself, but also the organization of society surrounding that technology. Expanding on the methods of design fiction co-design proposed by Nagele et al [56], we were able to engage 6 OTs in creating 'story worlds' of the near future where people with disabilities could find support for dressing challenges using not yet existent technology. The OTs worked with researchers on our team to develop story boards positioning their proposed technologies in a future societal backdrop. Occupational therapists and researchers explored the potential benefits and drawbacks of future technology and the possible social and economic constraints surrounding its use. By working with experts in disability it allowed us to examine the potential for new technology to avoid the trap of solutionism [7], minimizing ways in which technology may be designed for perceived problems without consideration for how they would be used in daily life or consulting those that would use the solution. Occupational therapists proposed technology that preserves the autonomy, dignity, and safety of the user through multi-modal interaction, which could reduce the impact of ableism in the design and development of assistive technologies.

Chapter 5: Discussion

In this study we asked the following research questions: *1) What do occupational therapists envision the future of e-textiles and technology could be to support people with disabilities with dressing challenges?* and *2) In what ways might e-textiles and technology assist disabled people to become more independent with dressing?* The OTs in the first study answered these questions by first identifying challenges and then developing visions of e-textile solutions. Occupational therapists identified several challenges identified by people with disabilities related to dressing challenges. They not only identified person challenges, but also challenges within the design of clothing itself and within the environment (both social and built). They were then able to imagine a future where these challenges were overcome. The OTs in the second study contributed to further imagining the future of dressing technology by creating more comprehensive story worlds in which future dressing solutions might exist. They then contributed to discussions on design requirements for future technologies to support dressing challenges. Further, the OTs explored the potential downfalls and difficulties that could be associated with technology for dressing challenges. Finally, as a cumulative result of these discussions, storyboarding and creative writing exercises we developed a design fiction called *Wonder Wear* which explores the issues and design requirements brought to light by the OTs through a comic book style vignette and fictional website.

It is possible to imagine a future where disabled people have increased control over their environment, ability to manage their health and increased independence in dressing themselves with the use of existing or yet to be invented technology. The solutions identified offer a roadmap to how wearable technology could be designed in the

future to support people with disabilities. The technology that the OTs sought to identify as future solutions echoed currently existing prototypes and not so distant future technologies: self-mechanized clothing such as self-tying laces exist on the market today [58] and we find research prototypes for self - regulating clothing [21]. However, a new concept OTs identified focused on instructional clothing, the idea that clothing can teach independence to its wearer.

5.1 Instructional Clothes as a Means to Independence

Overall, most technology identified by the OTs as promising, did not fully take over the independence of the individual and 'do for' them. Instead, the technology proposed by the OTs offered guidance and even step-by-step instruction to support independence. This is in line with the tradition of rehabilitation in which individuals are taught to regain function or adapt to disability incrementally while maximizing the independence of the individual. The benefits of collaborating with OTs are because of their unique experience with rehabilitation. HCI researchers can benefit from incorporating this perspective into their design approach. Through the lens of OTs, wearable technology of the future should not take over the individuals' ability to manage their own body, and instead should augment the abilities that a person has to empower greater independence.

This is echoed in the thoughts of researchers like Foley and Ferri [24] who consider that assistive technology should avoid the trap of offering a new body or miracle solution to disability, but instead, should enable and offer new ways of increasing participation/independence while honouring the abilities a person has instead of "creat[ing] 'new dimensions of disability'[25] as cited by [24]. Foley and Ferri [24:196] argue that "social inclusion must be a key consideration when technology is developed."

This is in line with the OTs concepts in this thesis who seek to include people with disabilities in the occupation of dressing themselves as opposed to having a carer or technology dress them. It does not exclude people from learning how to dress, or as in one case, participate in sports, but instead encourages new ways of participating that maximizes a person's current level of ability.

This has far-reaching implications for people, not only for the disabled, but also those without disabilities. For example, shoes that can teach the wearer how to tie them has benefits for children with developmental coordination disorders, but also for children in general who are learning to tie their shoes. This extends the idea that technology for people with disabilities should not be 'othering' or further disabling. In fact, when designed properly, it should contribute to honoring those abilities that a person has. Clothing that can provide a blind or partially sighted wearer with instructions on how to don them could also offer small children instructions on how to put on a coat or t-shirt for the first time. This could make that technology accessible to a wide audience while attending to the needs of an individual.

The OTs in both studies offered suggestions for exploration that interaction and e-textile designers might investigate:

Design Requirement	**Description**
Multi-modal	Using multi -modal methods of cueing by including interactions such as vibration, sound, light or shape changing to provide the wearer with salient cues as to what part of the clothing to don next.
Inclusive Instructions	Ensuring that the instructions provided by the clothing are inclusive and

	empowering, allowing the user the most agency possible in donning clothing and ensuring that the language used is appropriate to the user
Discreet	Providing clothing technology solutions that are discreet. By ensuring that the adaptive clothing looks like commonly worn items users have the option to keep their needs for support private.
Easy to Care For	Ensuring the clothes be easy to care for, washable, durable and potentially available for trial to ensure that they adequately meet the needs of the user.
Safety and Security	Future dressing technology should take into account the safety and security of the user. For example, there should be adequate attention paid to the potential for breaches in privacy as well as the potential to do physical harm to the user.
Preserve Autonomy	Technology should preserve the autonomy of the user as much as possible. For example, by providing ways in which the technology supports the user but does not take over the agency or independence that the user may possess.
Funding	Support for the purchase of assistive technology should be imbedded in future society, such as funding programs or governmental support to provide the required technology.
Customizable	There is no one solution for dressing challenges, a variety of technologies should be designed and customized to support the individual needs of the user.

Table 1: Table of Design Requirements Suggested by OTs for Dressing Technology

What these requirements emphasize is creating space for technologies that increases independence not by 'doing for' but by 'helping do' which re-enforce the human need for self-determination. We are allowed the opportunity to learn and grow with the support of technology, not be passive objects to which the technology acts upon the user.

5.2 Co-Designing with Occupational Therapists

One of the contributions of this study is the act of co-designing with occupational therapists. Although occupational therapists have been involved in HCI research in the past, limited studies have explored co-designing with occupational therapists. Occupational therapists are primarily health care workers, although one could argue that they are designers in their own right with their use of DIY practices to create assistive technology and supports for their clients. In creating a co-design space for occupational therapists to explore the future of adaptive technologies for people with disabilities to improve their access to dressing, we were able to venture into new territory for occupational therapists as designers. The occupational therapists who participated in this study were open minded and creative in creating their story worlds. Each OT expressed excitement and delight at the exercise of imagining a future world. They presented thoughtful and provocative descriptions of a future that leveraged new technologies to support the independence of disabled people. Although each one described a different imagined technology, they all described something that would assist the user with sequencing the task of dressing. None of the occupational therapists described technology that would actually complete the dressing task for the disabled person.

A challenge in co-designing with occupational therapists in this study was that most OTs did not feel comfortable drawing a story board on their own. The OTs were

able to select icons to provide a direction for the researchers to select imagery to support the storyboard but did not choose to add further illustrations. Perhaps had the workshops taken place in person or had drawing exercises been completed in the warmup activities it would have further encouraged the OTs to draw their storyboards. Occupational therapy students in British Columbia compete with student engineers in designing new assistive devices as part of their curriculum, perhaps as opposed to competition, collaborative projects with OTs and HCI researchers or other designers where there is shared learning and skills training could improve OTs comfort with design while allowing designers to gain insight into rehabilitation focused approaches.

5.3 Remote Co-Design with Occupational Therapists

We developed a process to co-design remotely with OTs in this study, contributing further understanding of how a collaboration between OTs and HCI researchers may provide useful insights into the design of e-textiles in the future. While co-design with OTs has been undertaken in the past, as in the case of Aflatoony et al. [1] remote collaborations have to our knowledge not been widely explored. Through the remote nature of this study, we were able to introduce both American and Canadian OTs to a unique method for co-design. Harrington and Dillahunt [31] used remote co-design in their study of future technologies with black youth, where they conducted their design activities over Zoom, but mailed out workbooks to the participants in advance. Similarly, Sanoubari et al. [66] investigated the use of social robots to prevent bullying using remote co-design with children. They sent asynchronous activities to the children and had Zoom interviews with their parents. Remote co-design is a new area in HCI and I was

only able to find three examples of its use in the literature, this thesis documents another way for remote co-design to be employed in HCI research.

Due to the remote nature of the workshops, we were able to leverage technology that assisted the researchers to capture and share the ideas of occupational therapists both visually and verbally using multiple formats (i.e., sticky notes, story boards and verbal descriptions). This created an atmosphere of mutual understanding where the OTs were able to clarify their ideas through different mediums with the support of the HCI researchers. The result was a rich data set in an easy to organize format for data analysis.

With respect to the response to the co-design methods, the OTs all reported that they enjoyed the workshops and had fun collaborating with the researchers, indicating that they were open to future collaborations. This demonstrates that creative collaboration can take place remotely with OTs, providing an opportunity to gather insights across long distances, with busy professionals in demanding areas of research like healthcare.

5.4 Reflections on Current Dressing Technology, Occupational Therapists and Design Futures

The occupational therapists in this study proposed design solutions for dressing challenges that reflect current designs. Bleecker [5:16] states that "design fiction, borrowing from science fiction, is the embodiment of materialized reflections on design today, as well as projections and anticipations of the designed futures.". Interestingly, many OTs were unaware of the available technology today that support the realization of their future visions for dressing technology. This was not surprising given the difficulties with knowledge dissemination from experimental research prototypes to the public and the lack of time for OTs in a demanding profession to scour the literature for new

inventions. For example, in the case of the robotic dressing aid proposed by Participant 2, an early version of technology for this proposed design has existed since at least 2016 when Chance et al. [13] proposed a robotic system to assist with dressing tasks. This system included Baxter Robot to assist a mannequin with dressing it's shoulder. It employed a camera system, force sensors as well as simple voice interactions to assist with dressing errors and dressing preferences. Where the participant in our study furthered our understanding of perhaps more complex considerations related to these types of design ideas, was in her proposal that the dressing robot should carry out the sequencing steps on behalf of the wearer. In the case of Baxter Robot [13], the wearer must use voice commands such as 'up', 'left', 'down', etc. to help guide the robot requiring the wearer to be able to direct the correct sequencing and positioning of the robot. For people who have difficulty with sequencing tasks, as in the case of dementia, this type of interaction would not be helpful. The participant also brought to light the limitations and potential concerns associated with dressing robots, in particular the potential to harm the user and the user's anxiety and potential fear in interacting with a robot. In the case of someone with dementia, these can be critical issues to address to ensure the adoption and usability of the robot. With respect to including occupational therapists and their knowledge of current technology in developing technologies, Bleecker said it best, "to gain cultural legibility takes more than a scientist demonstrating an idea in a laboratory" [5:41]. Knowledge translation from scientists to people who might actually use their designs in the case of dressing technology has not yet happened. According to Bleecker, "What is needed is a broader, context — such as one that great storytellers and great filmmakers can put together into a popular film, with an engaging

narrative and some cool gear." [5:41]. This is perhaps where our preliminary design fictions, and future design fictions in this area, can bridge the gap between the user, specialists like OTs that work daily with users, and the scientists developing these near future technologies. Such an approach can create discourse about their use and related considerations while they are still in development. Design fictions lay the groundwork for the necessary social conditions to make technologies relevant [5]. In the case of this study, the occupational therapists described not only the individual use case for each technology, but also the cultural and societal conditions where the technology might make sense.

5.5 On Possible, Plausible, Probably and Preferable Futures

Voros [88] wrote about the concepts of possible, plausible and probably futures when considering ways to imagine future technologies or ways of being. Possible futures are defined as "all the kinds of futures we can possibly imagine – those which "might happen" – no matter how far-fetched, unlikely or "way out"" [88]. Plausible futures refers to "those futures which "could happen" (i.e., they are not excluded) according to our current knowledge (as opposed to future knowledge) of how things work" [88]. Probably futures refers to "those which are considered "likely to happen", and stem in part from the continuance of current trends." [88]. Occupational therapists imagined *probably futures* in the case of self-regulating and postural alignment clothing. Although some visions for the future included technology that does not yet exist, many of the smart clothing solutions identified were possible and practical. For example, one OT indicated that they would like a shirt that could aid the user to manage self-regulation using compression. This technology exists today in examples like CalmWear and the "hugging"

vest which provide compression in response to anxiety and nervous system reactions [21], [27]. Another OT indicated that it would be useful to have clothing that could indicate to the wearer that they were out of postural alignment. This technology also exists today in examples like Mattman et al's [53] textile sensors which recognize upper body postures and Tormene et al,'s [86] clothing that estimate trunk movements using wearable strain sensors. As the OTs were unaware of this existing technology, this perhaps speaks to a need in the HCI community to communicate research findings to those who might use them and for the field of OT to span beyond core clinical training, to research and training in novel technologies to solve dressing challenges. Perhaps this could be incorporated into training programs such as the Assistive Technology Certificate offered to OTs through Tufts University in the United States.

Occupational therapists also imagined ideas situated in *plausible futures* in the case of instructional clothing. When the OTs identified ways that the instructional clothing could function, using light or vibration to indicate how clothing could be instructing its wearer, they were alluding to technology that could exist in the near future. An example of technology that might be leveraged to light up clothing exists in the work of Hanton et al. [30] where the technology they proposed could be used to create interactive displays on irregular shapes, which could be used for instructional purposes. Hanton et al. [30] currently use ProtoSpray to create interactive displays by the use of "3D printed conductive channels to create base electrodes on 3D shapes. This is then combined with spraying active materials to produce illuminations." [30]. In the future, something like this could be transferred to clothing/wearable shapes which could then illuminate portions of the clothing to create sequencing cues on the garment itself.

With regards to *possible futures*, OTs spoke of compression stockings that would use water to help shrink the fabric onto the body or help take off the stocking. This type of innovation is far from being currently possible as the technology required is not yet invented. However, a step in that direction exists as in the case of Narayana et al. who are using stimuli responsive stress-memory filaments to design compression stockings that can change shape in response to pressure changes [57]. The OTs' vision for compression stockings does also present an interesting discussion around how technology could be leveraged to aid fabrics to change shape and perhaps aid the wearer to don and doff them. Another example of a similar type of interaction exists in the aforementioned invention of Enfold [49], which uses shape memory alloy and an origami like configuration to assist users with cerebral palsy to dress without outside help.

Preferable futures that allow people with disabilities to increase their independence in dressing using technology was a theme across all the solutions suggested by OTs. Should we have the desire as a society to pursue some of the futures described by the OTs, it may be possible to achieve the preferred future of enabling people with disabilities to leverage technology in a way that best suits their needs and preference for engaging with clothing.

5.6 Ableism and Technology Design

A risk in developing new technologies is that they may be developed from the designers' point of view without taking into account the actual needs of disabled people. Designers and researchers often stumble upon "solutionist" [7] technology. Solutionism is effectively the invention of a problem that does not exist, followed by mis-representing an urgent need to solve the problem and finally promoting technology as the solution to

the problem [17]. Solutionism is demonstrated in the case of an assistive cane [70] developed by Stanford researchers to assist blind and partially sighted individuals. This solution was designed by sighted researchers who perceived that LIDAR and camera and GPS would assist the user to navigate the environment. Although they clearly had the best intentions, their design was criticized by members of the blind and partially sighted community as the design failed to take into account the ways that blind people actually navigate the environment [83]. In fact, the technology had the opposite of the intended effect and created barriers for people who are blind and partially sighted given that the blind use echolocation from standard white canes tapping to help them navigate, whereas the proposed cane's wheels pose a problem in using echolocation. Additionally, the weight of the proposed cane could add stress to the joints [3]. Although a more robust study would address the direct feedback of people with disabilities, our study seeks to gain the perspective of professionals who work closely with the disabled on a regular basis. Occupational therapists are required by their professional colleges to be sensitive to the cultural, spiritual, emotional, cognitive and physical needs of people with disabilities. This positions them in an interesting place to fight ableism in technology design. Their visions of the future can be seen as practical in solving problems that actual currently exist in the disability community that they are aware of through their daily clinical practices. The OTs discussed numerous ways to preserve the autonomy of the user to ensure that their agency was preserved in dressing tasks. In one example, a participant proposed an override system to be integrated into a design that would assist the wearer to select their clothing. This system would allow the user to make different choices then the technology solution proposed. Another OT proposed that the clothing would wait a

certain amount of time before intervening to allow the disabled person an opportunity to complete as much of the dressing task as they were able to, to promote their own skill preservation and acquisition.

5.7 Reflections on the Use of Methodology

Future visioning, co-design and design fiction are interesting methods for exploring the potential of new technologies. In choosing to use these methods for exploring the future of dressing for people with disabilities, we open up a discussion regarding whether these methods are effectively able to contribute a new understanding of what is needed for dressing technology. Baumer et al [2], when discussing how to evaluate the contributions of design fiction, asked the following two questions: "What assumptions about the speculative technology does this fiction reveal?" and "Does the fiction thoroughly explore the consequences of this speculative design?" [2]. The design fiction used in this study revealed the following assumptions regarding the speculative technology imagined by the OTs: technology of the future may continue to be out of reach without intervention from the government or social programs; and robots will become everyday technology that exists within the homes of individuals.

The design fiction, WonderWear, explored some possible consequences of the speculative design, for example that the cost of these designs may continue to be out of reach for their intended audience. Additionally, some potential consequences are the environmental impact that new technologies have if not designed appropriately to take into account the looming climate emergency. Technology, if not designed discreetly, may not be the solution to dressing challenges and may in fact create isolation for people with disabilities. Finally, through this design fiction, I explored the potential for new

technology to create harm for the users either through privacy breaches, faulty technology design or unintended consequences of the design.

5.8 Reflections on the Role of the Researcher

In writing this thesis I came to recognize something that Brinkman states: “knowledge isn't unitary or even necessarily methodical, but local, situated, embodied, relative, intersubjective, relational, discursive, gendered and many other things” [11:33]. As such, I will reflect on my experience as a researcher and situate the knowledge gained in this study in my own lived experience. As a female HCI researcher I come to this project with a certain lens on technology and reflect on my stance that technology has potential to improve the lives of users in many ways, but that it also has the potential to do harm, and as researchers and designers we have an obligation to consider whether what we are creating is developed in a thoughtful manner that minimizes potential harms. This stance impacts my interpretation of the stories presented. Additionally, as stated earlier I come with the experience of working as an occupational therapist for the last 15 years in pediatrics, community OT, dementia care and brain injury. When interacting with the other OTs, I used my shared understanding of these practice areas to inform my understanding of their proposed solutions. This profession subscribes to a shared set of values and ethics that govern our treatment of people with disabilities and orients OTs toward increasing independence and meaningful participation and inclusion in society. This possibly biased me towards envisioning certain types of solutions because of my knowledge of how OTs work with people with disabilities. This interestingly led to discussions between myself, and the other researchers involved in the project that explored how my interpretation of the data differed from theirs.

In addition to being an OT, I am an HCI researcher. This positionality offered an interesting perspective on how the two fields can work together to develop future visions for new technology. While OT and HCI research have many things in common, such as the interest in how humans interact with their environment (namely technology in the case of HCI), there are many ways in which the two fields differ. This presents a challenge in the two fields collaborating on research, but also opportunities.

The challenges we encountered included developing a common language to understand the problem space. Often throughout the process, I acted as a go between for the OTs and the other HCI researchers by explaining topics of discussion in more common language. For example, often the OTs spoke in acronyms or short hands such as "AFO" (ankle foot orthoses) to describe a type of issue or technology they wished to communicate. I then explained the meaning of these shorthand terms to the HCI researchers. On the other hand, I also provided descriptions of e-textile technology to assist the OTs to understand this niche field in HCI. By ultimately developing a common understanding of topics, this allowed the OTs and researchers to collaborate in a rich and meaningful way. Some of the opportunities that arose included the OTs envisioning practical real-life applications for novel technologies that although currently exist, they do not presently have application beyond the research domain. If these two fields are able to communicate easily and work more closely together, they offer each other a significant relationship on which to develop novel and practical technologies. The design fiction created in this thesis can be seen as a jumping off point to further the discussions between these two fields.

5.9 Limitations

Some limitations of this study are that the design fictions have not yet been presented to disabled people for their opinions and insights into the usefulness and drawbacks of the proposed technology. We conducted this study with the expertise of occupational therapists who work with people with dressing challenges, a more robust study would have also included the perspectives of people with dressing challenges themselves to ensure their voices were heard in the solutions and challenges explored. The original study design included people with disabilities, however despite making efforts to recruit participants with dressing challenges, through disability associations and social media, only one person agreed to participate in the study. Additionally, the limited sample size of occupational therapists did not provide a robust data set from which to draw conclusions or recommendations. The specialized profession of occupational therapy is small and those that directly work with dressing challenges is even smaller, therefore recruitment was slow and limited.

Additionally, due to the COVID-19 pandemic all workshops were conducted remotely which perhaps did not allow for a fulsome exploration of the story boarding activities. The opportunity to sketch or draw in person may have further added to the data set. Recruitment and scheduling difficulties also lead to most workshops to be individual, instead of the intended group workshops.

5.10 Contribution and Future Work

This thesis contributes to the literature in the following ways:

1) Firstly, it contributes to the e-textile and dressing technology literature a path forward for the future of how e-textiles or technology may be used to support

people with disabilities. In particular, the results of this thesis suggest that a new and desirable path for e-textiles to support people with disabilities would consist of technology that provides instruction and cueing on how to dress in an item of clothing without dressing for them. Although there were several directions for the future proposed, instructional clothing is a new concept in the field of e-textiles. This thesis outlines the OTs perspectives on the design requirements for instructional clothing.

2) Secondly, this thesis contributes a method of remote co-designing with occupational therapists that has not been explored in the HCI literature. Our study showcases a way to use remote co-design with a mix of interviews, challenge identification, brainstorming, creative ideation and storyboarding to elicit the experiences and expertise of occupational therapists. To our knowledge, these methods have not been used within a single remote co-design workshop.
3) With this thesis I offer two contributions to the field of design fiction and HCI. The first contribution is the use of participatory design fiction with occupational therapists on the topic of adaptive clothing. To our knowledge, design fiction has not yet been used to explore the visions of occupational therapists for the future of adaptive clothing.
4) The contribution of the stories themselves facilitate cross disciplinary communication using design fiction. Design fiction has not been used as a means to communicate between occupational therapists and the HCI community t
5) Finally, as an OT and HCI researcher, I offer a new lens on HCI research. There are limited OTs completing HCI research and limited HCI research that

incorporates OTs as participants and co-designers. My background in OT lends a new perspective on how technology can be used to support rehabilitation while viewing the practical applications of that technology to the field of HCI.

Future Work

Following the results of this thesis, I plan to present the design fiction Wonder Wear to people with disabilities and their caregivers to elicit their feedback regarding any benefits and drawbacks to the proposed technology, as well as their perceptions of the social and economic factors that may impact their day-to-day use of an instructional garment. A next step, following this feedback would be an interdisciplinary collaboration to develop a prototype inspired by the Wonder Wear.

Chapter 6: Conclusion

This thesis explores the potential for smart clothing, e-textiles and technology to assist disabled people to address dressing challenges. Currently, people with disabilities in motor control, cognitive functioning and difficulties with sensory integration experience challenges with dressing. Dressing challenges can be created by the design of clothing, the abilities of the person and the environment in which dressing takes place. Occupational therapists are professionals who work with disabled people to develop strategies and implement low-tech solutions to address dressing challenges. Occupational therapist face challenges in implementing dressing strategies and technology due to limitations of time, staffing, the environment, client priorities and abilities and ineffectiveness of low-tech solutions. E-textiles and dressing technologies have been used in other areas of rehabilitation and offer potential for use in dressing challenges.

I engaged OTs with experience in addressing dressing challenges to explore possible solutions and future possibilities for e-textiles and technology to support increased independence in dressing tasks. Future visioning and design fiction offer methods for exploring potential solutions and to allow for a thorough discussion of the ethical, social and personal impact of dressing technologies. I undertook two studies to investigate OTs' visions for future dressing technology to support people with disabilities. I gathered a variety of data using co-design and design fiction online workshops, which included interview data, virtual sticky notes and storyboards. In the first study I coded the data using Saldana's concept coding and thematic analysis. Occupational therapists identified dressing challenges that included personal, environmental and clothing challenges. They also identified future solutions/visions that

included self-mechanized clothing, regulating clothing and corresponding clothing. A unique contribution of the OTs in this study was their proposed solutions that provided instruction to the wearer for dressing tasks. In the second study I used Brickman's abductive analysis and thematic analysis to explore the data. As a result of the analysis, I created a design fiction, Wonder Wear using storyboarding and a fictional website to synthesize the main themes I heard in the co-design sessions and to explore the future of dressing technology. Occupational therapists identified requirements for the design of technology situated in the near future that would support the autonomy of disabled people. They identified that technology that offered sequencing/task instructions could offer people with disabilities support for dressing challenges. According to the OTs, dressing technologies of the future should be multi-modal, preserve the dignity of the individual, be discreet, washable and durable, encourage autonomy, maintain safety and security, be customizable and be funded by governments or social groups. This thesis contributes a path forward for e-textiles and dressing technologies and a method of remote co-design with OTs. Additionally, this thesis contributes to the design fiction literature with an exploration of dressing technologies with OTs and the potential for cross communication among OTs and HCI researchers using the 'story worlds' created.

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Appendices

Appendix A Ethical Clearance

A.1 CUREB-B Ethics Clearance

Office of Research Ethics
4500 ARISE Building | 1125 Colonel By Drive Ottawa, Ontario K1S 5B6
613-520-2600 Ext: 4085
ethics@carleton.ca

CERTIFICATION OF INSTITUTIONAL ETHICS CLEARANCE

The Carleton University Research Ethics Board-B (CUREB-B) at Carleton University has renewed ethics clearance for the research project detailed below. CUREB-B is constituted and operates in compliance with the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (TCPS2).

Title: Smart Textile Visions

Protocol #: 115731

Principal Investigator: Lee Jones

Department and Institution: Faculty of Engineering and Design\Information Technology (School of),

Project Team (and Roles): Lee Jones (Primary Investigator)

Karen Cochrane (Co-Investigator) Sarah Moore

(Student Researcher)
Dr. Audrey Girouard (Research Supervisor)

Funding Source (If applicable):

Awards File No	Title	Status	
103495	Developing Deformable User Interfaces to Improve Manual Dexterity	Active	A. OVPRI Approval Form
105849	Design and Evaluation of Screen-less Deformable User Interfaces	Active	A. OVPRI Approval Form

Effective: **July 12, 2022** Expires: **July 31, 2023**.

Please ensure the study clearance number is prominently placed in all recruitment and consent materials: CUREB-B Clearance # 115731.

Restrictions:

This certification is subject to the following conditions:

1. Clearance is granted only for the research and purposes described in the application.
2. Any modification to the approved research must be submitted to CUREB-B via a Change to Protocol Form. All changes must be cleared prior to the continuance of the research.
3. An Annual Status Report for the renewal or closure of ethics clearance must be submitted and cleared by the renewal date listed above. Failure to submit the Annual Status Report will result in the closure of the file. If funding is associated, funds will be frozen.
4. During the course of the study, if you encounter an adverse event, material incidental finding, protocol deviation or other unanticipated problem, you must complete and submit a Report of Adverse Events and Unanticipated Problems Form.
5. It is the responsibility of the student to notify their supervisor of any adverse events, changes to their application, or requests to renew/close the protocol.
6. Failure to conduct the research in accordance with the principles of the

Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans 2nd edition and the *Carleton University Policies and Procedures for the Ethical Conduct of Research* may result in the suspension or termination of the research project.

Upon reasonable request, it is the policy of CUREB, for cleared protocols, to release the name of the PI, the title of the project, and the date of clearance and any renewal(s).

Please email the Research Compliance Coordinators at ethics@carleton.ca if you have any questions.

CLEARED BY: Date: July 12, 2022

Natasha Artemeva, PhD, Chair, CUREB-B

A.2 CUREB-B Ethics Change of Protocol Clearance

Carleton University

Office of Research Ethics
4500 ARISE Building | 1125 Colonel
By Drive Ottawa, Ontario K1S 5B6
613-520-2600 Ext: 4085
ethics@carleton.ca

CERTIFICATION OF INSTITUTIONAL ETHICS CLEARANCE

The Carleton University Research Ethics Board-B (CUREB-B) has granted ethics clearance for
the changes to protocol to research project described below and research may now proceed. CUREB-B is constituted and operates in compliance with the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (TCPS2).

Ethics Clearance ID: Project # 115731

Principal Investigator: Lee Jones

Co-Investigator(s) (If applicable): **Lee Jones (Primary Investigator)**

Karen Cochrane (Co-Investigator) Sarah Moore (Student Researcher)
Dr. Audrey Girouard (Research Supervisor) **Project Title**:

Smart Textile Visions Funding

Source:

Awards File No	**Title**	**Status**	
103495	Developing Deformable User Interfaces to Improve Manual Dexterity	Active	A. OVPRI Approval Form
105849	Design and Evaluation of Screen-less Deformable User Interfaces	Active	A. OVPRI Approval Form

Effective: **March 21, 2022** Expires:

June 30, 2022. **This certification is subject to the following**

conditions:

1. Clearance is granted only for the research and purposes described in the application.
2. Any modification to the approved research must be submitted to CUREB-B via a Change to Protocol Form. All changes must be cleared prior to the continuance of the research.
3. An Annual Status Report for the renewal or closure of ethics clearance must be submitted and cleared by the renewal date listed above. Failure to submit the Annual Status Report will result in the closure of the file. If funding is associated, funds will be frozen.
4. During the course of the study, if you encounter an adverse event, material incidental finding, protocol deviation or other unanticipated problem, you must complete and submit a Report of Adverse Events and Unanticipated Problems Form.
5. It is the responsibility of the student to notify their supervisor of any adverse events, changes to their application, or requests to renew/close the protocol.
6. Failure to conduct the research in accordance with the principles of the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans 2nd edition* and the *Carleton University Policies and Procedures for the*

Ethical Conduct of Research may result in the suspension or termination of the research project.

Special requirements for COVID-19:

If this study involves in-person research interactions with human participants, whether on- or off- campus, the following rules apply:

1. Upon receiving clearance from CUREB, please seek the approval of the relevant Dean for your research. Provide a copy of your CUREB clearance to the Dean for their records. See Principles and Procedures for On-campus Research at Carleton University and note that this document applies both to on- and off-campus research that involves human participants. Please contact your Dean's Office for more information about obtaining their approval.
2. Provide a copy of the Dean's approval to the Office of Research Ethics prior to starting any in- person research activities.
3. If the Dean's approval requires any significant change(s) to any element of the study, you must notify the Office of Research Ethics of such change(s).

Upon reasonable request, it is the policy of CUREB, for cleared protocols, to release the name of the PI, the title of the project, and the date of clearance and any renewal(s).

Please email the Research Compliance Coordinators at ethics@carleton.ca if you have any questions.

CLEARED BY: Date: March 21, 2022

Bernadette Campbell, PhD, Chair, CUREB-B

Kathryne Dupre, PhD, Co-Chair, CUREB-B

Appendix B Code Books

A.3 Smart Textile Visions Code Book

Term/ Code	Definition
Challenges Identified	Responses to the question: what dressing challenges do you face in your practice/ life?
Clothing Challenges	Challenges that pertain specifically to the design of clothing or textile that create dressing challenges.
Person Challenges	Challenges that pertain to a person's abilities or functional impairments that they face within the body that create dressing challenges.
Environmental Challenges	Challenges that pertain to the design of the built, social or physical environment that create dressing challenges
Future Visions/Solutions Identified	Responses to the question: if there were no technology limitations what solutions would they create for the problems they identified?
Self-moving/mechanized Clothing	
Automatic Opening and Closing Item	An item of clothing that has fasteners that leverages technology to open or close.
Shape Changing Clothing	Clothing that leverages technology to change shape to assist with either donning and doffing or fitting properly.
Positioning Aids	Clothing that acts as an aid to keep a person in a particular position or to encourage them to change position such as that is needed when someone has spasticity or postural needs.
Regulating Clothing	
Clothing that Helps with Emotional Regulation	Clothing that either monitors or reacts to a persons' emotions using technology and then provides some type of feedback or reassurance to assist with emotional regulation.

Temperature Regulating Clothing	Clothing that monitors and adapts its temperature based on user needs or preferences either in response to the environment or individual.
Self Managing Clothing	Clothing that acts in a way to assist the user to manage the use of or care of that clothing.
Clothing that Leverages Technology to Manage Health	Clothing that monitors, manages or regulates health using technology such as sensors etc.
Corresponding Clothing	
Instructional Clothing Using Technology	Clothing that provides instruction either on how to wear or use it using technology. For example clothing that instructs someone how to tie their shoes in a step by step manner.
E-Textile/Clothing as Communication Device	Clothing that is in itself a communication device.
Stylish Clothing through Technology	Clothing that automatically changes it style, colour or look to become stylish.

A.4 Design Fiction Code Book

Larger theme: Usability

Maintaining Autonomy of the User	This refers to instances where OTs discussed how the technology proposed would support the autonomy of the user.
Sequencing Cues/ Task Instructions	This refers to instances where OTs described how the technology proposed provided cues to the user to assist with completing dressing tasks, as opposed to completing the task for them.
Providing System Overrides	This refers to instances where OTs discussed providing ways for the user to override or stop the technology from providing assistance for dressing tasks.
Anxiety Regarding Faulty Technology	This refers to instances where OTs described their or the proposed character's anxiety regarding the potential downfalls or failures of the technology proposed.

Societal Evolution to Support People with Disabilities	This refers to the ways in which OTs described how society has evolved in some manner to better support people with disabilities.
Multi-modal interaction	This refers to the interaction or mechanism of the clothing that uses a variety of interaction methods (ie: sensation/ vibration, auditory etc.)
Modular Ability to Increase Levels of Support	This refers to the technology being able to add or reduce features as needed for the user.
Individualization and Customization of Dressing Technology	This refers to the ability to change or customize dressing technology to the individual needs or desires of the user.
Features that Support Device Maintenance and Retention	This refers to features indicated by the OTs that ensure the device is maintainable or remains available to the user
Enjoyment of Technology/Clothing to Support Comfort	This refers to how the user interacts with technology to increase enjoyment with dressing tasks.
Discreet Interactions	This refers to interactions that are hidden or less noticeable to others to help maintain the privacy of the user.
Clothing or Technology that Increases Individual Control	This refers to clothing or technology that increases the control of the user.
Simplicity of use	This refers to the ability to use the technology with limited requirements.
Need for Privacy and Security	This refers to the OT expressing that the technology should have controls surrounding privacy and security.