Adaptive Soft Switches: Co-Designing Fabric Adaptive Switches with Occupational Therapists for Children and Adolescents with Acquired Brain Injury

Karen Anne Cochrane
Carleton Univeristy
Ottawa, Canada
karen.cochrane@carleton.ca

Chau Nguyen
International Academy of Hope
New York, New York, United States
chau.nguyen@yai.org

Yidan Cao
School of Architecture, Design and Planning, The University of Sydney
Sydney, Australia
yidan.cao@sydney.edu.au

Noemi M. E. Roestel
Carleton Univeristy
Ottawa, Canada
noemiroestel@cmail.carleton.ca

Lee Jones
Carleton Univeristy
Ottawa, Canada
leejones@cmail.carleton.ca

Audrey Girouard
Carleton Univeristy
Ottawa, Canada
audrey.girouard@carleton.ca

ABSTRACT

Acquired brain injuries have many complexities, largely affecting motor and cognitive functioning. Occupational therapists often use switches attached to electronics that activate the devices to give people with disabilities the ability to interact with toys and electronics. However, current switches on the market are expensive, break easily and are unable to customize. We ran two co-design workshops and follow-up interviews with 14 occupational therapists specializing in students with acquired brain injuries. In phase one, the occupation therapists built three soft switches and brainstormed iterations. In phase two, we gained valuable insights into the iterations from occupational therapists. This paper contributes to Human-Computer Interaction as a case study, designs guidelines to support co-design with occupational therapists, and discusses the potential of adaptive soft switches. This work contributes to the growing literature around supporting occupational therapists as makers and how researchers can support them during the co-design process.

CCS CONCEPTS

• **Human-centered computing → Accessibility technologies**.

KEYWORDS

e-textiles, proxies, wearable, accessibility, disability, occupational therapy, brain injury, children, adolescent, students

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1 INTRODUCTION

Acquired Brain Injuries (ABI) are injuries to the brain that occur after birth, including traumatic brain injuries, cerebrovascular accidents, brain tumours, infections of the central nervous system, hypoxic brain injury, and infections [46]. These injuries can affect motor skills, cognition, and behaviour and present with other medical challenges. Participation is disrupted in activities related to school, work, play, and home life [52, 64]. Electronic toys and other technologies are common interests among children and adolescents with ABI. However, the devices are difficult due to the physical properties of access (generally small buttons) and the challenging mechanisms that require more complex fine motor and coordination skills.

Toys and electronics not originally designed to be adaptive technologies (ATs) can be modified using electronic buttons, and other simple electronic sensors called adaptive switches. Adaptive switches are useful for children and adolescents to increase participation and self-expression in activities that are meaningful and interesting to them. The switches help them communicate and allow them to have control and direction over tasks. [81]. Switches can be pre-existing products or products built using electronic hardware components. The switches are then attached to support mechanical access to the device [57]. The switches can promote the participation and development of children and adolescents by providing alternative access to activities and routines. Students use switches at schools to access learning materials [37].

People with ABI can use adaptive switches to support differences related to motor skills and cognition that may affect opportunities for engagement. Though there are many different types of adaptive switches, the more popular pre-existing adaptive switches (Figure 1) are expensive hard plastic devices with limited customization options for different skills and activities. Using fabric as a medium, there are opportunities to use the malleable soft material to build customized adaptive switches that can be easily adapted to the individual needs of the end user. Though many people with disabilities can use adaptive switches, the complexities and challenges with

ABI make it a unique user group to explore the potential of adaptive soft switches.

Figure 1: An adaptive switch connected to a toy dog.

Occupational therapists (OTs) frequently assess for and utilize ATs due to their expertise in activity analysis and adapting materials and environments to promote participation [47]. As members of an interdisciplinary team, OTs are responsible for identifying and implementing ATs. OTs often adapt materials, objects and technologies and turn them into low/no tech and high-tech assistive technologies to support their client's needs and goals [67, 85]. OTs are not only proxies, stakeholders, and advocates for their clients but they are also users of AT where they often have to test, plan activities, and implement the use of ATs with their clients. Especially if their clients have complex and multiple disabilities such as ABI, it is critical to collaborate with OTs in the co-design process as they will implement the switches with the child and adolescent clients. They will customize and fix the adaptive soft switches if they are broken. With expertise in understanding their clients, they make ideal collaborators for human-computer interaction (HCI) researchers to co-design soft adaptive switches.

For this study, we co-designed with OTs at The International Academy of Hope (iHOPE), a school that supports students aged 5 to 21 with ABI in New York, New York, United States. OTs work with the students on physical, cognitive, vision, and sensory-related challenges, promoting participation and engagement through adaptation and using compensatory and remedial strategies rather than working towards complete independence. Occupational therapists frequently utilize the concept of independence partly as a measure of participation. Independence is generally understood as having complete physical control over a task. In occupational therapy, independence is a highly complex and individualized construct determined in collaboration between the student/user and therapist with the end goals of participation, autonomy, self-determination, and self-expression. The goal varies by person, environment, and cultural context [7].

Switch-adapted toys at the school examples include toys and musical instruments. Switches are also used for activities such as arts and crafts (e.g. pouring paint), cooking (e.g. using a blender), and activities for daily living (e.g. using a hair dryer). In academic activities, switches are used to access digital materials (e.g. playing video games). The OTs in this study have first-hand knowledge of working daily with students at the institution and have experience soldering and sewing to augment toys to attach adaptive switches. We do understand that not all OTs have these skills. However, we were fortunate enough to work with OTs with these skills.

Given their experience, we chose to investigate and co-design e-textile switches with OTs. The paper aimed to understand the opportunities and challenges of OTs building adaptive soft switches for their students with ABI. We were also interested in ways we could incorporate OTs into the design process to encourage them to make their own iterations of the adaptive soft switches. Therefore, our paper asks the following research questions:

RQ1: What design considerations emerged through the co-designing of adaptive soft switches alongside occupational therapists?

RQ2: What are the potentials of using soft adaptive switches in educational environments for students with acquired brain injuries?

Though previous work such as Slegers et al. [85] have looked into the potential of co-design assistive technology using 3D printers with CAD designers and OTs, there is limited work on co-designing wearable technology with OTs. E-textile switches are easily repaired [45], and have easy variability in size and shape for different abilities [88]. Finally, they can be less expensive than the commercial adaptive switches on the market or the cost of a 3D printer. In North America, it is easy to purchase conductive fabrics and other household materials to build the switches. We chose this method as co-designing with experts allows designers to exchange knowledge between industries to solve a problem that neither can accomplish alone [56]. In the domain of brain injuries, most co-design research focuses on designing for rehabilitation for adults [78, 91, 93] whereas designing ATs for children and adolescence with ABI are under-explored.

Our study is split into two phases. In Phase One, we ran two co-design workshops with 14 OTs from iHope. The first author facilitated the workshop over Zoom and taught the group to build three different adaptive soft switches. After the OTs built the adaptive soft switches, they had time to explore the switches and brainstorm iterations of the prototype. In Phase Two, the research team turned the ideas from the OTs into ten different adaptive soft switch prototypes. During a group interview with the same 14 OTs, we ran a group interview and presented the iterations during a group interview. The OTs in the Zoom call discussed what they liked and did not like about the switches and the potential of using the switches with the students at the institution.

This paper contributes to the field of HCI by presenting our prototypes of soft adaptive switches for children and adolescents with ABI. To further the research in adaptive switches, we present two design guidelines while co-designing with OTs and discuss the potential of implementing adaptive soft switches in educational environments for students with ABI.

2 RELATED WORKS

To support our research, we describe current trends in HCI research around ABI, then describe adaptive switches, literature around the maker community and e-textile toolkits, and how to co-design with proxies.

2.1 HCI Research for Acquired Brain Injuries

In HCI, research on acquired brain injuries (ABI) is limited. Commonly, researchers tend to focus on mild cases rather than severe ones with designs that favoured rehabilitation through virtual reality [3, 15, 21, 39, 71]. In addition to the abundance of virtual therapy approaches for motor and cognitive skills, most of the research projects were conducted in collaboration with adults with ABI [3, 21, 28, 60, 66, 69, 71, 86, 95]. We were unable to find any work that explored design challenges for children and adolescents with ABIs. We have a unique opportunity to learn from OTs who work with younger clients and gain insights from their expertise.

2.2 Current Adaptive Technologies

Currently, converting a regular toy or electronics into an adaptive technology can be modified by purchasing a battery interrupter, switch control interface (for electronics), and do-it-yourself (DIY) modifications to the toys. Each example adds a mono-male jack to the electronic or toy. On the other side of the jack, an adaptive switch uses a female mono jack to connect to the augmented toy or electronic. To our knowledge, the switches are hard plastic switches (example 1), and no one is using soft adaptive switches. According to Isabelle et al., things to consider when picking an adaptive switch include the "force required to operate the device, portability, size, weight, safety, and the need for multiple switch access" [37, p. 37].

There is a heavy focus on using 3D printers and CAD software to develop cheap adaptive switches for people with disabilities. For example, theoddartisan on the website Instructables, posted a tutorial on how to 3D print an adaptive switch [90]. In the literature, HCI researchers have been co-designing with a range of therapists [2, 33, 61, 73], non-professionals [14, 34, 73] and people with disability [1, 63, 79, 89]. However, many proposed solutions use 3D printers, which are not readily available for many OTs in the workplace and might require additional training to use the CAD software independently.

2.3 Maker Movement

The maker movement describes an individual's ability to make, design, and adapt things through the use of technology [19, 51, 65, 74], making the do-it-yourself (DIY) mindset its primary indication [34, 65, 74]. The movement has increased in popularity over the last decade due to the advances in personal fabrication technologies, the lowering cost and increased speed of prototyping [65, 74, 85]. Inside the disability community, there is increased interest in empowering people with disabilities to become their own makers [14, 35, 36, 63]. The empowerment gives people with disabilities the ability to design customized technology for their needs with first-hand knowledge of their lived experience. However, some ABIs result in significant and multiple disabilities that make the parts of physical and cognitive components of the maker process difficult. There is potential for OTs and other healthcare professionals and caregivers to become the makers. Both perspectives have to lead to the utilization of do-it-yourself assistive technology (DIY-AT) by finding online communities and involving users with disabilities, as well as their caregivers, teachers, and therapist, in the participatory design, creation and customization of DIY-ATs. [14, 31, 34–36, 63, 85].

Nonetheless, only a few researchers (such as [45]) have looked at how crafting e-textiles with OTs can benefit the lives of people with disabilities. The Skweezee toolkit [22, 67, 92] enables OTs to quickly design squeeze interactions using everyday materials such as soft toys to make interactive systems with the integrated development environment Processing. Similar to the 3D printers, OTs will need additional training to design squeeze interactions, and it is unclear if they would use the program without support from programmers. Other areas of DIY e-textile research include interest in supporting makers with disabilities on their crafting projects [23–27, 45] or focusing on accessible clothing [42, 53, 55, 62]. To our knowledge, there has been limited research on co-designing soft fabric adaptive switches with OTs for children and adolescents with ABI.

2.4 E-textile Toolkits

Constructive assemblies are toolkits of modular components that can be put together, taken apart, and iteratively built upon [38, 54]. For fast prototyping, toolkits such as LittleBits [4, 5] and MakerWear [49] have hard components that snap together and are easy for beginners to connect without previous electronics or computing knowledge. For e-textiles, many toolkits aim to support individuals in prototyping their concepts. However, many are difficult to iterate for beginners because of the robust nature of sewn-in components, which must be taken apart to fix issues [77]. The LilyPad [11, 13] is an Arduino-based microcontroller toolkit that enables makers to use e-textile threads with sewable components. Still, this toolkit has more reusable iterations, such as Craftec [40]. Projects like QuiltSnaps [12], iCATCH [70], and Wearable Bits [43, 44] use sewing snaps to make connections easy to take apart and undo. Other prototyping toolkits aim to support the fashion design process, such as Mannequette [83], which is a mixer for prototyping analog and digital interactions on a mannequin, Rapid Iron-on-Interfaces [50] with iron-on (and iron-off) traces and components. Brookdale [82] uses sewable "beads" to make prototypes that can withstand the extreme environment and constraints of runway fashion shows.

A Kit-of-No-Parts [75] is an "un-toolkit" that uses craft supplies and techniques to support beginner creativity and to use more accessible materials and tools. This paper uses this approach to develop an adaptive soft switch prototype that OTs can re-create with local supplies and materials. OTs constantly use a DIY and prototyping mindset to develop solutions for their clients, so this approach ensures that OTs can use our proposed solutions in the wild [33]. Again, many of these kits require some base knowledge of programming. As our OT collaborators already have a knowledge base in crafting and sewing, we plan to utilize their skills in this study to design and fabric simple non-programmed soft fabric switches which can activate electronics.

2.5 Participatory Design with Proxies

Though previous researchers have conducted co-design workshops with participants who were minimally verbal or non-verbal [96], we were interested in understanding the potential of the OTs being able to build the soft adaptive switches. The students with ABI at the institution we were collaborating with do not have the fine and gross motor skills to make the switches and, therefore, would need the support of the OTs to build the switches for them. Therefore, there are opportunities to use participatory design with proxies. Proxies can include individuals familiar with the user group, such as family members or experts. Experts are ideal for designing with proxies because they work closely with the user group and have additional expertise around supporting them. HCI research projects that use proxies include Boyd-Graber et al. [8], who used speech-language pathologists to co-design desktop-PDA systems to support their clients with Aphasia. Loke et al. [56] designed a framework to support the design of technology for safety, connection, and reflection to support social-emotional learning by co-designing with therapists for children with serious emotional behaviour issues. Hamidi et al. co-designed with special education teachers and adult school psychologists to design an ambient digital living media display for children with limited communication. One important aspect of their discussion of Hamidi et al. [30] is that proxies represent indirect representation and do not always represent the end users. However, there are limited challenges and opportunities for co-designing with proxies when they are responsible for building and customizing the AT.

3 STUDY DESIGN

To answer our research questions, we developed a study that consisted of design steps and two main phases (see Figure 2). Before the first phase, the HCI authors brainstormed switch ideas with the OT second author and then built the three soft adaptive switches we would teach the OTs in Phase One to build. We will discuss these in detail in section 4, the design of the three initial soft adaptive switches. In the study's first phase, we ran two co-design workshops and group interviews with 14 OTs from iHope. After the first phase, the paper's authors iterated the three initial designs of adaptive soft switches into ten different prototypes. In the second phase, we ran a follow-up group interview with the 14 OTs who participated in the first phase. We presented the ten iterated prototypes and conducted a group interview.

3.1 First Phase: Co-Design Workshops

This study received approval from our institution's research ethics board. After approval, we recruited by email 14 OTs who worked with students with ABI at iHope through the second author. Eleven participants were female-identifying and three were male-identifying, with an age range of 25 - 55 years old. The experience of OTs is different, ranging from 1 to 5 years. All the participants had learned how to sew in their OT training, but most of the participants do not use the skill regularly. Each participant signed a consent form on Qualtrics XM and received a $20 USD Amazon gift card as compensation. Participants then received an embroidery hoop and instructions on basic sewing stitches to practice before the workshop.

We ran the workshops in person, in two different classrooms at the school. We took precautions in ensuring participant safety while conducting in-person sessions, including social distancing and masks. The first author facilitated the workshop remotely using Zoom, whereas the second author was on-site. The other authors joined remotely because of geographical reasons. Along with assisting the OT participants, the second author also organized the materials so that the workshop would run smoothly. The workshop took about an hour and a half to complete. In the first hour, participants split into groups of two to three participants and built one of the three adaptive soft switches. For the last half hour, the OTs showcased their built switches and discussed use-case scenarios and iterations of each others' switches in a short group interview. We asked them questions about what context they would use the switches in, their preference, opportunities and challenges around building adaptive soft switches and the tutorial, the use-case of each of the switch prototypes, and changes they might make to the adaptive soft switches.

Using thematic analysis [9], the first and fourth authors coded the workshops into categories. Thematic analysis is a method that is widely used to analyze qualitative research [9, 29]. We coded both workshops independently and then met up to agree upon a set of codes. Then the first author went back to the data to re-categorize the data again according to the agreed-upon themes. The results yielded insights along with ten iterations and use-case scenarios for the adaptive soft switches.

3.2 Second Phase: Group Interview

After the analysis, the research team designed and built ten prototypes. Due to an increase in COVID-19 cases, we could not meet the OTs in person and instead showed them the iterations over Zoom, where we conducted a group interview to gauge their opinions on the changes we made to the initial prototypes. Using thematic analysis, the first and third authors coded the group interviews into categories. We report the results of the three phases in the following sections.

4 PRELIMINARY DESIGN OF ADAPTIVE SOFT SWITCH PROTOTYPES

Initially, the research team explored the Instructables website to brainstorm options on how to design and build adaptive soft switches. Authors 1 and 2 informally scrolled through Instructables by using the search term "soft switch". However, all the solutions proposed on the website were complicated (i.e. used physical computing components such as the Lilypad) or required the user to have fine motor skills. By needing fine motor skills, most of the students with ABI would be unable to interact with the prototypes. After extensive conversations among the authors (which included HCI researchers and an OT), we came up with three rules that gave OTs the ability to iterate the switches in the workshop.

(1) Only uses equipment that they are familiar with (i.e. thread and needle). Though all the sensors could be made on a sewing machine, we decided to solely use hand sewing as many OTs at the institution were not familiar with using a sewing machine.

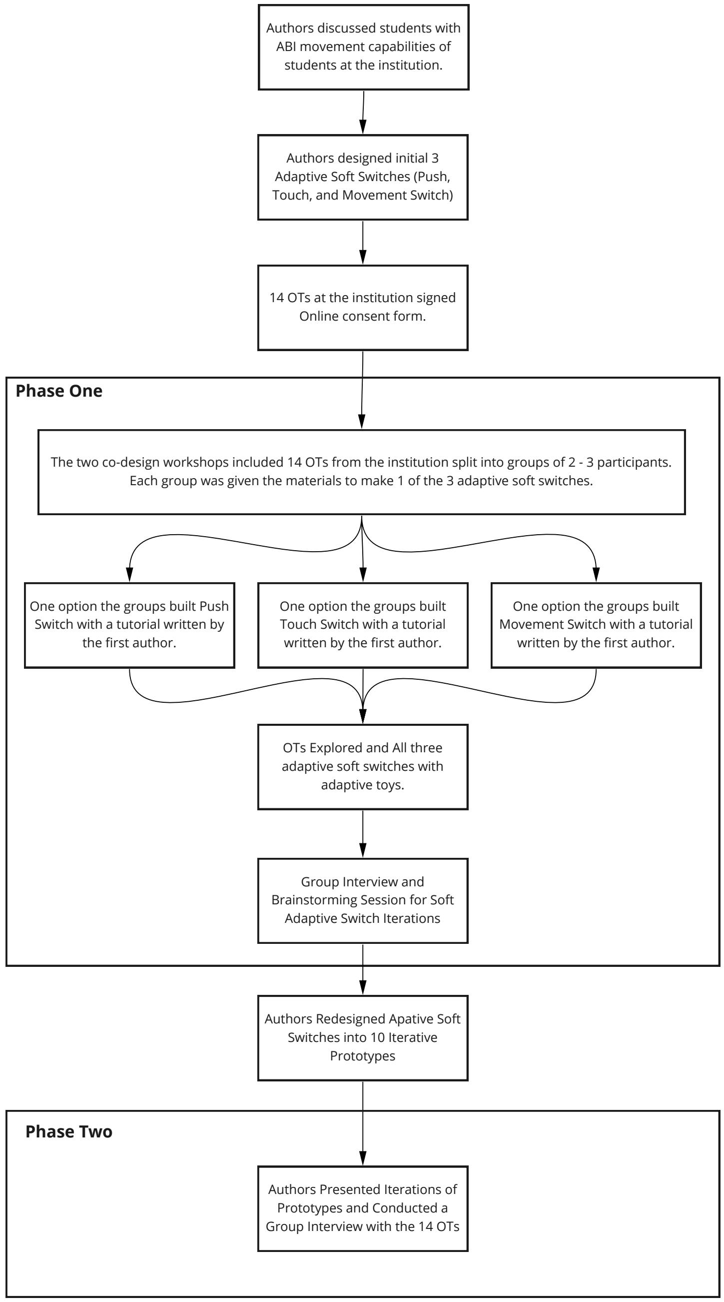

Figure 2: A diagram that visually shows the study design process.

(2) Keep the tutorials simple. Early on we decided that we would not build any switches that required programming and we would not be using software (e.g., CAD software) to keep learning to a minimum.

(3) Our designs included easily detachable wires (via snaps) so that all the switches were machine washable.

After discussions, we decided upon three adaptive soft switches, a push, a touch and a movement switch (Figure 3). We chose these

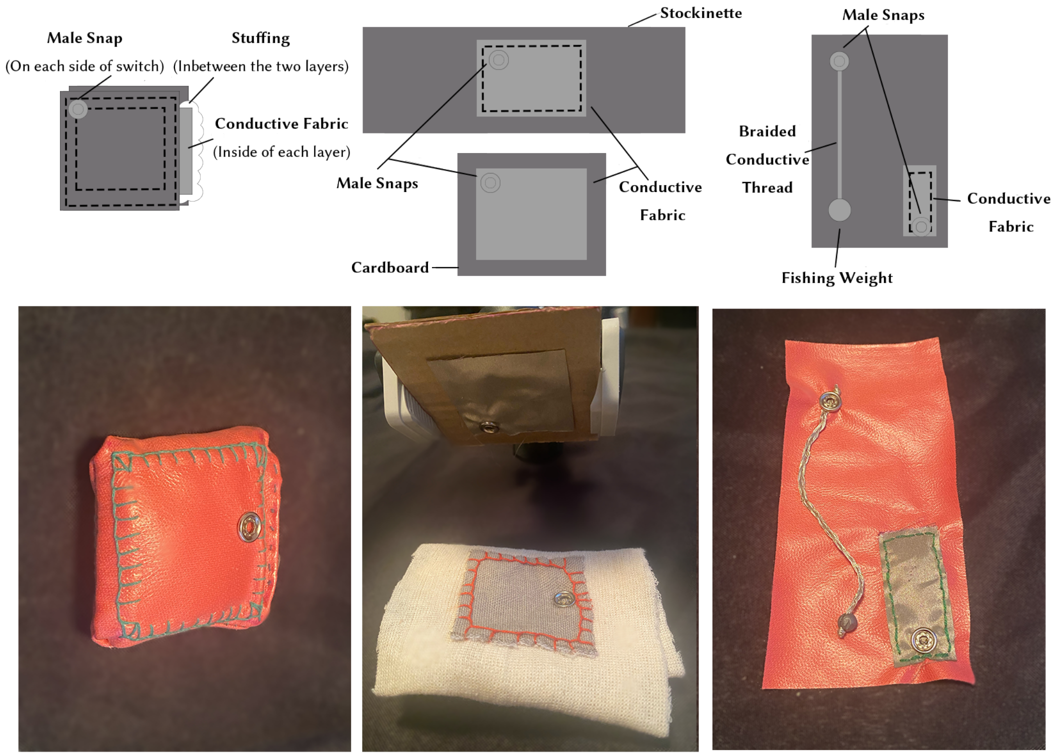

Figure 3: (Top) Diagram showcasing the material components of each sensor with (Left) the Push Switch, (Middle) the touch switch, and (Right) the movement switch. (Bottom) Images of the three different adaptive switches used in the workshop. The switches are as followed (Left) Push Switch , (Middle) Touch Switch, and (Right) Movement Switch.

three switches because they followed the three design rules that we developed with the authors and they were easy for the OTs to build in a single session. None of the switches were based on tutorials from Instructables, rather they were built on previous knowledge of the researchers. Each of the three switches used snaps that are attached to a wire that can connect to a toy or electronic device (Figure 4).

The push switch (left Figure 3) visually looks like a small pillow. There are two-piece of conductive fabric sewn onto each side on the inside of the switch. The more stuffing in the switch, the more difficult it can be to activate. To connect to the toy, we attached a female snap to each side of the push switch using pliers. To activate the switch, you push the two sides together to connect the two pieces of conductive fabric.

The touch switch consisted of two pieces: one piece is attached to the body and the other was designed to attach to a mount (middle Figure 3). The touch switch consisted of two pieces - the first piece was attached to the mount and included a piece of conductive fabric glued to cardboard. Device mounts are support arms which can be attached to tables and wheelchairs. It is common practice to mount switches so that they are able to be activated. A female snap was attached to the fabric. The second piece of conductive fabric was attached to a tube stockinette. Another female snap was also attached to the conductive fabric. The stockinette could be wrapped around the hand of the student, who could then activate the toy by pressing their hand on the piece of cardboard.

Finally, the movement switch (right Figure 3) was activated by gravity. Sewn onto a long piece of fabric, the switch included a piece of braided conductive thread with a fishing weight at the bottom and a female snap attached at the top. On the right-hand side, a longer piece of conductive fabric with another female snap was sewn onto the fabric.

Figure 4: Toy dog attached to the push switch.

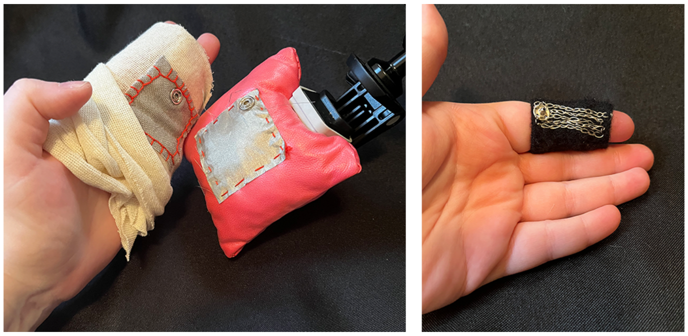

Figure 5: Left: First iteration of the touch switch which replaces the cardboard with a pillow. Right: Small version of the touch switch with conductive thread replacing the conductive fabric.

5 PHASE ONE: WORKSHOP RESULTS

In this section, we present the results of our analysis of the two workshops. We organized our results based on three different types of activities that OTs participate with the students at iHope including play activities, everyday activities, and school-specific activities to work on their motor and cognition skills. All OTs in the workshop see the potential of adaptive soft switches used for each type of activity.

5.1 Adaptive Soft Switches for Play Activities

For any child, engagement in play is an exciting and interesting way to build motor and cognitive skills. [10]. Adaptive switches are a great tool to encourage the act of play and give the students with ABI the tools to interact with technology. The OTs had many great ideas on how to integrate adaptive soft switches into the student's playtime. P4 stated, "we should embed the push sensor inside of a talking toy so that the [students] could hug or squeeze to activate it." Though many OTs felt the movement sensor would not work with their students as they were concerned that their students would just pull it apart, P2 explained "the sensor could be inside a ball and the students could hold or kick it without us worrying they are going to grab the switch a break it". This would provide access for students to use pushing or kicking movements to activate the switch. There are limited adaptive switches in the switches they currently use at the institution that use the lower body to activate devices and as P2 suggested, would be a great way to encourage movement and play in the school. Another option to encourage play would be to attach a larger-sized ball at the end of the movement sensor so that it would be able to be grasped and pushed across the desk to activate it. Finally, P6 suggested that the movement switch "could be activated if it was attached to a hat - perhaps like a pom pom."

5.2 Adaptive Soft Switches to Active Devices in Everyday Activities

The current switches used at the school need to be attached to a mount. Nine OTs commented on the versatility of the adaptive soft switches, whereas even the touch switch, originally designed to use a mount, would be able to both be attached to different items in the environment (e.g., a wheelchair) and be attached to the body. For instance, P1 commented that "parents could even attach one of the touch switches to the kitchen table and wrap the other around their kid's hand to activate a blender in the kitchen".

Unless it is a specific toy designed to be activated with the feet, OTs found it difficult to use adaptive switches with the lower body. However, three OTs suggested that the participants could either strap a small push switch under their foot or have one of the touch switches wrapped around their foot and the other on the floor or footrest on the wheelchair. Due to the nature of building the touch switch, P10 stated that "it would be easy to change the length and width of the wrap to accommodate a range of different-sized students." Another issue brought up specifically by P2, and P9 mentioned their caution from activating the hard plastic switches with their head; though, using an adaptive soft switch would alleviate their concerns of injury.

5.3 Adaptive Soft Switches for School Activities

Four OTs emphasized the importance of customization and options that adaptive soft switches could provide the students who have mobility differences. They explained that switches are frequently accessed via hand or head movements that generally press into the switch from one direction (but largely dependent on switch type). Incorporating additional movements such as twisting, pulling, and pushing with different body parts could impact participation through ease of switch access. P8 commented that one of their students "struggle with holding and pushing their switch at the same time", however, they "could twist or use another movement pattern to activate the switch". Two of the OTs suggested using these switches for school-based activities, such as using the switches to support access to educational materials and for communication. Three OTs suggested changing the size and shape; producing and testing the switches could benefit the students. P7 suggested making a "large push switch that covered a large portion of [their students'] wheelchair trays". P5 and 6 suggested the addition of an opening using a zipper to a push-activated switch would allow the addition or removal of stuffing to increase or decrease the amount of force/strength for activation. P9 suggested that adding weight inside the pillow could also improve switch access.

5.4 Limitations and Preferences of the Adaptive Soft Switches

Twelve out of 14 OTs commented that each of the switches they built in the workshop could have multiple uses for various types of activities. As fabric switches have the potential to be located on the body or close by in the environment, there are many opportunities to encourage students to interact concerning their movement. Overall, 8 participants preferred the touch switch, and 6 participants preferred the push switch. In its current state, eight participants agreed that the movement switch was less useful for their students than the other two switches.

Though a valuable option, there are some limitations of adaptive fabric switches. Four of the 14 OTs noted that even though they learned to sew during the training, they do not often use the skill as part of their job, and found sewing the switches difficult. Secondly, two OTs who built the push switch were frustrated that it did not work at first, then realized that the removal of the stuffing led to successful activation. Without the support of the designers, they may not have found the solution for the inactive switch. However, a simple FAQ could also support the OTs or comments on a form instead of an HCI designer. Six participants commented that the conductive fabric was more difficult to work with than the non-conductive fabric. Finally, all participants noted the time and effort used to prepare the workshop and acknowledged the difficulty for people unfamiliar with the process of replicating the setup. One participant suggested the creation of a toolkit and video tutorials to support OTs interested in making the switches.

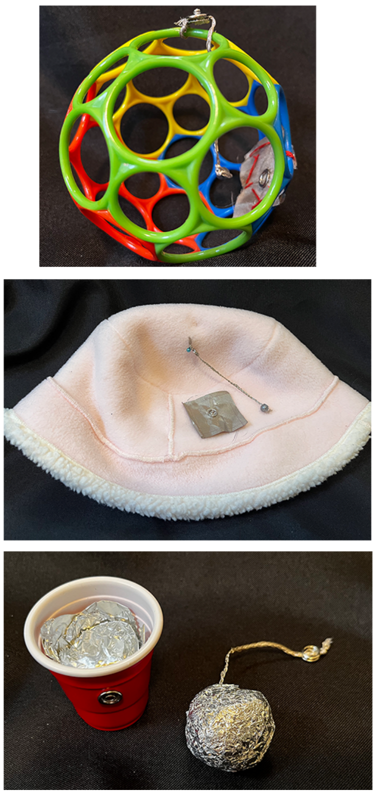

Figure 6: Three iterations of the movement switch. Left: The first is a ball with a movement switch on the inside. Middle: The second is a larger version of the movement switch. Right: The third is a movement switch attached to a hat.

Although it takes time and assistance to learn how to use the adaptive soft switches, the deformability and adaptability of the fabric and sewing skills they already have present opportunities for adaptive soft switches. P12 noted that they "found the tutorial less overwhelming because of their previous sewing knowledge". Overall eleven of the twelve OTs felt more confident making customization to the switches because of the simplicity and complete understanding of how the switch works. P11 also noted that "a few switches that they use regularly to do similar activities that soft, adaptive switches would be used for were too complex for them to repair", and they often had to purchase new ones when they broke. Additionally, P9 noted that OTs found the quick process of making the adaptive soft switches and ease of implementation gives them a lot of ideas to enact the switches into their daily activities with the students. The OTs unanimously agreed that the benefits outweighed the limitations and were interested in building switches for use during their therapy sessions and in the classroom.

5.5 Phase One: Iterated Prototypes

After the interview data from the workshops was used to iterate the prototypes, the first and second authors designed and developed 10 prototypes. Each prototype was iterated from the verbal discussion at the end of the workshop with the OTs. Then the authors of the paper discussed the ideas and developed their interpretations of the iterations to present to the OTs in the group interview.

5.5.1 Touch Switches. The OTs suggested two different iterations for the touch switch. The first (Figure 5 left image) was to change the cardboard out for something softer so that students that use a lot of strength to activate the switch would not injure themselves. Secondly, they thought students who do not like wrapping a large switch around their body might like something smaller such as a ring or small piece of fabric (Figure 5 right image).

5.5.2 Push Switches. The OTs suggested four different iterations for the push switch. First, they thought as the switch is soft it could be sewn right into the stuffed animal so students could hug the toy to activate it (Figure 7 top left). Secondly, they thought for students who liked using different body parts to activate the switch (such as their head or foot), perhaps merging the touch and push switch to add a small pillow onto the stockinette (Figure 7 bottom image). This would alleviate the pressure of finding a place to mount the second half of the switch. Thirdly, the OTs suggested adding a zipper to the push switch where they could change the difficulty of the switch for students that had a range of motor control and grip strength (Figure 7 top middle). Finally, the OTs suggested making the switch different sizes so that the students could use different movement patterns (such as twisting) and a larger switch to fit the whole area of a wheelchair tray (Figure 7 top right).

5.5.3 Movement Switches. Finally, for the last switch, the OTs suggested three different iterations. The first was to integrate the movement switch inside a ball so that the students could kick it around in play activities (Figure 6 left). The second idea was to make a larger version of the ball so students could pick it up on the table and move it around. As we were iterating this idea, we also added a cup so the students would have somewhere to place the ball (Figure 6 middle). Finally, they suggested that the movement switch could be placed on the top of the hat in lieu of a pom-pom (Figure 6 right).

6 PHASE TWO - GROUP INTERVIEW RESULTS

Overall, all 14 OTs noted improvements from the initial three prototypes built in the workshops. In the group interview, the OTs provided positive feedback on 8 of the 10 iterations. All OTs agreed that two of the iterations (touch switch around the finger and movement switch on top of a hat) would require movement patterns to activate accurately, which is difficult for students to complete consistently.

Figure 7: Four different iterated push switches. Top Left: The first switch has the push switch sewn into the chest of the dog toy. Top Middle: The second switch has a zipper sewn into the switch. Top Right: The third includes two different sizes of push switches. Bottom: The fourth switch has a pillow switch attached to a stockinette.

6.1 Potential of Switches

Contrary to the results of phase one, the most preferred soft adaptive switch iteration was the movement switch inside the toy ball. Three OTs all noted that they had a few younger students not interested in switches at all, and the idea of embedding a switch into a toy had the potential to capture their interest and motivate them to engage with the adaptive switches. P3 suggested adding "multiple activation points inside the ball". P4 even extended it with a suggestion that along with a ball, "the movement switch could also be activated inside a tube to encourage alternate movement patterns". Though P10 did not have any students that would use the ball, they were still intrigued by the uniqueness of the switch.

Along the lines of play, an OT in the previous workshop suggested increasing the size of the movement switch to encourage reaching and target practice for the students. Four OTs noted that they liked that the switch turned into a tabletop basketball game, and there were opportunities to play around with the sizes of the ball for different students' abilities. P5 stated that sometimes kids want things to "light up and make cool sounds." This switch has the potential to be turned into a toy to practice different movement patterns in a fun environment. As P1 states, it "would help reinforce different types of movement patterns for the students who do not usually get visual or auditory feedback."

All the OTs noted the versatility of the push switch. The various sizes and shapes were supported by different movement patterns, including force, squeezing, and twisting, which vary depending on the student's ability. P4 explained that "the large switch they currently use with students has a specific movement pattern that makes it more difficult for the students to activate". P1 suggested that the push switches could have more than one activation point to engage in educational activities such as communication. P3 made an interesting observation by explaining not only can the student activate the switch during lessons, but there is potential for them to assist the OT in preparing the switch for the activity. For instance, they could help by adding or removing stuffing or using a zipper pull to open or close the zipper on the side of the adaptive switch.

6.2 Wearable Adaptive Soft Switches

P3 noted that for parents who do not have the space or time to put up a mount, the touch or push switch sewn-on tube wrap can be easily set up. They also disclose that some of their students have difficulty with behaviour regulations (for example, P2 stated their students "like to bang their heads on the switch") and using pillows on the mount or attaching a push sensor to their bodies might decrease the need to repair the sensors. Seven OTs discussed the endless positions on the body where both adaptive switches could be attached, which are either impossible or uncomfortable to execute with traditional adaptive switches. For instance, it could be worn as a headband or attached to the foot. The switch can also be attached to chairs or tables without much effort. P10 noted "that there are some students who often miss or struggle activating the traditional plastic switch" and have a bit more flexibility due to the size and location of the switches. This would decrease the number of times the students overshoot their switches.

7 DISCUSSION

In our study, we co-designed soft adaptive switches with occupational therapists (OTs). Our results showcase ten different iterated prototypes (Figure 5, 7, and 6). To continue the discourse around the potential of using soft adaptive switches for ABI, we (1) present opportunities and challenges of co-designing soft adaptive switches with OTs in the form of two design considerations and (2) understand the potential of using soft adaptive switches in educational environments for students with acquired brain injuries (ABIs).

8 DESIGN CONSIDERATIONS TO CO-DESIGN WITH OCCUPATIONAL THERAPIST

We consider two important design considerations for any researchers interested in co-designing with OTs. Though our focus was on the potential design of adaptive soft switches that could easily be customized and built by OTs, we believe that these design guidelines could be beneficial for anyone interested in co-designing with OT proxies.

8.1 Design for Familiarity

HCI researchers should consider utilizing skills that their collaborators already have. For instance, the OTs we collaborated with had two skills we utilized sewing and their knowledge of how adaptive switches work. HCI researchers have considered familiarity to describe our experiences with unfamiliar technology. For example, calling the computer screen a window or the list of commands a user can complete on an application menu. In modern work, many HCI researchers still use metaphors to explain complex technologies to people without a background in computing [32, 72, 97]. We propose to push this idea further by taking the time to understand your collaborator's knowledge and use the knowledge to support the design process.

In our study, the OTs already had previous knowledge of sewing and understanding AT technology, and we could quickly instruct them on how to build the adaptive soft switches and how they work. Though none of the OTs had used conductive fabric before, they quickly understood that touching two pieces of fabric together would trigger the toy and has the same action as when you press down on a hard adaptive switch. With the knowledge of how to use conductive fabric to design adaptive soft switches, the OTs could easily iterate the adaptive soft switches and brainstorm new ideas that they think would engage the students at the institution. In future work, we encourage HCI researchers to consider utilizing familiar skills that their proxies have in the co-design process rather than teaching them completely new skills. Though we know that many collaborations will need complexities that include special skills such as CAD software or programming, we encourage HCI researchers also to consider designing prototypes that can be easily built independently by OT professionals. This will encourage OTs that might not have the financial means and additional equipment (such as 3D printers) readily available. Secondly, more simplistic prototypes, utilizing skills that OTs already possess, may make the prototypes more accessible and assist more people with disabilities. By employing the skills, the proxies should be able to continue designing and making their adaptive technologies and comfortably customize the adaptive soft switches to their client's needs without the support of designers or HCI researchers. By designing simple, easy-to-build adaptive soft switches, we feel that the OTs feel more comfortable being able to design, customize, and implement adaptive soft switches into their practice.

8.2 Design for Multi-Users

Co-designing with proxies is a common practice for HCI researchers to implement for people with disabilities for various reasons, including safety [56], and limited ability to participate in the co-design process [30]. However, though students with ABI are the end users, we argue that because OTs are so heavily involved in integrating the adaptive switches into the school and in the home, they can also be considered users. Due to the student's limited cognitive and motor functions, the students will always need support, and the school's goal is to teach the students to actively participate in home activities (for example, being able to turn on a blender with an adaptive switch while their family is making dinner). Therefore, most of the students will always be working with caregivers, including OTs. Though many ATs are designed for independence, we might need to shift our design goals of the ATs for the specific students at the institution to work on interdependence. Per Bennett et al. [6] explain that interdependence is a shift to designing AT so that all people, including people with disabilities, have equal access. ATs give students with ABI the ability to actively engage in their environments, including with other disabled individuals and caregivers and give them the ability to communicate. Though not tested in this study, OTs stated in our co-design workshop that the addition of soft switches could make the interactions easier due to customization of the switch for the users' motor and cognitive skills. They feel they have the potential to make interacting with soft switches more engaging and meaningful.

OTs are also responsible for purchasing the product, understanding how it works, and repairing it when it is broken. Therefore, it is critical for HCI researchers working with people with complex or multiple disabilities that the caregivers can be both considered proxies and users of the assistive technologies. Copley and Ziviani [16] emphasize that lack of assistive technology use in classrooms includes staff training and support, insufficient funding, difficulties acquiring AT technology, and time constraints. By designing with these factors in mind and an emphasis on developing designs that OTs can build without additional support, we believe adaptive soft switches have the potential to alleviate some of the concerns researchers have with the integration of ATs in the classroom.

Repairing ATs extends the life of the technology, and other researchers such as Lee Jones [41] have explored the potential of e-textiles and the ability to repair them. Unlike plastic materials, fabrics have a history of being easily repaired, and mending cycles are quite common to extend the life of textiles which makes the material ideal to use within educational communities, especially in educational spaces with insufficient funding. All the materials needed for the adaptive soft switches are available for an inexpensive price and are readily available in online stores in North America. We encourage HCI researchers to be aware that ATs, especially with multi- and complex disability end users, have multi-users that interact with the technology daily. We encourage researchers to understand stakeholders, proxies, and the different users interacting with the assistive technologies and their roles during the design process.

9 POTENTIALS OF SOFT SWITCHES FOR STUDENTS WITH ACQUIRED BRAIN INJURIES

Our study showcases the importance of collaborating with experts to design adaptive soft switches for students with acquired brain injuries (ABI). There is a range of cognitive and motor capabilities in the students at the institution, which can be supported through the materiality of the switches and the ability of OTs to adapt and customize the switches to the individual needs of the students with ABI.

9.1 Materiality

In recent years, HCI researchers have discovered the importance of materiality during the iterative design process. Dourish and Mazmanian emphasize that within the design, it is essential to consider specific material properties, including "mutability, persistence, robustness, spatiality, size, durability, flexibility, and mobility" [20, p. 1]. Materiality significantly impacts how digital products are designed and experienced [48] while also prompting us to conceptualize the computer as a material that works in concert with other materials and brings about new user experiences and practices [94]. Though in its infancy, similar to healthcare technology, more AT products are being developed that emphasize material properties [59, 87].

Conductive fabric and other e-textiles can potentially support material properties for AT technologies such as adaptive soft switches. For example, textiles with electronic components integrated into the fabric are durable, inconspicuous, comfortable and often washable [58]. In addition, the adaptive soft switch has the advantages of stable response, easy manufacturing, and accessible electronic interface [84]. Recently, with the advancement of fabrication methods and easy-to-source materials, there has been an increase in healthcare professionals, especially OTs, integrating the material into AT.

The OTs involved in our study rapidly fabricated different switches based on the ABI students' additional motor and cognitive capabilities. In addition, the OTs could see benefits in building their switches instead of purchasing ones. The OTs commented that many of the students at the school are strong, and it is common for the current plastic adaptive switches to break. Without the knowledge of the repair, they find themselves purchasing expensive switches quite regularly. However, by building switches, they gain knowledge of repair. Other researchers found that having the knowledge of repair and using open-source technologies increases access to the technology, reduces cost, and supports sustainability [17, 45].

9.2 Adaptability and Customization

It can be challenging to support the individual needs of the students with ABI as often their motor and cognitive abilities are on a spectrum [81]. In addition, the adaptive switches have to accommodate different movement patterns. For example, one OT in the study discussed how having multiple shapes of the push switch would support a wide arrange of his students. Some can only activate the switch with a slight movement in their hand, while others enjoy making more complex twisting movements. The ability for OTs to easily create and adapt similar switches and customize them in various ways makes adaptive soft switches ideal pieces of ATs to use at the school. In our study, we also designed the adaptive soft switches to be activated with different body parts. For example, some activities might be more accessible for students to accomplish by activating the switch with their heads. In contrast, others might find it easier to activate it with their foot. The design also makes it easy to merge the switches with toys, such as sewing in a push switch inside a teddy bear or having a movement switch inside a ball. In other studies, HCI researchers have indicated that there is a high abandonment rate of ATs and that 8 - 75 percent of ATs fail to meet the needs of the user [18, 76, 80]. Though our adaptive soft switches did not test in this study, we hope that using adaptive soft switches and the endless customization options of adaptive soft switches have a higher chance of implementation inside classroom activities. Other researchers second this conclusion by noting that ATs need to be adaptable and support customization for their diverse customers [68].

Previous Research [85] has suggested that OTs and CAD designers should participate in the design process and assist each other. But not all OTs have access to CAD and connect with CAD designers. Moreover, OTs often work with clients long-term, whereas collaborations with HCI researchers and designers do not last as long. ATs need to be constantly modified and repaired. It is vital to ensure that when other designers leave the project, they can continue to use and adjust these switches based on individual clients. Given the complexity and constant change of natural work environments, switches being able to support customization is essential. We believe that adaptive soft switches can be adaptive to the client's individual needs and have enough flexibility for customization where we hope to reduce abandonment.

10 LIMITATIONS AND FUTURE WORK

Our findings showcase the importance of co-designing with occupational therapists when designing adaptive soft switches for students with acquired brain injuries. The most significant limitation of the work was that we did not collaborate with the institution's students. Though our first study wanted to focus on the potential of collaborating with occupational therapists, we do not want to lessen the importance of HCI researchers collaborating with people with disabilities on assistive technologies. However, due to numerous factors and safety concerns, including the COVID-19 pandemic, it made more sense to focus on this preliminary collaboration with OTs for the initial study. As emphasized throughout the paper, if the OTs struggled with developing and being part of the iterative process, it would not have made sense to introduce the switches to the students because once the HCI researchers had stopped collaborating with the OTs, there was a higher chance of abandonment. However, in future work, we plan to introduce an iterative version of the adaptive soft switches to the students with ABI and integrate them into the teaching environment. Secondly, we are interested in collaborating with other proxies such as speech therapists in looking at opportunities to use the fabric assistive technologies in their practice. Finally, we plan to work with the staff at the institution to disseminate tutorials and other resources so OTs, caregivers, and even people with disabilities will be able to construct their adaptive soft switches.

11 CONCLUSION

In this paper, we present our co-design workshop with occupational therapists and follow-up group interviews to inform the design of adaptive soft switches for students with acquired brain injury. Through the workshop prototypes and interactions of the switches, we identified two design guidelines for co-designing with OTs, including Design for Familiarity and Design for Multi-Users. We also discussed materiality, adaptability and customization in designing adaptive soft switches for students with ABI. We hope these strategies can support future projects around helping the community to build assistive technology for people with disabilities.

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REFERENCES

[1] Leila Aflatoony and Su Jin (Susan) Lee. 2020. AT Makers: A Multidisciplinary Approach to Co-Designing Assistive Technologies by Co-Optimizing Expert Knowledge. In *Proceedings of the 16th Participatory Design Conference 2020 - Participation(s) Otherwise - Volume 2* (Manizales, Colombia) *(PDC '20)*. Association for Computing Machinery, New York, NY, USA, 128–132. https://doi.org/10.1145/3384772.3385158

[2] Leila Aflatoony and Shreya Shenai. 2021. *Unpacking the Challenges and Future of Assistive Technology Adaptation by Occupational Therapists.* Association for Computing Machinery, New York, NY, USA, 1–8. https://doi.org/10.1145/3464385.3464715

[3] Sergio Albiol-Pérez, Guillermo Palacios-Navarro, Nancy Guerrón-Paredes, José-Antonio Gil-Gómez, José-Antonio Lozano Quilis, Hermenegildo Gil-Gómez, and Pilar Manzano. 2014. The Perfetti method, a novel virtual fine motor rehabilitation system for chronic acquired brain injury. In *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare.* ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), Cleveland, Ohio, USA, 451–454. https://doi.org/10.4108/icst.pervasivehealth.2014.255251

[4] Ayah Bdeir and Paul Rothman. 2012. Electronics as Material: LittleBits. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction* (Kingston, Ontario, Canada) *(TEI '12)*. Association for Computing Machinery, New York, NY, USA, 371–374. https://doi.org/10.1145/2148131.2148220

[5] Ayah Bdeir and Ted Ullrich. 2010. Electronics as Material: LittleBits. In *Proceedings of the Fifth International Conference on Tangible, Embedded, and Embodied Interaction* (Funchal, Portugal) *(TEI '11)*. Association for Computing Machinery, New York, NY, USA, 341–344. https://doi.org/10.1145/1935701.1935781

[6] Cynthia L Bennett, Erin Brady, and Stacy M Branham. 2018. Interdependence as a frame for assistive technology research and design. In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility.* Association for Computing Machinery, New York, NY, USA, 161–173. https://doi.org/10.1145/3234695.3236348

[7] Sarah Bonikowsky, Amanda Musto, Kerry Ann Suteu, Sherry MacKenzie, and Donna Dennis. 2012. Independence: an analysis of a complex and core construct in occupational therapy. *British Journal of Occupational Therapy* 75, 4 (2012), 188–195.

[8] Jordan L Boyd-Graber, Sonya S Nikolova, Karyn A Moffatt, Kenrick C Kin, Joshua Y Lee, Lester W Mackey, Marilyn M Tremaine, and Maria M Klawe. 2006. Participatory Design with Proxies: Developing a Desktop-PDA System to Support People with Aphasia. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Montréal, Québec, Canada). Association for Computing Machinery, New York, NY, USA, 151–160. https://doi.org/10.1145/1124772.1124797

[9] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101.

[10] Jane Brodin. 2005. Diversity of aspects on play in children with profound multiple disabilities. *Early Child Development and Care* 175, 7-8 (2005), 635–646.

[11] Leah Buechley, Mike Eisenberg, Jaime Catchen, and Ali Crockett. 2008. The LilyPad Arduino: Using Computational Textiles to Investigate Engagement, Aesthetics, and Diversity in Computer Science Education. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Florence, Italy) *(CHI '08)*. Association for Computing Machinery, New York, NY, USA, 423–432. https://doi.org/10.1145/1357054.1357123

[12] Leah Buechley, Nwanua Elumeze, Camille Dodson, and Michael Eisenberg. 2005. Quilt snaps: A fabric based computational construction kit. In *IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE'05)*. IEEE, IEEE, Tokushima, Japan, 3 pp.–221. https://doi.org/10.1109/WMTE.2005.55

[13] Leah Buechley and Benjamin Mako Hill. 2010. LilyPad in the Wild: How Hardware's Long Tail is Supporting New Engineering and Design Communities. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems* (Aarhus, Denmark) *(DIS '10)*. Association for Computing Machinery, New York, NY, USA, 199–207. https://doi.org/10.1145/1858171.1858206

[14] Erin Buehler, Stacy Branham, Abdullah Ali, Jeremy J. Chang, Megan Kelly Hofmann, Amy Hurst, and Shaun K. Kane. 2015. *Sharing is Caring: Assistive Technology Designs on Thingiverse.* Association for Computing Machinery, New York, NY, USA, 525–534. https://doi.org/10.1145/2702123.2702525

[15] Ja Young Choi, Sook-Hee Yi, Lijuan Ao, Xin Tang, Xuan Xu, Dain Shim, Beomki Yoo, Eun Sook Park, and Dong-wook Rha. 2021. Virtual reality rehabilitation in children with brain injury: a randomized controlled trial. *Developmental Medicine & Child Neurology* 63, 4 (2021), 480–487. https://doi.org/10.1111/dmcn.14762

[16] Daniel Cruz, Maria Luisa G Emmel, Mariana G Manzini, and Paulo V Braga Mendes. 2016. Assistive technology accessibility and abandonment: challenges for occupational therapists. *The Open Journal of Occupational Therapy* 4, 1 (2016), 10. https://doi.org/10.1002/oti.213

[17] Carmelo De Maria, Licia Di Pietro, Alice Ravizza, Andres Diaz Lantada, and Arti Devi Ahluwalia. 2020. Open-source medical devices: Healthcare solutions for low-, middle-, and high-resource settings. In *Clinical Engineering Handbook* (second edition ed.). Elsevier, Cambridge, Massachusetts, USA, 7–14. https://doi.org/10.1016/B978-0-12-813467-2.00002-X

[18] Dries De Roeck, Karin Slegers, Johan Criel, Marc Godon, Laurence Claeys, Katrina Kilpi, and An Jacobs. 2012. I would DiYSE for it! A manifesto for do-it-yourself internet-of-things creation. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design.* ACM, New York, New York, 170–179.

[19] Dale Dougherty. 2013. *The maker mindset.* Routledge, Oxfordshire, England, UK. 7–11 pages.

[20] Paul Dourish and Melissa Mazmanian. 2011. Media as material: Information representations as material foundations for organizational practice. In *Third international symposium on process organization studies*, Vol. 92. Oxford University Press, Kettering, Northamptonshire, UK, 1–33.

[21] Jonathan Duckworth. 2010. *The Design of an Interactive Virtual Environment for Movement Rehabilitation of Traumatic Brain Injury Patients.* Ph.D. Dissertation. RMIT University.

[22] Luc Geurts, Jolien Deville, Vero Vanden Abeele, Jelle Saldien, and Karen Vanderloock. 2014. Skweezee Studio: Turn Your Own Plush Toys into Interactive Squeezable Objects. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction* (Munich, Germany) *(TEI '14)*. Association for Computing Machinery, New York, NY, USA, 377–380. https://doi.org/10.1145/2540930.2567896

[23] Emilie Giles. 2017. Touch, E-Textiles and Participation: Using E-Textiles to Facilitate Hands-On Making Workshops with Blind and Visually-Impaired People. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems* (Edinburgh, United Kingdom) *(DIS '17 Companion)*. Association for Computing Machinery, New York, NY, USA, 384–385. https://doi.org/10.1145/3064857.3079164

[24] Emilie Giles and Janet van der Linden. 2014. Using ETextile Objects for Touch Based Interaction for Visual Impairment. In *Proceedings of the 2014 ACM International Symposium on Wearable Computers: Adjunct Program* (Seattle, Washington) *(ISWC '14 Adjunct)*. Association for Computing Machinery, New York, NY, USA, 177–183. https://doi.org/10.1145/2641248.2641351

[25] Emilie Giles and Janet van der Linden. 2015. Imagining Future Technologies: ETextile Weaving Workshops with Blind and Visually Impaired People. In *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition* (Glasgow, United Kingdom) *(C I& '15)*. Association for Computing Machinery, New York, NY, USA, 3–12. https://doi.org/10.1145/2757226.2757247

[26] Emilie Giles, Janet van der Linden, and Marian Petre. 2018. *Weaving Lighthouses and Stitching Stories: Blind and Visually Impaired People Designing E-Textiles.* Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3174044

[27] Emilie Giles, Janet van der Linden, and Marian Petre. 2020. Tactile Stories: Interactive E-Textile Wall-Hangings Created by Blind and Visually Impaired Makers. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society* (Tallinn, Estonia) *(NordiCHI '20)*. Association for Computing Machinery, New York, NY, USA, Article 120, 3 pages. https://doi.org/10.1145/3419249.3421233

[28] Javier Gómez, Germán Montoro, Pablo A Haya, Xavier Alamán, Susana Alves, and Mónica Martínez. 2013. Adaptive manuals as assistive technology to support and train people with acquired brain injury in their daily life activities. *Personal and ubiquitous computing* 17, 6 (2013), 1117–1126. https://doi.org/10.1007/s00779-012-0560-z

[29] G Guest, KM MacQueen, and EE Namey. 2011. *Applied thematic analysis.* sage publications, United States.

[30] Foad Hamidi, Melanie Baljko, and Isabel Gómez. 2017. Using participatory design with proxies with children with limited communication. In *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility.* ACM, New York, New York, 250–259. https://doi.org/10.1145/3132525.3132527

[31] Foad Hamidi, Patrick Mbullo, Deurence Onyango, Michaela Hynie, Susan McGrath, and Melanie Baljko. 2018. Participatory Design of DIY Digital Assistive Technology in Western Kenya. In *Proceedings of the Second African Conference for Human Computer Interaction: Thriving Communities* (Windhoek, Namibia) *(AfriCHI '18)*. Association for Computing Machinery, New York, NY, USA, Article 8, 11 pages. https://doi.org/10.1145/3283458.3283478

[32] Jo Herstad and Harald Holone. 2012. Making sense of co-creative tangibles through the concept of familiarity. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design*. ACM, New York, New York, USA, 89–98.

[33] Megan Hofmann, Kristin Williams, Toni Kaplan, Stephanie Valencia, Gabriella Hann, Scott E. Hudson, Jennifer Mankoff, and Patrick Carrington. 2019. *"Occupational Therapy is Making": Clinical Rapid Prototyping and Digital Fabrication*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3290605.3300544

[34] Jonathan Hook, Sanne Verbaan, Abigail Durrant, Patrick Olivier, and Peter Wright. 2014. A Study of the Challenges Related to DIY Assistive Technology in the Context of Children with Disabilities. In *Proceedings of the 2014 Conference on Designing Interactive Systems* (Vancouver, BC, Canada) *(DIS '14)*. Association for Computing Machinery, New York, NY, USA, 597–606. https://doi.org/10.1145/2598510.2598530

[35] Amy Hurst and Shaun Kane. 2013. Making "Making" Accessible. In *Proceedings of the 12th International Conference on Interaction Design and Children* (New York, New York, USA) *(IDC '13)*. Association for Computing Machinery, New York, NY, USA, 635–638. https://doi.org/10.1145/2485760.2485883

[36] Amy Hurst and Jasmine Tobias. 2011. Empowering Individuals with Do-It-Yourself Assistive Technology. In *The Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility* (Dundee, Scotland, UK) *(ASSETS '11)*. Association for Computing Machinery, New York, NY, USA, 11–18. https://doi.org/10.1145/2049536.2049541

[37] Selena Isabelle, S Fiona Bessey, Kathryn Lawrence Dragas, Patricia Blease, Jayne T Shepherd, and Shelly J Lane. 2003. Assistive technology for children with disabilities. *Occupational Therapy in Health Care* 16, 4 (2003), 29–51. https://doi.org/10.1080/J003v16n04_03

[38] Hiroshi Ishii and Brygg Ullmer. 1997. Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems* (Atlanta, Georgia, USA) *(CHI '97)*. Association for Computing Machinery, New York, NY, USA, 234–241. https://doi.org/10.1145/258549.258715

[39] Nancy Jacho-Guanoluisa, Sergio Albiol-Pérez, Cesar A. Collazos, Habib M. Fardoun, and Sandra Cano. 2019. Cognitive Rehabilitation Using Virtual Reality for Children with Rare Diseases. In *Proceedings of the 5th Workshop on ICTs for Improving Patients Rehabilitation Research Techniques (REHAB '19)*. Association for Computing Machinery, New York, NY, USA, 183–186. https://doi.org/10.1145/3364138.3364176

[40] Ben Jelen, Anne Freeman, Mina Narayanan, Kate M. Sanders, James Clawson, and Katie A. Siek. 2019. Craftec: Engaging Older Adults in Making through a Craft-Based Toolkit System. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Tempe, Arizona, USA) *(TEI '19)*. Association for Computing Machinery, New York, NY, USA, 577–587. https://doi.org/10.1145/3294109.3295636

[41] Lee Jones. 2021. The E-Darning Sampler: Exploring E-Textile Repair with Darning Looms. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, New York, New York, USA, 1–5. https://doi.org/10.1145/3430524.3444700

[42] Lee Jones, Meghrik Isagholi, Elizabeth Meiklejohn, Snow Xu, Kara Truskolawski, Jessica Hayon, Grace Jun, Pinar Guvenc, and Christina Mallon-Michalove. 2020. Hack-Ability: Using Co-Design to Develop an Accessible Toolkit for Adding Pockets to Garments. In *Proceedings of the 16th Participatory Design Conference 2020 - Participation(s) Otherwise - Volume 2* (Manizales, Colombia) *(PDC '20)*. Association for Computing Machinery, New York, NY, USA, 95–99. https://doi.org/10.1145/3384772.3385124

[43] Lee Jones, Sara Nabil, and Audrey Girouard. 2020. Swatch-Bits: Prototyping E-Textiles with Modular Swatches. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Sydney NSW, Australia) *(TEI '20)*. Association for Computing Machinery, New York, NY, USA, 893–897. https://doi.org/10.1145/3374920.3374971

[44] Lee Jones, Sara Nabil, Amanda McLeod, and Audrey Girouard. 2020. Wearable Bits: scaffolding creativity with a prototyping toolkit for wearable e-textiles. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, New York, New York, USA, 165–177. https://doi.org/10.1145/3374920.3374954

[45] Lee Jones, Miriam Sturdee, Sara Nabil, and Audrey Girouard. 2021. Punch-Sketching E-Textiles: Exploring Punch Needle as a Technique for Sustainable, Accessible, and Iterative Physical Prototyping with E-Textiles. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Salzburg, Austria) *(TEI '21)*. Association for Computing Machinery, New York, NY, USA, Article 21, 12 pages. https://doi.org/10.1145/3430524.3440640

[46] Pru Jones, Avril Drummond, and Kristina Vella. 2007. Occupational therapy for children with acquired brain injury: A survey of current practice. *British Journal of Occupational Therapy* 70, 4 (2007), 154–160. https://doi.org/10.1177/030802260707000404

[47] Sharon Judge, Kim Floyd, and Tara Jeffs. 2008. Using an assistive technology toolkit to promote inclusion. *Early Childhood Education Journal* 36, 2 (2008), 121–126.

[48] Heekyoung Jung and Erik Stolterman. 2010. Material probe: exploring materiality of digital artifacts. In *Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction*. ACM, New York, New York, USA, 153–156.

[49] Majeed Kazemitabaar, Jason McPeak, Alexander Jiao, Liang He, Thomas Outing, and Jon E. Froehlich. 2017. *MakerWear: A Tangible Approach to Interactive Wearable Creation for Children*. Association for Computing Machinery, New York, NY, USA, 133–145. https://doi.org/10.1145/3025453.3025887

[50] Konstantin Klamka, Raimund Dachselt, and Jürgen Steimle. 2020. *Rapid Iron-On User Interfaces: Hands-on Fabrication of Interactive Textile Prototypes*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3313831.3376220

[51] Bo-Ram Kwon and Junyeong Lee. 2017. What makes a maker: the motivation for the maker movement in ICT. *Information Technology for Development* 23, 2 (2017), 318–335. https://doi.org/10.1080/02681102.2016.1238816

[52] Mary Law, Dana Anaby, Carol DeMatteo, and Steven Hanna. 2011. Participation patterns of children with acquired brain injury. *Brain Injury* 25, 6 (2011), 587–595. https://doi.org/10.3109/02699052.2011.572945

[53] Joanne Leong, Patrick Parzer, Florian Perteneder, Teo Babic, Christian Rendl, Anita Vogl, Hubert Egger, Alex Olwal, and Michael Haller. 2016. ProCover: Sensory Augmentation of Prosthetic Limbs Using Smart Textile Covers. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (Tokyo, Japan) *(UIST '16)*. Association for Computing Machinery, New York, NY, USA, 335–346. https://doi.org/10.1145/2984511.2984572

[54] Joanne Leong, Florian Perteneder, Hans-Christian Jetter, and Michael Haller. 2017. What a Life! Building a Framework for Constructive Assemblies. In *Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction* (Yokohama, Japan) *(TEI '17)*. Association for Computing Machinery, New York, NY, USA, 57–66. https://doi.org/10.1145/3024969.3024985

[55] Jason Lin, Jasmine Zhou, and Helen Koo. 2015. Enfold: Clothing for People with Cerebral Palsy. In *Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers* (Osaka, Japan) *(UbiComp/ISWC'15 Adjunct)*. Association for Computing Machinery, New York, NY, USA, 563–566. https://doi.org/10.1145/2800835.2801671

[56] Lian Loke, Aaron Blishen, Carl Gray, and Naseem Ahmadpour. 2021. Safety, Connection and Reflection: Designing with Therapists for Children with Serious Emotional Behaviour Issues. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, New York, New York, USA, 1–17.

[57] Toby M Long, Maria Woolverton, Deborah F Perry, and M Janet Thomas. 2007. Training needs of pediatric occupational therapists in assistive technology. *The American Journal of Occupational Therapy* 61, 3 (2007), 345–354.

[58] Diana Marculescu, Radu Marculescu, Nicholas H Zamora, Phillip Stanley-Marbell, Pradeep K Khosla, Sungmee Park, Sundaresan Jayaraman, Stefan Jung, Christel Lauterbach, Werner Weber, et al. 2003. Electronic textiles: A platform for pervasive computing. *Proc. IEEE* 91, 12 (2003), 1995–2018.

[59] Wendy Martin, Gabriella Spinelli, and Massimo Micocci. 2019. Materiality, Assistive Technologies and Everyday Life. In *British Society of Gerontology 48th Annual Conference - Resilience and Living Well in Local Communities*. British Society of Gerontology, Liverpool, UK, 53–53.

[60] Rachel McCrindle, Stephen Simmons, Richard Case, Malcolm Sperrin, Andy Smith, and Carol Lock. 2014. Encouraging brain injury rehabilitation through Ludic engagement. In *International Conference on Universal Access in Human-Computer Interaction*. Springer, Heidelberg, Germany, 310–320. https://doi.org/10.1007/978-3-319-07446-7_30

[61] Samantha McDonald, Niara Comrie, Erin Buehler, Nicholas Carter, Braxton Dubin, Karen Gordes, Sandy McCombe-Waller, and Amy Hurst. 2016. Uncovering Challenges and Opportunities for 3D Printing Assistive Technology with Physical Therapists. In *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility* (Reno, Nevada, USA) *(ASSETS '16)*. Association for Computing Machinery, New York, NY, USA, 131–139. https://doi.org/10.1145/2982142.2982162

[62] Amanda McLeod, Sara Nabil, Lee Jones, and Audrey Girouard. 2020. SMAller Aid: Exploring Shape-Changing Assistive Wearables for People with Mobility Impairment. In *Adjunct Proceedings of the 2020 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2020 ACM International Symposium on Wearable Computers* (Virtual Event, Mexico) *(UbiComp-ISWC '20)*. Association for Computing Machinery, New York, NY, USA, 86–89. https://doi.org/10.1145/3410530.3414418

[63] Janis Lena Meissner, John Vines, Janice McLaughlin, Thomas Nappey, Jekaterina Maksimova, and Peter Wright. 2017. Do-It-Yourself Empowerment as Experienced by Novice Makers with Disabilities. In *Proceedings of the 2017 Conference on*

Designing Interactive Systems (Edinburgh, United Kingdom) *(DIS '17)*. Association for Computing Machinery, New York, NY, USA, 1053–1065. https://doi.org/10.1145/3064663.3064674

[64] Cheryl Missiuna, Carol DeMatteo, Steven Hanna, Angela Mandich, Mary Law, William Mahoney, and Louise Scott. 2010. Exploring the use of cognitive intervention for children with acquired brain injury. *Physical & occupational therapy in pediatrics* 30, 3 (2010), 205–219. https://doi.org/10.3109/01942631003761554

[65] Iqbal Mohomed and Prabal Dutta. 2014. The age of DIY and dawn of the maker movement. *GetMobile: Mobile Computing and Communications* 18, 4 (2014), 41–43. https://doi.org/10.1145/2721914.2721929

[66] Francisco Montero, Víctor López-Jaquero, Elena Navarro, and Enriqueta Sánchez. 2011. Computer-aided relearning activity patterns for people with acquired brain injury. *Computers & Education* 57, 1 (2011), 1149–1159. https://doi.org/10.1016/j.compedu.2010.12.008

[67] Argyro Moraiti, Vero Vanden Abeele, Erwin Vanroye, and Luc Geurts. 2015. Empowering Occupational Therapists with a DIY-Toolkit for Smart Soft Objects. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction* (Stanford, California, USA) *(TEI '15)*. Association for Computing Machinery, New York, NY, USA, 387–394. https://doi.org/10.1145/2677199.2680598

[68] Argyro Moraiti, Vero Vanden Abeele, Erwin Vanroye, and Luc Geurts. 2015. Empowering occupational therapists with a DIY-toolkit for smart soft objects. In *Proceedings of the ninth international conference on tangible, embedded, and embodied interaction*. ACM, New York, New York, USA, 387–394.

[69] Francisco J. Navarro, Elena Navarro, and Francisco Montero. 2012. HABITAT: A Tool for Interactive Activities in the Treatment of Acquired Brain Injury. In *Proceedings of the 13th International Conference on Interacción Persona-Ordenador (INTERACCION '12)*. Association for Computing Machinery, New York, NY, USA, Article 5, 2 pages. https://doi.org/10.1145/2379636.2379641

[70] Grace Ngai, Stephen C.F. Chan, Vincent T.Y. Ng, Joey C.Y. Cheung, Sam S.S. Choy, Winnie W.Y. Lau, and Jason T.P. Tse. 2010. *I*CATch: A Scalable Plug-n-Play Wearable Computing Framework for Novices and Children.* Association for Computing Machinery, New York, NY, USA, 443–452. https://doi.org/10.1145/1753326.1753393

[71] Miguel Oliver, Francisco Montero, Antonio Fernández-Caballero, Pascual González, and José Pascual Molina. 2015. RGB-D assistive technologies for acquired brain injury: description and assessment of user experience. *Expert Systems* 32, 3 (2015), 370–380. https://doi.org/10.1111/exsy.12096

[72] Zhengxiang Pan, Chunyan Miao, Han Yu, Cyril Leung, and Jing Jih Chin. 2015. The effects of familiarity design on the adoption of wellness games by the elderly. In *2015 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT)*, Vol. 2. IEEE, New York, New York, USA, 387–390.

[73] Jeremiah Parry-Hill, Patrick C. Shih, Jennifer Mankoff, and Daniel Ashbrook. 2017. *Understanding Volunteer AT Fabricators: Opportunities and Challenges in DIY-AT for Others in e-NABLE*. Association for Computing Machinery, New York, NY, USA, 6184–6194. https://doi.org/10.1145/3025453.3026045

[74] Kylie Peppler and Sophia Bender. 2013. Maker movement spreads innovation one project at a time. *Phi Delta Kappan* 95, 3 (2013), 22–27. https://doi.org/10.1177/003172171309500306

[75] Hannah Perner-Wilson, Leah Buechley, and Mika Satomi. 2010. Handcrafting Textile Interfaces from a Kit-of-No-Parts. In *Proceedings of the Fifth International Conference on Tangible, Embedded, and Embodied Interaction* (Funchal, Portugal) *(TEI '11)*. Association for Computing Machinery, New York, NY, USA, 61–68. https://doi.org/10.1145/1935701.1935715

[76] Betsy Phillips and Hongxin Zhao. 1993. Predictors of assistive technology abandonment. *Assistive technology* 5, 1 (1993), 36–45.

[77] Irene Posch, Liza Stark, and Geraldine Fitzpatrick. 2019. ETextiles: Reviewing a Practice through Its Tool/Kits. In *Proceedings of the 23rd International Symposium on Wearable Computers* (London, United Kingdom) *(ISWC '19)*. Association for Computing Machinery, New York, NY, USA, 195–205. https://doi.org/10.1145/3341163.3347738

[78] Cynthia Putnam and Jinghui Cheng. 2013. Motion-Games in Brain Injury Rehabilitation: An in-Situ Multi-Method Study of Inpatient Care. In *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility* (Bellevue, Washington) *(ASSETS '13)*. Association for Computing Machinery, New York, NY, USA, Article 58, 2 pages. https://doi.org/10.1145/2513383.2513390

[79] Ravihansa Rajapakse, Margot Brereton, Paul Roe, and Laurianne Sitbon. 2014. Designing with People with Disabilities: Adapting Best Practices of DIY and Organizational Approaches. In *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: The Future of Design* (Sydney, New South Wales, Australia) *(OzCHI '14)*. Association for Computing Machinery, New York, NY, USA, 519–522. https://doi.org/10.1145/2686612.2686694

[80] Marti L Riemer-Reiss and Robbyn R Wacker. 1999. Assistive Technology Use and Abandonment among College Students with Disabilities. *IEJLL: International Electronic Journal for Leadership in Learning* 3, 23 (1999), 1–15.

[81] Mandy Rispoli, Wendy Machalicek, and Russell Lang. 2014. Assistive technology for people with acquired brain injury. In *Assistive technologies for people with diverse abilities*. Springer, Heidelberg, Germany, 21–52. https://doi.org/10.1007/978-1-4899-8029-8_2

[82] Teddy Seyed, James Devine, Joe Finney, Michal Moskal, Peli de Halleux, Steve Hodges, Thomas Ball, and Asta Roseway. 2021. *Rethinking the Runway: Using Avant-Garde Fashion To Design a System for Wearables*. Association for Computing Machinery, New York, NY, USA, 1–15. https://doi.org/10.1145/3411764.3445643

[83] Teddy Seyed and Anthony Tang. 2019. Mannequette: Understanding and Enabling Collaboration and Creativity on Avant-Garde Fashion-Tech Runways. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (San Diego, CA, USA) *(DIS '19)*. Association for Computing Machinery, New York, NY, USA, 317–329. https://doi.org/10.1145/3322276.3322305

[84] Lin Shu, Xiaoming Tao, and David Dagan Feng. 2014. A new approach for readout of resistive sensor arrays for wearable electronic applications. *IEEE Sensors Journal* 15, 1 (2014), 442–452.

[85] Karin Slegers, Kristel Kouwenberg, Tereza Loučova, and Ramon Daniels. 2020. Makers in healthcare: The role of occupational therapists in the Design of Diy Assistive Technology. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–11. https://doi.org/10.1145/3313831.3376685

[86] Dianne Smith, Courtney J Wright, Ali Lakhani, and Heidi Zeeman. 2017. Art processes: a research tool for acquired brain injury and residential design. *Arts & Health* 9, 3 (2017), 251–268. https://doi.org/10.1080/17533015.2017.1354899

[87] Gabriella Spinelli, Massimo Micocci, Emmanuel Tsekleves, Yu-Han Wang, Wendy Martin, Yonghun Lim, and Umber Shamim. 2020. Contemporary Themes in the Design of AT for the Ageing Population: Materiality, Co-design and Cultural Influences. In *Design of Assistive Technology for Ageing Populations*. Springer, Heidelberg, Germany, 41–58.

[88] Matteo Stoppa and Alessandro Chiolerio. 2014. Wearable electronics and smart textiles: A critical review. *sensors* 14, 7 (2014), 11957–11992.

[89] Theresa Jean Tanenbaum, Amanda M. Williams, Audrey Desjardins, and Karen Tanenbaum. 2013. Democratizing Technology: Pleasure, Utility and Expressiveness in DIY and Maker Practice. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 2603–2612. https://doi.org/10.1145/2470654.2481360

[90] Theoddartisan and Instructables. 2020. Create adaptive switches with TinkerCAD and 3D printing. https://www.instructables.com/Create-Adaptive-Switches-With-TinkerCAD-and-3D-Pri/

[91] Ahmad Turki, Kan Ding, Rong Zhang, Ming Li, Kathleen Bell, and Khosrow Behbehani. 2020. A Wearable Fitness Tracking Ecosystem for Exercise Therapy for Traumatic Brain Injury Patients. In *Proceedings of the 13th ACM International Conference on PErvasive Technologies Related to Assistive Environments* (Corfu, Greece) *(PETRA '20)*. Association for Computing Machinery, New York, NY, USA, Article 49, 8 pages. https://doi.org/10.1145/3389189.3397984

[92] Bert Vandenberghe, Kathrin Gerling, Luc Geurts, and Vero Vanden Abeele. 2019. Skweezee for Processing: A Software Library to Make Squeeze Interactions. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Tempe, Arizona, USA) *(TEI '19)*. Association for Computing Machinery, New York, NY, USA, 375–381. https://doi.org/10.1145/3294109.3300984

[93] Maitreyee Wairagkar, Rachel McCrindle, Holly Robson, Lotte Meteyard, Malcolm Sperrin, Andy Smith, and Moyra Pugh. 2015. Combined Language and Motor Therapy for Brain Injury Patients. In *Proceedings of the 3rd 2015 Workshop on ICTs for Improving Patients Rehabilitation Research Techniques* (Lisbon, Portugal) *(REHAB '15)*. Association for Computing Machinery, New York, NY, USA, 131–134. https://doi.org/10.1145/2838944.2838976

[94] Mikael Wiberg, Hiroshi Ishii, Paul Dourish, Anna Vallgårda, Tobie Kerridge, Petra Sundström, Daniela Rosner, and Mark Rolston. 2013. Materiality matters—experience materials. *interactions* 20, 2 (2013), 54–57.

[95] Danielle Wilde, Jenny Underwood, and Rebecca Pohlner. 2014. PKI: Crafting Critical Design. In *Proceedings of the 2014 Conference on Designing Interactive Systems (DIS '14)*. Association for Computing Machinery, New York, NY, USA, 365–374. https://doi.org/10.1145/2598510.2598603

[96] Cara Wilson, Margot Brereton, Bernd Ploderer, and Laurianne Sitbon. 2019. Co-Design Beyond Words: 'Moments of Interaction'with Minimally-Verbal Children on the Autism Spectrum. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, New York, New Youk, USA, 1–15.

[97] Hao Zhang, Qiong Wu, Chunyan Miao, Zhiqi Shen, and Cyril Leung. 2019. Towards age-friendly exergame design: The role of familiarity. In *Proceedings of the annual symposium on computer-human interaction in play*. ACM, New York, New York, USA, 45–57.