
Socializing via a Scarf: Individuals with Intellectual and Developmental Disabilities Explore Smart Textiles

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ABSTRACT¹

Smart textiles, a subset of wearable technologies, inspire novel human-interactions that leverage people’s physical and cognitive actions. However, people with intellectual and developmental disabilities (IDD) have different communication, social, and sensory experiences than non-disabled people. We empirically investigate how adults with IDD determine the functionality of smart textiles and which smart textile qualities impact comfort. We demonstrate a research design method that elicits social interaction among adults with IDD. We found that smart textiles facilitate embodied and social interactions among adults with IDD. We also present an emerging design space based on smart textile capabilities and user needs.

INTRODUCTION

From 2017 to 2021, the wearable technology market is estimated to nearly double from 125.5 million wearable devices to 240.1 million devices [8]. Thus, people—including those with disabilities—will become increasingly exposed to wearables such as smart watches and smart

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KEYWORDS

Wearable technology; autism; accessibility



Figure 1: Participants explored smart textiles (from top to bottom): LED scarf and gloves, vibration bracelet, and LED bike jacket.

clothing. Wearable technology responds to active or passive inputs in different and new forms such as body movements and biometric sensors, increasing opportunities for natural, full-bodied interactions. Smart textiles are a subset of wearable technology crafted from soft form factors (e.g., fabric) with electronic properties (Figure 1) [2]. Wearable technology has universal appeal because of our familiarity with clothing and accessories, with the additional promise of “access to information Anytime, Anyplace by Anyone” [10]. In particular, people with intellectual and developmental disabilities (IDD), such as those with autism spectrum disorder or Down’s Syndrome, have different social, communication, cognitive, and embodied experiences than non-disabled people [3,4]. Key dimensions of wearable technologies—improved sensing of the human body and environment and facilitating social, embodied interactions [7]—may well harness characteristics and strengths of individuals with IDD. Notably, autistic people exhibit strengths in visual processing, logical thinking, and attention to detail. They report being hyper- or hypo-sensitivity to sensory inputs such as textures and sounds. Unfortunately, historically, people with disabilities have been excluded from being considered a primary user group for emerging technology [12]. Consequently, products like ‘wearables’ emerge that are not always usable by them. We aim to bridge smart textiles and their usability for people with disabilities by providing baseline knowledge about how adults with IDD engage with smart textiles as first-time users.

To investigate the comfort and discoverability of functionality of smart textiles for people with IDD, we conducted an empirical study with ten adults with IDD. Our two research questions were (1) *In what ways do adults with IDD engage with a smart textile object when trying to determine its functionality?*; and (2) *What are qualities of smart textiles that impact comfort for adults with IDD?*

Study participants explored smart textiles in workshops comprised of hands-on explorations of four smart textiles followed by interviews about their experiences. We found that participants engaged in a range of embodied interactions that revealed insights into their sensory and cognitive processing. We found that a prominent aspect of smart textile design, obscured relationships between user input and the object’s outputs, resulted in barriers to comprehension and usability. We conclude that smart textiles facilitate social interactions among adults with IDD, a counterpoint to often-reported difficulties with social interactions among this population. Our contributions include: (1) baseline empirical evidence showing how adults with IDD engage with smart textile objects, (2) an emerging design space of smart textiles capabilities and the needs of people with IDD, and (3) demonstration of a research design method that elicits social interaction between adults with IDD.

RELATED RESEARCH ON WEARABLE TECHNOLOGIES AND ACCESSIBILITY

Since wearable technology is an emerging field, it remains uncertain what user experience factors have the strongest impact on user acceptance and adoption. Models of user acceptance primarily examine functionality and hedonic (e.g., comfort, aesthetics) qualities [9]. Our research highlights impressions of functionality and comfort of users with IDD that differ from those of non-disabled users. A prominent line of autism-related research is behavioral and therapeutic technology

Table 1: Participant Demographics

<i>Workshop # – participant #</i>	<i>Self-reported condition and affected areas</i>
P1-1	Autism; Attention Deficit Hyperactivity Disorder (ADHD)
P1-2	Autism
P2-1	Autism, mostly affects writing
P2-2	Autism
P3-1	N/A - Center staff
P3-2	Autism, mostly affects social interaction
P4-1	Down's Syndrome, mostly affects fine motor and gross motor skills
P4-2	Autism
P5-1	Autism, mostly affects memory, observation, and social skills
P5-2	Autism, mostly affects social skills, starting conversations, picking up social cues
P6-1	N/A - Center staff
P6-2	Autism, mostly affects everyday life

Table 2: Codebook

<i>Category 1: Engagement</i>
Turning on
On-collaboration
After turning on: <i>Fiddling</i>
<i>Exploring spatially</i>
<i>Not engaging</i>
<i>Turning off</i>
Discover modes
Put on garment
Show partner the object
<i>Category 2: Comprehension</i>
Determine purpose
Misconception of smart textile
<i>Category 3: Attitude</i>
Texture
Smart textile functionality
Item itself

interventions, such as developing computational models and technology to manage emotional and physical behavior, such as repetitive motions of autistic children (e.g., [1]). In contrast, we seek to center the perspective of adults with IDD, aligned with how Frauenberger et al [6] used participatory design to co-design smart objects with autistic children. They advocate for designers to focus on ways that technology can meaningfully fit into the lives of people with IDD, rather than focusing on their functional limitations. To our knowledge, our research is the first to demonstrate a research design method with adults with IDD for exploring smart textiles.

METHOD

We conducted six 30-minute workshops, each comprised of a pair of adults with IDD. There were ten participants with IDD (3 female) and two staff members of a local resource center for adults with IDD. The staff members were needed to complete two pairs due to scheduling constraints. We paired participants to provide a partner with whom to problem-solve and discuss ideas since we anticipated usability issues with the smart textiles. Staff let participants take the lead and made few suggestions, usually to redirect participants to the workshop topic using verbal prompts and gestures. We recruited participants enrolled in the center's Technology and Gaming class. Nine of the participants self-disclosed as autistic, one as having Down's Syndrome (Table 1). All participants were over 18 years old; nine had legal guardians on account of having an IDD. We distributed consent forms to the participants and their legal guardians prior to the workshop.

To begin each workshop, the researchers reviewed the signed consent forms with the participants. We reiterated that the goal of the workshops was to learn about people's perspectives of "objects one can wear that have built in electronics like lights." We implemented best practices for conducting research with autistic individuals [4], including displaying a visual schedule showing allotted time for exploring the objects and the closing interview. As the researcher placed a smart textile on the table between the pair, they were prompted to "learn about this interactive object and discover what it can do." They were asked to think aloud and feel free to talk with their partners. Participants interacted with four smart textiles (Fig. 1): (1) a scarf and (2) pair of gloves that light-up with different patterns; (3) a mindfulness bracelet that vibrates at intervals, and (4) a bicyclist jacket. The jacket is designed to increase the rider's visibility at night and displays turn arrows on the rider's back. The researchers selected these objects to represent a range of popular smart textile functionality. The objects are commercially available online, except the bracelet, which a researcher made per online instructions [11].

Data from this study comprised of video recordings of the workshops. To frame analysis of the audiovisual data, two researchers created an affinity diagram based on their workshop observations, arriving at three preliminary themes: engagement, comprehension, and attitude. They used the resulting codebook (Table 2) and a software application, Boris, to code actions and verbal communication between two pairs. The researchers discussed discrepancies, refined the codebook, and re-coded the first two pairs. Assessing the codes marked within 1 second of each other, we obtained an inter-rater reliability of $\kappa=0.64$, which indicates satisfactory agreement between the coders. The researchers then independently coded the remaining pairs.



Figure 2: Participants P3-2 and P2-1 explored smart textiles using different types of touches.



Figure 3: Participant P5-2 pointed out misalignment of “Press here” sticker and hidden button.

FINDINGS

Our findings demonstrate that autistic adults gain an understanding (and unfortunately, sometimes, mis-understanding) about smart textiles through embodied interactions [5] and surprisingly, social interactions. Their embodied interactions provided insight to their sensory and cognitive processing. Although smart textiles tend to be designed with hidden functionality that users are expected to discover, these hidden interfaces were problematic for our participants.

Use of Embodied and Social Interactions to Determine Functionality

To our initial research question on how adults with IDD determine smart textile functionality, we observed that discovery primarily occurred through embodied and social interactions. Their embodied interactions were tactile and spatial explorations, using their hands, arms, and face (Figure 1). Some motions were unexpected, such as when P3-2 wrapped the scarf around his wrist and stroked it in the manner of using a sensory soothing item known to be used by autistic individuals to self-sooth (Figure 2). We observed that participants used embodied interactions as their first step in engaging with the new technologies to understand their purpose. Participants experienced the most difficulty relying on embodied interactions to turn on the smart textiles, particularly because common items (i.e., a scarf) imbued unexpected and unintuitive (for participants) interactive interfaces. For example, participants had difficulty locating buttons; or they believed they pressed buttons but did not perceive any feedback. The scarf and gloves used the same button to cycle through On/Off states and various light patterns. Most participants' first action to turn off the object was to press the same button used to turn the object on, and they became confused by the change in light patterns. Some participants were confused by this cycling through states with a single button, with participant P2-2 saying, “*I can't figure out how to turn it off.*” The object that was most problematic to turn on was the jacket. Its power button was on the end of a sleeve, but this button was not as prominent as the battery pack located at the bottom of the jacket back. Participants focused on the battery pack, some even trying to undo the stitches that held the battery pack in place. The preoccupied focus on a single element, which is characteristic of autism, was also evident when participants noticed the glove's “Press Here” sticker indicating the location of the On/Off button. The sticker moved as participants repeatedly tried pressing in the right location and with the right pressure (Figure 3). As a result, participants spent considerable time trying to work the On/Off functionality; their efforts highlighted usability challenges in manipulating input controls while wearing the smart textile.

Although participants individually struggled with turning on at least one smart textile, all eventually collaborated with their partner or the researcher to turn on the object. Participants regularly relied on social interactions to raise attention to problems they were having and to share in delight when they discovered new functionality. Participants verbally described textures and discussed ideas about objects' purposes. They manipulated the object, expressing their interest through body language (i.e., leaning closely to the object, stroking it against their cheek) and verbal dialog. The participants shifted between exploring the objects independently and with their partner. Participants often traded objects, showing each other interesting features and helping



Figure 4: Participant P5-2 cradled the unlit scarf in his neck.

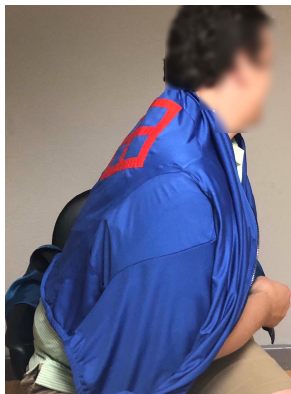


Figure 5: Pair 1 discovered output modes by fiddling and wearing jacket.

each other figure out how to work with the objects. Their opinions varied from aligning to disagreeing with each other. These social interactions were notable because a core component of IDD is having difficulties with verbal and non-verbal communication. Although the smart textiles were designed for single-person use, and not to facilitate collaboration, our observations show they provided opportunities for social and technological engagement for adults with IDD.

Tensions Between Affordances, Comfort, and Functionality

To our second research question about the smart textile qualities that impact comfort, we observed that the participants' sensory experiences impacted their perception of comfort; and notably, they had strong reactions to both passive and active qualities of the smart textiles. First, participants were drawn to the passive qualities of the smart textile, such as texture and form. Mentioning object texture was an early indicator for a participant's fondness of an object. Eight of the ten participants commented on the scarf's softness, and seven claimed the scarf was one of their favorite smart textiles because of its pleasing texture. P3-2 repeatedly raised the scarf to his face or neck and rubbed it against his skin (Figure 4). In contrast, participants who commented that a given texture, or noticeable bumps from the lights, felt uncomfortable and reported an overall negative perception of the object.

Second, participants enjoyed active qualities of the smart textiles, such as lights that responded to presses; however, hidden relationships between the active qualities and user input created usability barriers. Participants were most confused by the purpose of the bracelet, i.e., participant P2-2 thought it was a type of belt. This confusion was likely due to the hidden nature of its primary affordance—the vibration sensor. Due to the aesthetics and behavior of the meditation bracelet—it vibrated for a few seconds in 30 second intervals—participants presumed simple actions, such as monitoring vitals or indicating reminders, precipitated the vibrations. To guess the purpose of the bracelet, participants referenced everyday objects with which they are familiar. For instance, P3-2 assumed the bracelet acted as a reminder system because its functionality reminded him of his cell phone's alarm functionality. Although these actions were not the intended purpose of the bracelet, their ideation demonstrated creativity and imagination, which was a positive outcome of our research design method. In the case of the jacket, the lights were apparent, but its usefulness was obscured. The light pattern on the jacket changes depending on the angle of the left sleeve since this is the arm that cyclists typically use as a turn signal (Figure 5). Most participants were unable to figure out this connection, thus causing un-intended behavior of the jacket's output lights and lowering the participants' comfort levels and impressions of the jacket.

DISCUSSION AND EMERGING DESIGN SPACE

Our study showed participants' discoverability of smart textile functionality was heavily influenced by their sensory experiences and their ability to comprehend its functionality. Hidden relationships between user input and smart textile output were difficult for our participants to discover. In addition, we observed a social value in the smart textiles—even ones designed for solo use—that drew out conversations between otherwise non-loquacious participant pairs. Designers

Table 3: Design Space for Smart Textiles Usable by Adults with IDD***Areas to probe in future research**

<i>Smart Textile Affordances</i>	<i>Primary User Needs</i>
Texture	Strong sensory preferences, distracted by sensors that can be felt; Durable
Input through:	
Touch, Press (e.g., Switch, Push Button)	Discoverable; Usable when wearing and not wearing object; Fine motor capabilities
*Speech	Unusual speech patterns; discoverable speech commands
Body Motion	Clear relationships between motions and outputs
Outputs through:	
Lights (random; patterns)	Option for alternate modes that are more perceivable to user; Adjustable flash rate to prevent flash-inducing seizures
Tactile (e.g., haptics, *shape)	Hypo- or hyper-sensitivity to physical sensations
Power:	
Power source	Easy access; Instructions
Social:	
Verbal; Non-verbal; Social cues	Scaffolding (e.g., prompts) to support social interactions; Reward joint discovery

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and researchers should anticipate and leverage social interactions around smart textiles, particularly for diverse users. These findings contextualize an emerging design space, which we present here to initiate discussion and promote understanding of inclusive user needs for smart textiles. This design space captures the factors that impacted the comfort, understanding, and user experience for adults with IDD (Table 3). The design space adds user experience considerations not currently highlighted in other (nondisabled) user experience models for smart textiles, yet that warrant equitable consideration for designing inclusive wearable technology.

In conclusion, we demonstrated an accessible research design workshop as an avenue for exploring the social, sensory, and cognitive experiences of adults with intellectual disabilities—important target areas for future for HCI and disability fields. We presented an emerging design space that we hope informs the evolving field of smart textiles in order to provide comfort and opportunities for socializing for adults with IDD.

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