



Development of Wearable Technology for Autism Spectrum Disorder

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Introduction and Literature Review. There has been a massive increase in the rates of autism spectrum disorder (ASD) (Centers for Disease Control and Prevention, 2014; Valacchi & Ashwood, 2014). The high lifelong care costs are a huge burden on individuals with ASD and the U.S. annual medical costs associated with ASD are anticipated to be \$200-400 billion in 10 years (Buescher, Cidav, Knapp, & Mandell, 2014). ASD is a developmental disorder that affects social interaction and communication, including restricted, repetitive, and stereotyped interests/behaviors (Valacchi & Ashwood, 2014). Persons with ASD have daily challenges in understanding their emotional changes and self-regulation in social situations (Bölte, Feineis-Matthews, & Poustka, 2008). The literature review was conducted focusing on the products of wearable technology for ASD and ASD symptoms to understand the needs for wearable technology. Despite the extensive progress in wearable sensors for physiological monitoring, little attention has been directed at developing wearable monitoring systems for psychological parameters for ASD, which require constant and lifelong care. This study is to learn what makes an item of wearable technology appealing for individuals with ASD and their parents and what functions would be most effective in daily life. The results are expected to be beneficial when developing wearable technology (WT) for ASD designed to identify early signs of hyperarousal, which is a state of heightened physical and mental stress that may result in anxiety, fatigue, and reduced tolerance to pain in people with ASD.

Methods. After receiving IRB approval, participants who are in the ages between 7-40 without an intellectual disability who have a diagnosis of ASD or their parents were recruited through the center for neurocognitive development institute in the West of the U.S. Volunteers were asked to participate in a 30-minute survey. There was a total of purposely sampled 16 participants, including 9 parents (5 male, 4 female, whose children were diagnosed in the ages of 2.5 to 8) and 7 individuals with ASD (5 male, 2 female, age range=12-26, $m=18$, $SD=5.94$). There were 30 open- and close-ended questions: 3 on demographic information (age, gender, city of residence), 5 on ASD symptoms (age of diagnosis, most prevalent ASD symptoms, most difficult challenges faced in daily life, current medications, and current therapies), and 8 on WTs for people with ASD (use experience with WT, preferred WT type, preferred functions of WT, preferred types of WT, expected use frequency of WT, use preferences in physiological monitoring WT for ASD, preferences in receiving monitoring data, payment willingness), 13 on the importance of design factors (safety, data accuracy, comfort, flexible material, portability, durability, reasonable pricing, ease of use, lightweight feeling, small size, unobtrusive design, and unique design) using a 5-Likert chart, and 2 for further suggestions. The data were analyzed with color-coding, major theme extraction, and descriptive analysis, such as percentage, mean, and standard deviation.

Results and Discussions. Per individuals with ASD (IASD), 25% used smartphone apps for their ASD symptoms and about 40% of parents responded that their children with ASD were using WT, such as sleep monitoring and fitness trackers. The most preferred WT types for IASD (57%) and parents (63%) in daily life were accessories, such as a watch, a bracelet, or an ear piece. In addition, garment types, like socks, were preferred by IASD (29%) and parents (13%). IASD preferred to use WT that can record vital signs (38%) and stress levels so they can calm down and that provide a way to control their emotions and how strongly they react to stimuli (29%). The parents preferred having the functions of tracking their children's vital signs (75%), anxiety levels, or emotions (62.5%), and aid in recording information, such as in class (25%). More than 70% of IASD and 87% of parents responded that they would wear such a device every day and the others wanted to wear it whenever they went somewhere stressful (14%). Interestingly, all parents (100%) wanted to use a WT that can monitor emotion or stress levels and most IASD (86%) wanted to use it in stressful situations, such as social gatherings with new people and to prevent embarrassing situations by increasing their self-awareness through WT products. Parents (75%) and IASD (57%) preferred to receive the monitored data through smartphone apps (57%), followed by the device itself (29%) or through webpages (25%). The most preferred cost range was \$100-\$200 by IASD (43%) and parents (38%), and also parents had a willingness to pay as much as they could if the product was useful (38%). The most important design factor of WT for IASD was flexible material ($m=4.29$, $SD=.76$) followed by portability, data accuracy, durability, reasonable pricing, comfort, ease of use, safety, unique design, unobtrusive design, and small size. Parents considered comfort ($m=4.75$, $SD=.46$) as the most important to care about by designers, followed by portability, ease of use, data accuracy, flexible material, safety, lightweight feeling, unobtrusive design, durability, small size, reasonable pricing, and unique design respectively. About 30% of parents suggested making the product customizable, adding GPS (12.5%), or using the WT for future research and therapy of ASD (12.5%).

Conclusion. Designers and product developers are encouraged to develop the WT for ASD as accessories made of flexible materials with compatible smartphone apps that can monitor wearers' vital signs and sense changes of emotions and stress level for everyday use by considering important design factors, such as comfort, portability, data accuracy, and ease of use. It would be worthwhile to do the survey with a wide range of participants or users and test developed prototypes for future research.

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