Chapman University

Chapman University Digital Commons

Engineering Faculty Articles and Research

Fowler School of Engineering

4-2020

Supporting Self-Regulation of Children with ADHD Using Wearables: Tensions and Design Challenges

Franceli L. Cibrian

Kimberley D. Lakes

Arya Tavakoulnia

Kayla Guzman

Sabrina Schuck

See next page for additional authors

Supporting Self-Regulation of Children with ADHD Using Wearables: Tensions and Design Challenges

Franceli L. Cibrian
Informatics Department,
University of California, Irvine.
Irvine, CA, USA.
fcibrian@uci.edu

Kimberley D. Lakes
Psychiatry Department, University of California, Riverside.
Riverside, CA, USA.
kimberley.lakes@medsch.ucr.edu

Arya Tavakoulnia
Pediatrics Department,
University of California, Irvine.
Irvine, CA, USA.
atavakou@uci.edu

Kayla Guzman
Department of Pediatrics
University of California Irvine
Irvine California USA
kmguzma1@uci.edu

Sabrina Schuck
Department of Pediatrics
University of California Irvine
Irvine California USA
sabrina@uci.edu

Gillian R. Hayes
Informatics Department,
University of California, Irvine.
Irvine, CA, USA.
gillianrh@ics.uci.edu

ABSTRACT
The design of wearable applications supporting children with Attention Deficit Hyperactivity Disorders (ADHD) requires a deep understanding not only of what is possible from a clinical standpoint but also how the children might understand and orient towards wearable technologies, such as a smartwatch. Through a series of participatory design workshops with children with ADHD and their caregivers, we identified tensions and challenges in designing wearable applications supporting the self-regulation of children with ADHD. In this paper, we describe the specific challenges of smartwatches for this population, the balance between self-regulation and co-regulation, and tensions when receiving notifications on a smartwatch in various contexts. These results indicate key considerations—from both the child and caregiver viewpoints—for designing technological interventions supporting children with ADHD.

Author Keywords
Wearable, smartwatch, ADHD, children, design tensions.

CSS Concepts
• **Human-centered computing ~ Human computer interaction (HCI)**;

INTRODUCTION
Neuro-Developmental Disorder (NDD) is an umbrella term for a group of disorders arising during the developmental period. NDD is characterized by severe and often co-occurring deficits in the cognitive, social, communicative, motor, behavioral, and emotional spheres that result in significant challenges in school and home settings [1]. NDD includes Intellectual Disability (ID), Attention Deficit Hyperactivity Disorder (ADHD), Autism, and other disorders. Children with NDD, and particularly with ADHD, exhibit symptoms across two broad areas: inattention and hyperactivity/impulsivity [1]. Children with ADHD, who display symptoms of inattention, are most notably easily distracted and have trouble sustaining attention for a prolonged amount of time [1]. Meanwhile, children expressing hyperactive/ impulsive symptoms are often unable to regulate their bodies as well as their emotions [1].

Behavioral interventions are promising as approaches to improving the control of attention and impulsivity in the development of self-regulation skills [39]. Self-regulation is controlling one's behavior, emotions, and thoughts to pursuit long-term goals. This skill involves self-monitoring, goal setting, reflective thinking, decision making, self-evaluation, and management of emotions arising as a result of behavior change [31,39]. Self-regulation is fundamental to adaptive developmental tasks at all stages of life [28].

For children who struggle with self-regulation, caregivers (e.g., parents, teachers) tend to support them, either with motivational or emotional scaffolding. Motivational scaffolding involves the caregivers' ability to initiate and sustain children's enthusiasm for a task, by praise and encouragement, to redirect child attention, or to restart the task [16] (i.e., co-regulation [48]). When caregivers provide co-regulation strategies successfully, children with ADHD have more possibilities to reduce problematic behaviors, increase more successful behaviors, develop greater feelings of personal self-efficacy and confidence, and improve parent-child interaction [10,15,24]. This collaborative work requires that interventions and assistive technologies for people coping with ADHD be designed as collaborative tools.

Ubiquitous and wearable computing solutions have been used to support children and adults with NDD, such as intellectual disabilities [52], ADHD [33], and autism [49]. These technologies, however, have traditionally been designed for individual users and without substantial input from the children with ADHD themselves. Thus, in this work, we explicitly considered a model of intervention that involves both children and caregivers working together and focused on input from the children themselves.

We hypothesize that smartwatch-based interventions could help in supporting self-regulation, and this research is part of a larger long-term project focused on developing and evaluating such interventions. In this paper, we present the results of the first phase of this work. Based on the findings from workshops and focus groups with children with ADHD and their caregivers, we present three design tensions that should be considered surrounding the use of wearable technology to support self-regulation in children. The tensions are: greater capabilities versus smaller form factors; balancing self- and co-regulation; and notifications as supports as well as distractions. While the issues of form factor and notification have been seen elsewhere (e.g., [9,11,21]), their combined effects in this space alongside the unique issues of self- and co-regulation intersect to create a design space that requires particular care, as we describe in this paper.

RELATED WORK

Here we first present the general approaches of wearable technology supporting people with NDD. Then, we focus specifically on approaches using smartwatches.

Wearable Technologies for People with Neurodevelopmental Disorders

Wearable technologies provide portable computing solutions that can be used nearly anywhere and have the ability to record, simulate, communicate, and provide timely feedback to users [4]. Currently, research on the design and development of wearable technologies supporting people with NDD have explored how to use head-mounted devices, such as wearable immersive virtual reality, or wearables glasses to support social skills [5,14] and everyday tasks [3]. For example, HoloLearn [3], is a wearable virtual reality application to improve the autonomy of people with NDD in simple everyday tasks. An exploratory study, with 20 adolescents with NDD, found that HoloLearn is well-accepted and enjoyable but has some usability problems surrounding the wearable interactions. Slightly more intrusive wearable technologies, such as EEG wearable devices to support self-regulation using neurofeedback [2], have been explored more recently.

The research focused on wearable sensors, placed on different body parts, has demonstrated the potential to sense behaviors of people with ADHD and give timely feedback to avoid inattention episodes [43,45]. For example, CASTT (Child Activity Sensing and Training Tool), is a wearable prototype designed to provide real-time assistance in regaining attention for children with ADHD. CASTT uses a heart rate band, accelerometers on the arms and feet to sense movement, an EEG device, and a smartphone. A preliminary evaluation with 20 children, with and without ADHD, found that monitoring physical and physiological activities in real-time could potentially assist them. However, using multiple wearable sensors was uncomfortable for children, and sometimes the notifications were unnoticed.

Taken together, this research indicates that wearable devices could be worn by people with NDD to support the development of new skills and practicing of existing ones. However, few efforts have gone beyond wrist-worn technologies, given the inherent challenges of wearing substantial sensor and computational power.

Smartwatches Supporting Self-Regulation

Smartwatches offer promising platforms for improving therapeutic interventions. Researchers have demonstrated that they can be used to help people monitor their health, improving outcomes, and feelings of self-efficacy [17]. Smartwatches can support the cognitive [9], social [47], and motor [13] skills for children [38]. For example, EnhancedTouch is a bracelet that measures human-human touch events and provides visual feedback to augment the interaction of children with autism. An evaluation study with six children with autism shows that visual feedback provided by the bracelet motivates children with autism to touch one another [47].

Recently, research on smartwatch technologies aimed to design and develop applications to display self-regulation strategies for people with NDD [49] when they show stress or anxiety [42]. For example, Taimun-Watch is a system that helps caregivers of adults with autism create and edit visual self-regulation strategies. The visual supports created are sent to adults with autism and appear on their watches [49]. A preliminary evaluation with two adults with autism indicated that adults with autism could employ the self-regulation strategies created by their caregivers effectively. Similarly, Snap is a digital wristband that records interaction (e.g., gripping, huddling, and stretching)[42]. The data recorded can help detect anxiety and support users' reflections of their experiences and needs [42]. Snap was co-designed with seven adults with autism and their caregivers. Researchers identified wrist-worn technology as a solution for identifying triggers of anxiety and provide positive feedback to adults with autism when they needed.

Only a few works have explored how to support self-regulation strategies for people with ADHD specifically. For example, Focus is a smartwatch application to aid adults with ADHD to focus and reduce their stress [12]. To design the prototype, 27 adults with ADHD answered a survey, followed by a prototyping and usability test with ten adults. The evaluation found that calm down activities and timers could support the self-regulation of adults with ADHD [12]. Similarly, WELI (Wearable Life) is a wrist-based application that assists adults with intellectual disabilities to support self-regulation in class. WELI was designed through 8 user studies with 58 participants. Results indicate that mood regulation, reminders, checklist, surveys, and rewards should be integrated into a smartwatch application [52–54].

Examined collectively, this prior work shows that smartwatches can be useful for providing visual and auditory feedback to children and adults to assist them in the acquisition of different skills. Particularly, smartwatches can help people with NDD to support self-regulation by using feedback and mindfulness activities when they experience behavioral challenges. However, open questions remain regarding the impressions and concerns of children with ADHD regarding wearing a smartwatch, and how this might impact design. Therefore, in this work, we present the results of a co-design process that included both children and their caregivers. We describe design tensions that should be taken into account when designing wearable technology supporting the self-regulation skills of children with ADHD in a collaborative environment.

METHODS

We conducted a qualitative study for eight months. We conducted a series of participatory design sessions with children with ADHD and their caregivers as well as focus groups and interviews that did not include design activities.

Participants

This research was conducted collaboratively with a school for children with ADHD and related behavioral challenges. We recruited 24 students (3 girls; 21 boys; on par with the population of the school) between the ages of 10 and 13. Each child participated in five one-hour workshops for a total of five hours per child. We also conducted one focus group with 9 staff working at the school, including teachers and assistants. Finally, we conducted one focus group with three parents and a semi-structured interview with one mother who was unavailable during the scheduled focus group but wanted to participate.

Procedure

First, we conducted a series of participatory design workshops with the children. Participatory approaches to designing technology are particularly valuable for children with disabilities, but workshops need to provide specific structures and supports for them [13]. To determine the best structure for the workshops, we combined the information we gathered from our collaborators in the school with six hours of non-participatory observation at the school. Then, we conducted ten workshop sessions during a designated class. The participants were divided in two groups; each group completed five sessions (see Table 1). Each workshop with the children began with a group discussion about topics related to wearable technology, self-regulation strategies, and potential features for a smartwatch application. Each child then sketched their own ideas using a smartphone and a smartwatch paper prototypes (see Figure 1). Finally, they presented their ideas in front of the group, allowing other children to ask questions about the sketches.

Figure 1. Paper prototypes material used by the children to draw their sketches.

We then conducted a focus group with the staff and teachers. In this session, we first presented the main outcomes from the first four workshops with the children. The group then discussed their challenges and strategies to help children with self-regulation during class, their concerns about using technologies during class, and potential activities that could help children to be more regulated. Finally, we conducted one focus group with three parents and one semi-structured interview with one mother during which we discussed their concerns about their children wearing a smartwatch. They also brainstormed potential opportunities to design an application supporting self-regulation at home.

Data Collection and Analysis

We collected detailed field notes during the observation sessions. All workshops and interviews were audio-recorded and transcribed for analysis. Given the conditions of the focus group recordings, our transcripts only identified the moderator the type of participant and gender as a "boy," "girl," "father," "mother," or "teacher," and we use those

Participants	Data Collection	Aims
24 Children (10-13 years old)	5 workshops per child in two groups (1 hour each)	Sketch ideas for the smartwatch intervention Understand current strategies and how they could be improved using the smartwatch Brainstorm potential ideas for smartwatch applications
9 Instructional Staff	1 focus group (1 hour)	Understand current strategies and problems they face Discuss broad concerns about children using technology Develop requirements for smartwatch applications
4 Parents (2 males, 2 females)	1 focus group with 3 parents (30 min) 1 interview with 1 parent (30 min)	

Table 1. Summary of data collection

labels throughout this paper. We used a combination of open and axial coding to score our interviews and group our codes [7]. Then, we categorized our coding with instances related to tensions for design. All drawings, sketches, prototypes, and other visual artifacts created during the co-design sessions were collected, scanned, and categorized for greater understanding of design possibilities, imagined futures from the children's viewpoints, and areas of divergence from the research team's design concepts.

RESULTS

In this section, we describe the results of our qualitative analysis. In particular, we outline the challenges related to mobile and wearable form factors, the differences and tensions among proponents of self- and co-regulation, and the inherent conflict of notifications as support for people who can struggle to focus.

Wearable Platform Considerations for Children

Wearables are appealing as platforms for intervention due to their small size, long battery life, and increasingly capable processing power. Most of the children in our study found the smartwatch to be very practical due to their portability, glanceability, and low access time:

"The advantages of [smartwatches] are that it's right there (referring to their wrist). So, instead of taking your phone out continuously and watching it, you just go like this (showing his wrist), and [the smartwatch] is on." [Boy, 6th grade][1]

Despite the positive effects outlined above, two of the 24 children interviewed explicitly described watches as physically uncomfortable, an inconvenience they were unwilling to overcome for the perception of no additional benefit beyond a phone:

"I personally don't like the smartwatch. I think that a smartphone is enough." [Boy, 6th grade];

Many children with ADHD also have sensory processing disorder, or a related condition [23], that can make wearable technologies particularly bothersome, whether wrist-worn or otherwise. Although the school with which we worked is state-funded and not particularly wealthy, almost all of the children in our study reported already regularly having and using a smartphone. The notion of being responsible for and needing to carry two devices felt overwhelming in some cases. In these cases, it is an open question whether a standalone smartwatch application might be preferred given that most of the children—while owning a smartphone—did not use it regularly, smartphones are nearly forbidden at their school, and many times the use is restricted at home.

[1] Quotes identifiers represent the role and gender of the participant (male or female staff; father or mother). Identifiers of children represent their gender and their school grade level according to the American school system.

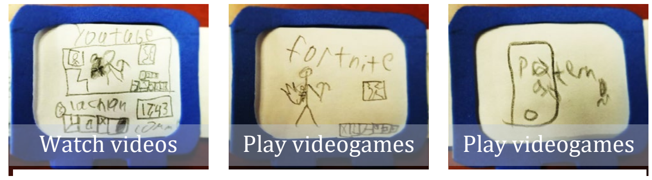

Figure 2. Sketches showing activities that children would like to have in a smartwatch but are difficult to use in a smartwatch.

While standalone wearable and smartwatch applications have their appeal, they are still a limited platform in terms of design and functionality. The size of the screen alone limits the interaction capabilities, a well-known challenge in wearable design. Although none had used such devices directly, the children displayed some inherent understanding of these challenges. For instance, some of the children acknowledged that playing videogames, texting, or even calling could be difficult for them when using a smartwatch. At the same time, they regularly drew such activities into their prototypes, demonstrating a strong desire for these capabilities (Figure 2). Therefore, wearable tools must balance their portability and display size with the support of activities that cannot be done with a smartphone to motivate and encourage children to wear the smartwatch.

On the other hand, parental control is an important feature currently used by most parent participants in our study, but some children complained about sharing their data with their caregivers,

"It would be nice to have a little privacy …" [Boy, 5th grade]

These results suggest that children in pre-adolescence are moving toward more independence from their parents. At the same time, their considerations around data privacy, control of information about them, and autonomous engagement with technology are in a state of rapid evolution. Even when the smartwatch of the children works by itself, our results suggest that parents would want to have it linked with their devices to have parental controls regarding smartwatch content. Additionally, in a collaborative environment—such as one dedicated to co-regulation as we describe in the next section—sharing these personal data with other caregivers might become essential even in the face of complicated relationships with those data and their owners.

Balancing Self-Regulation with Co-Regulation

The traditional approach to supporting children who struggle with self-regulation is through caregiver (e.g., parents, teachers) support, either with motivational or emotional scaffolding, broadly known as co-regulation [48]. However, ideally, these same children will have developed independent self-regulation skills by adulthood. The children in this study were remarkably aware of this tension. Our results indicate that they want more independence while recognizing their own need for support from their caregivers. All participants suggested that providing goals and rewards could help children with self-regulation. Teachers already use "token-based" economies [27] to help children improve self-regulation in class (e.g., participants earn points for appropriate behaviors that could be exchanged for rewards). This strategy includes setting goals, verifying and reflecting around them, and motivation through rewards. The aim is to provide consistent and continual reminders to sustain the child's enthusiasm for a task through praise and encouragement, redirection of the children's attention, or re-starting the goals of the task [16].

Collective Goals Setting

Our results indicate that goal-rewards structures should cross boundaries of particular contexts. The children in our study, in particular, suggested having three types of goals regarding healthcare, school, and socialization (Figure 3). However, cross-context goals create an additional burden for caregivers—both professional and familial. In particular, our results indicate that parents and teachers may be reticent or not well enough informed to create or measure goals in contexts with which they are not familiar.

Some children would like to set their own goals, which would imply a particular security model and user interface, while others would expect a caregiver to determine these goals, implying a very different model and interface. For example, these two children differed in their opinions in the discussions:

"You should set the goals that you want to reach" [Boy, 6th grade]

"*Set the goals would be something my parents do"* [Boy, 6th grade].

On the other hand, despite wanting to encourage self-regulation, nearly all the caregivers reported wanting to set-up goals for their children. For example, one parent remarked:

"Well I'm thinking set some tasks for [the children], like clean the room, or when they go home they need to do some tasks..." [Father]

Notably, this parent, as with most of the others, described home-based goals only with teachers, typically only describing school-based goals. Thus, the goals that can be managed by any particular caregiver—or even the child themselves—may be insufficient. Moreover, all caregivers are busy, and the creation, tracking, and management of goals can be time-intensive, leading some to suggest this work should be offloaded to the children:

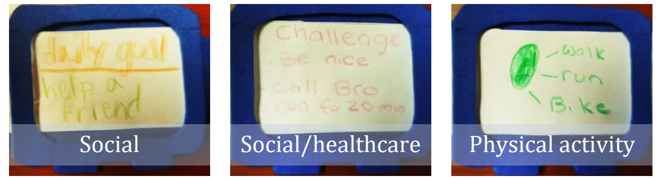

Figure 3. Sketches depicted different types of goals.

"Maybe [the children] can choose what kind of [goals] they want ... [Female Teacher]

Our findings indicate that a hybrid or collaborative approach may be ideal, which could be facilitated by collaborative technologies. For example, parents and teachers could use combined interfaces to share goals across contexts. Alternately, caregivers could guide the children in their goal-setting and help to monitor progress via their own interfaces.

Tracking and monitoring progress towards goals can be difficult. On the one hand, caregivers want to verify the goals directly:

I mean, something would be cool if I could verify [the goals] so he's not just checking oh I did everything, like ok really? like I'll have to open his mouth and look in his teeth [to verify if he brushes his teeth], or, for clean your room, I'm going to have to go in there and look… [Mother]

This approach indicates either a substantial amount of human work (e.g., in this case, checking inside the child's mouth) or a complex network of sensors and tracking technologies (e.g., a smart toothbrush).

On the other hand, children need to reflect and decide which goals they want to accomplish:

So there's a whole bunch of different goals that you can try to accomplish but still not be perfect at them. So at least just try your best… [Boy, 6th grade]

As this child noted above, visualizations and representations of progress should be motivational even if goals are not met. Tracking must always have some nuance and personalization. As the axiom goes, "measure what matters," but in this case, what matters is highly child, family, school, and context-dependent. Wearable technologies are particularly appealing given this issue, because some goals may be able to be tracked automatically at a highly detailed level via sensing and modeling techniques. For example, both children and caregivers suggested that physical activity and outside play is important for the children. Wearable technologies can easily automatically detect physical activity as well as the impact of that physical activity (e.g., heart rate). Such automatic tracking may provide additional independence and reduce the work related to tracking. However, automated tracking may be in tension with the mindfulness achieved from self-tracking and the inherent reflection associated with it [8].

Incentives and Rewards

Child development experts recommend continuing use of rewards even after children reach their initial goals [27]. The children in this study, all accustomed to a token economy from their school, understood and appreciated that the long-term goals were around intrinsic motivation. For example, one child noted:

"I feel like what should like to motivate you to go for the goals shouldn't be something physical. It would be like your internal motivation to, you know, to be better" [Boy, 6th grade].

Despite this awareness, most of the children suggested that they would also like to take advantage of receiving "real" rewards rather than either virtual rewards or relying on intrinsic motivation (Figure 4):

"After you've accomplished a goal, then you get a certain amount of coins that like your parents could put and then when you finish your goal, your parents can buy the gift for you…" [Boy, 5th grade]

These quotes indicate that children may be looking for some independence and use performing appropriate behaviors to earn money to fulfill their own desires. Then, to acquire self-regulation skills by children with ADHD, caregivers play an important role. Collaborative wearable technologies that engage both children and caregivers can support both the parental support provided by co-regulation and the long-term goal of independent self-regulation as we describe in more detail in the next sections.

Smartwatch as a Co-Regulation Assistant

As a child's ability to self-regulate increases, less caregiver co-regulation is required. Thus, any technological support should support the notion of fading out co-regulation strategies that involve humans. These might be removed entirely should independent self-regulation be developed or they might be replaced by the technologies themselves. Whether technological support is its own type of co-regulation is a larger debate within the child development community. One view indicates that the tool could be a therapeutic tool that teaches a skill to the child and then is abandoned. The alternative view would argue that the use of technology is a form of co-regulation, where the technology is the partner rather than a human caregiver.

Many of the children seemed to consider the use of technology to be a type of co-regulation but were divided about whether they should use technology aiming to be more "similar:" to neurotypical children. For example, one child described the use of such technology as "cheating":

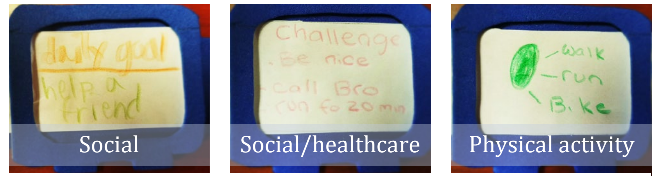

Figure 4. Sketches depicted different types of goals.

"it's better that you don't have [the reminders of stay on task from the teacher] because like I mean the only reason is if you wanted to be good at school, but like if you want to be a 'normal' kid like it doesn't have to have reminders so much. Like you should have [the reminders] and just get called out and stuff because it's kind of like 'cheating' like oh you got distracted…" [Boy, 5th grade]

While another child indicated that he would prefer to learn these strategies in a more traditional format:

"We don't want any feedback. It's nice here [at the school] when we're being told to focus. It's not ideal for us when it's the best that can happen because we do need to learn…" [Boy, 6th grade].

These quotes indicate that the children in this study currently understand technology more like something that should be used for lessons and less like assistive technologies that should be used in daily life. This response could be related to their existing experiences with technology. The students in the school from which we recruited all use iPads, Chromebooks, and large screens in their academic learning environment. During free time they are allowed to played videogames such as Nintendo Wii. However, none of them are current users of assistive technologies.

Tensions of Receiving Notifications

Our results indicate three inherent conflicts concerning notifications: attention and distraction; supporting emotion regulation without being overwhelming; and, notifications being notable for the children and unnoticed for their peers.

Attention and Distraction

Because notifications are a key function in wearables and mobile devices, it was not surprising that the children in this study described notifications as one of the most important features for supporting self-regulation and attention:

"It would be nice if the notification for 'be focused' was like a rumble, you know, something to make you think for a second…" [Girl, 6th grade]

However, prior research demonstrates that notification on mobile devices can also have a negative effect on conducting a task that requires high levels of attention [9]. The children themselves described this concern, particular while in class:

"[notifications] would make it more distracting to the teacher, to the class, distracting to the kids and it'd be a distraction to you." [Boy, 6th grade].

These results suggest that wearable technologies should avoid distraction when delivering notifications, in many ways, an inherent tension for wearable and mobile technologies more broadly [9,21,26].

Emotion Regulation

All participants suggested that providing notifications to support the regulation of emotions could be useful for the children. In the school, teachers and children use the "Zones of Regulation"[2] framework [22] to help children understand their emotions and behaviors during the day. Therefore, most of the discussion about emotion regulation with the children referenced the framework.

Children discuss opposing ideas of receiving notifications when they are in the "Green Zone" (regulated). While some of the children think that encouragement phrases (e.g., "You are doing great!") could serve as motivation, other children think that could be more useful when they are in the "Red Zone," this is, not-regulated (Figure 5):

"But if you're [not regulated, the smartwatch] must say 'be happy, be calm." [Girl, 5th grade]

However, during that time, notifications could also be harmful or ignored, as the children are having a difficult moment,

"If I was having a really hard time and I really didn't want to be talked to. I wouldn't want a [smartwatch] saying it, be calm or something, I would like some alone time sometimes" [Boy, 6th grade]

This result suggests that it is not enough to support the timing notification of children with self-regulation issues, as the arousal threshold of emotions is too small (*i.e.,* the intensity of the emotion). Then, timing notifications for when the child is not regulated should take into account the emotion and the intensity of the emotion to decide if notification is useful, or it could make the child feel worse. Additionally, there are still open challenges in identifying emotion using bio-sensors from wearables [6].

Visible Smartwatch with Invisible Notifications

Stigma remains a genuine concern with assistive technologies [41]. Although the advent of iPads, tiny hearing aids, and other mainstream technologies have served to reduce some of this stigma, the children in this study were still very much aware of the potential for embarrassment. Visible notifications, delivered at an incorrect time or in a way that draws attention, could create problematic situations for children with NDD, as in these two examples:

"What if I set down [my watch or phone] and my best friend comes by, and there's an alert right there saying [take deep breaths]." [Boy, 6th grade]

Figure 5. Sketches showing type of notification that children envision to have when they are dysregulated.

"I wouldn't want an alert saying "make sure to take deep breaths" when you are with your friends. That'd be kind of embarrassing." [Boy, 6th grade]

These children clearly envision themselves wearing a smartwatch, and receiving notifications, but those notifications must be unnoticed by others. Then, children suggested that the visual and tactile notifications are preferable than sounds:

"Umm, is it possible if [the smartwatch] can just give you like a little…like after the little vibration thing then it could just flash a color instead of saying it that way it can be a lot more quiet and a bit more efficient for when you want it to just be a bit more quiet…" [Boy, 5th grade]

Teachers suggested that encoding notifications in a manner that only the child will know what each notification means,

"I feel like if the notification was a vibration, or a very quiet ding, or something very quick, that's like a reminder that's like ok when there's 30 minutes left it vibrates once, if it's 10 minutes it vibrates twice, when there's 5 it vibrates three times, or it pulses when it's time to change, and they respond on it like a quick they click it like an I got it kinda thing…" [Male, Teacher]

These results show that not only the timing delivery of notification is important, but also how the notification is displayed has an important role when designing wearable technology in a social context where others could hear or see it, as this could be stigmatized. Then, wearables devices should be visible by all, but they could have an "invisible" application aim to assist.

Understanding physiological data

Most of the children described at least some interest in the physiological data available from a standard smartwatch. In particular, they all expressed awareness of heart rate measures even before the study and a basic understanding of the ubiquitous availability of such devices. For example,

[2] The zones of regulation framework divides the behaviors and emotions in four zones. In The Green is when children are calm, focus, and feeling ok. The Yellow is when they feel unfocused, silly or fidgety. The is when they are agitated, angry or mad. The Blue is when children are feeling lazy, tired or sad

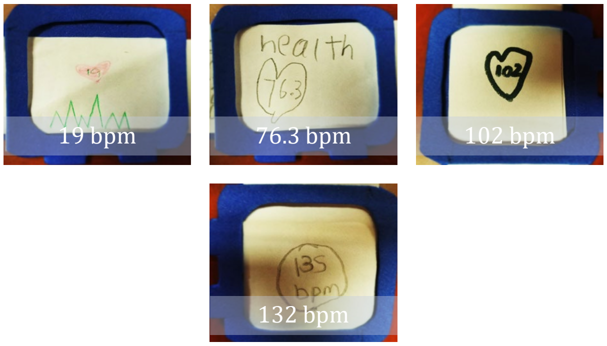

Figure 6. Sketches representing the beats per minute (bpm) from a heart rate.

"The good things about a smartwatch are that they can kind of detect your heart rate." [Girl, 6th grade]

However, the use of wearable technology for this information tended to be of relatively little importance to them beyond novelty. Most of the children described traditional approaches, such as measuring one's pulse by hand, or reflected on the limited utility of such a measure:

"I don't mind the idea of something that reads your heart rate, but you can do that by checking by hand…" [Boy, 6th grade]

"because you might want to check [the heart rate] just to know, but it's not going to be extremely important…" [Boy, 6th grade]

The comments regarding the heart rate, in particular, indicate that children may not fully understand physiological data measured by wearables. For example, in some sketches children drew a heart with a number indicating the beats per minute of a heart rate (Figure 6). However, this number was almost meaningless as it does not reflect an understanding of which values of numbers they get from a smartwatch.

Wearable technology for their use, then, should be able to provide information in a child-friendly manner. For example, children made inferences with heart rate information. Most of them match a "high" heart rate with being angry rather than for example, excited. They described lower heart rates as being associated with being sad, as opposed to at peace. They nearly universally showed a preference for inferring information from the raw data of the heart rate,

"Sometimes it's good to check your heart because sometime you'll be really mad and your heart rate raises levels." [Boy, 6th grade]

The challenge of heart rate levels changing due to many reasons (e.g., exercise, stress, consumption of foods and beverages) has long plagued wearable technology designers seeking to infer some emotional state or another context from this relatively simple sensor [35]. The children in this study made almost no attempt to deeply understand nor any interest in long-term tracking of these detailed data. They were, however, quick to infer causality of the heart rate levels (Figure 7). The end result, then, is that children may be

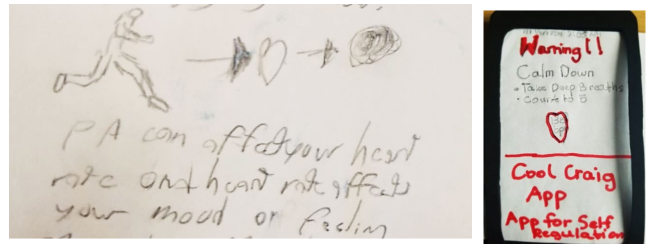

Figure 7. A child sketch showing a relationship between physical activity (PA), heart rate and mood (left). A smartwatch sketch showing a warning signal when the heart rate reaches a certain level.

particularly prone to misinterpretation and over-interpretation of simple bio-signals from wearable sensors. This leads to challenges concerning the proper manner to present physiological information to children and how they are going to interpret this information. Especially for children, it is recommended that heart rate feedback should be individualized to knowledge level, cognitive abilities, and interest of children [29]. Then, the automatic detection of emotion and behaviors could be useful to provide timing notification. However, this is currently an open challenge.

DISCUSSION

The results of this work show that children with ADHD are willing to participate in design sessions and wear a smartwatch. However, a variety of challenges and tensions are inherent to this platform as a solution for interventions in daily life. In this section, we discuss opportunities and challenges of conducting design sessions with children with ADHD and three key tensions that must be considered in the design of applications to support children with ADHD and their caregivers.

Participatory design with children with ADHD

Recent calls for greater participation by people with disabilities—especially children—in the design process [13,46] warrant engagement and inclusion at this level. Inclusion, in this case, necessitates creating processes and an environment in which children who process the world differently can be successful.

In our work, the research team encouraged children to discuss each topic in different manners (e.g., focus group, sketching). With ample time for breaks, discussions then focused sometimes on more general questions to understand children's overall experience with technology and self-regulation strategies. At other times, the discussions were focused on a specific topic, such as how a smartwatch could assist those practices. By including breaks and varying topics, activities, and times, we were able to create an inclusive environment and hear directly from the children about their own experiences.

Our research team also explicitly followed two strategies that had been successfully deployed in the school in which we were working. First, during focus groups, a TV always displayed the topic of discussion allowing children to self-direct of staff to redirect attention back to the topic of interest. Second, during the sketching activity, the researcher leading the workshops provided regular reminders about the current topic of the sketch and the time left to finish. The children shared their sketches to encourage engagement.

This study demonstrates that participatory design sessions with children with ADHD are possible and to be encouraged. With appropriate accommodations, including support from staff, structuring of the sessions, and motivation through sharing, researchers can better understand the point of view of children, while empowering children to participate in treatment and the design of applications to help support their needs.

Toward a Standalone Smartwatch

Most of the current smartwatches are not truly independent devices, but they are non-intrusive wearable technology that allows the users to gather physiological data given their continual connection with the skin [37]. However, to achieve this vision, the smartwatch must be small enough to be worn on the arm, even for small children. The size of the display restricts input and output interaction compared with larger devices [11], and the sensory and motor difficulties experienced by many children with ADHD [19] add to the challenges in both collecting and using sensor data.

Therefore, *a potential solution* is to explore how touch interactions could be supplemented with other types of interaction appropriate for a wearable context (e.g., voice, haptic, gestural, projections).

Smartwatches can easily sense and record private information, such as physiological responses, locations, social media, and movements. Children with ADHD in our study express concerns that their data could be stolen, and they would like to preserve some notion of personal and private data, even from their parents.

Therefore, *a potential solution when designing smartwatch applications* is that all the data should be secure and protected depending on the context of use to reduce stigma and unauthorized exposures. Moreover, children must be able to understand which data they are sharing with their parents and what mechanisms the devices are using to collect, analyze, and share these data.

Open questions remain about what kind of data parents could—and should—be able to access to help them be aware of their children's behavior without violating the children's views of where and how their data are stored, shared, and displayed. Because wearable technologies are so personal, being worn literally on the body, children tended to see them as something quite private and owned by the individual. In a collaborative system that involves parental support, additional work must be done from a design standpoint to ensure that children understand how private, personal, and sometimes physiological data might come off the device—and therefore off the body—and into the cloud to service the entire family.

Let's Regulate Together

Pre-adolescents, in general, are looking for independence, but they still need "social-support" [25]. For children with ADHD, as they continuously struggle to manage their attention, behaviors, and emotions, it is crucial to provide guidance on how to be more regulated. Therefore, learning self-regulation requires teamwork between caregivers and the child.

A potential solution is not to design an individual-focused application. We should create friendly environments where children feel secure and supported by their caregivers. Previous research in HCI has shown the importance of designing applications for families of children with disabilities [44], a finding echoed in this work.

Moreover, wearable individual and collaborative applications should supplement existing practices of self-regulation, as it has been shown that this could ease the transition between current interventions and technology-based interventions [20]. For example, in this study, teachers follow a token-based economy to maintain the motivation of children to accomplish goals, and the "Zones of regulation" framework [22], to reflect around their emotions and behaviors. This framework has been previously used in a smartwatch application supporting children with intellectual disabilities to inform their current emotions at the school [52,53]. However, adapting these largely individualized self-regulation frameworks and instructional aides to a collaborative co-regulation model is yet to be tested clinically.

In concern with the establishment of clinically validated co-regulation strategies, *a potential solution* is to develop collaborative technologies that use a mix of human and machine support. Wearable applications have the potential to empower children to engage in their own regulation activities while still depending partially on computational and human supports that collaboratively set goals, reward behaviors, and so on. In this way, we can support children and caregivers to accomplish goals in a more straightforward and usable manner. Because teachers and parents of children with disabilities are under continuous stress [34], mixed-initiative [18] collaborative technologies that support hybrid models of engagement amongst families and intelligent systems can shift some burdens.

The Paradox of Notification

The literature of HCI, UbiComp, and mobile technologies is filled with the paradox of mobile notification. The design of applications plays a crucial role in deciding which side we want to be, as Don Norman said:

> *"Can wearable devices be helpful? Absolutely. But they can also be horrid. It all depends upon whether we use them to focus and augment our activities or to distract. It is up to us, and up to those who create these new wearable wonders, to decide which it is to be.*" [32]

Notifications on mobile technology can cause inattention and hyperactivity in the general population [21]. However, in Psychiatry research, it has been shown that for people with ADHD (who exhibit those symptoms), notifications could help them in improving medication adherence [50] and increasing physical activity [40].

In particular, notifications should redirect the attention of children when not focused, without unnecessarily distracting them when they are focused. Indeed, with an appropriate intelligent model for the notion of "focus," devices could only deliver notifications when the children are unfocused. However, the development of sensing technologies and machine models for "focus" remains a technical challenge. Additionally, wearable technologies have the potential to interrupt nearby children, creating even more complexity to a model for when and how to deliver such notifications. Therefore, *solutions should be focused* on creating wearable applications that take advantage of notification and use the proper feedback for children with ADHD to avoid annoyance, harmfulness, and embarrassing situations.

Although there are still many open challenges in smartwatch sensing physiological data, our results indicate several opportunities for future work in this space. First, we need to collect and validate physiological data sets for children with ADHD against existing models for neurotypical children and adults. Using these datasets, we can generate models that allow us to ease the interpretation of emotional responses and behavior. Improved models can provide better timed and more helpful notifications with limited distraction.

LIMITATIONS

Although this works produces contributions to the design of wearable technologies, there are some limitations. The study was conducted only in one school, and all of the children had at least some experience with smartphones. The school was a special educational need (SEN) school. Therefore, children's experiences may differ from those within a mainstream school. For example, the strategies followed in the SEN could affect the strategies that children suggested to support self-regulation. Another limitation is that the number of girls enrolled in the study was very low, as a consequence of the current ratio of ADHD in girls (i.e., the sex ratio ranging from 2:1 to 10:1 [30,36,51]). Thus, in this study, we are not able to highlight differences of perspective between gender. Therefore, additional studies with more participants should be conducted to evaluate the transferability of our results. As future work, we plan to develop an application that balances the tensions we found in this study to deploy a pilot application and evaluate its efficacy as a tool to support self-regulation for children with ADHD.

CONCLUSION

This paper presents the results from a qualitative study with children and their caregivers in participatory design sessions. All the children in this study attend a school focused on behavioral challenges, many of whom have diagnoses of ADHD and other NDD. All of the participants were capable and excited to participate as designers of a novel piece of technology. In this study, we identified tensions and challenges when trying to design applications for wearable technology supporting children with ADHD. First, designers and HCI researchers should balance the capabilities of having a standalone smartwatch application or having a hybrid system. Second, when supporting self-regulation, researchers should take into account the needs of both children with ADHD and their caregivers. Finally, notifications should balance the tensions between 1) redirect the attention with the disruptions caused by them, 2) being visible for the child but invisible for others, and 3) supporting when children are not-regulated without annoying them. These results indicate not only what should be considered when designing such technologies and implementing policies around them but also reinforce the ability and appropriateness of inclusion of children, especially those with disabilities, in the design of their futures.

Overall, this qualitative study reveals design tensions for wearable applications supporting the self- and co-regulation of children with ADHD. This study reinforces that the form factor of wearables and balancing the trade-off of notifications are a fundamental part of designing useful applications supporting people with NDD. Moreover, our results indicate the urgent need for designing social wearables, where children and their caregivers can collaborate to accomplish common goals, and they can learn and practice valuable self-regulation skills.

ACKNOWLEDGMENTS

Research reported in this abstract was supported by AHRQ and the National Institutes of Health under award number 1R21HS026058-01A1 and a Jacobs Foundation Advanced Research Fellowship. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health nor the Jacobs Foundation.

REFERENCES

[1] American Psychiatric Association. 2013. Diagnostic and Statistical Manual of Mental Disorders (DSM-5®). https://doi.org/10.1176/appi.books.9780890425596.744053

[2] Alissa N. Antle, Leslie Chesick, Srilekha Kirshnamachari Sridharan, and Emily Cramer. 2018. East meets west: a mobile brain-computer system that helps children living in poverty learn to self-regulate. *Personal and Ubiquitous Computing* 22, 4: 839–866. https://doi.org/10.1007/s00779-018-1166-x

[3] Beatrice Aruanno, Franca Garzotto, Emanuele Torelli, and Francesco Vona. 2018. HoloLearn: Wearable Mixed Reality for People with Neurodevelopmental Disorders (NDD) Beatrice. In *Proceedings of the 20th International ACM*

SIGACCESS Conference on Computers and Accessibility - ASSETS '18, 40–51. https://doi.org/10.1145/3234695.3236351

[4] Matt Bower and Daniel Sturman. 2015. What are the educational affordances of wearable technologies? *Computers and Education* 88: 343–353. https://doi.org/10.1016/j.compedu.2015.07.013

[5] LouAnne E. Boyd, Alejandro Rangel, Helen Tomimbang, Andrea Conejo-Toledo, Kanika Patel, Monica Tentori, and Gillian R. Hayes. 2016. SayWAT: Augmenting Face-to-Face Conversations for Adults with Autism. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*: 4872–4883. https://doi.org/10.1029/EO068i003p00033-02

[6] Pascal Budner, Joscha Eirich, and Peter A Gloor. 2017. "Making you happy makes me happy" Measuring Individual Mood with Smartwatches. *arXiv preprint arXiv:1711.06134.*: 1–14.

[7] Kathy Charmaz. 2006. *Constructing grounded theory: a practical guide to through qualitative analysis*. Sage Publications Ltd, London. https://doi.org/https://doi.org/10.7748/nr.13.4.84.s4

[8] Eun Kyoung Choe, Saeed Abdullah, Mashfiqui Rabbi, Edison Thomaz, Daniel A. Epstein, Felicia Cordeiro, Matthew Kay, Gregory D. Abowd, Tanzeem Choudhury, James Fogarty, Bongshin Lee, Mark Matthews, and Julie A. Kientz. 2017. Semi-Automated Tracking: A Balanced Approach for Self-Monitoring Applications. *IEEE Pervasive Computing* 16, 1: 74–84. https://doi.org/10.1109/MPRV.2017.18

[9] Edward Cutrell, Mary Czerwinski, and Eric Horvitz. 2001. Notification, Disruption, and Memory: Effects of Messaging Interruptions on Memory and Performance. *Conference on Human-Computer Interaction Interact 2001*, 1999: 263–269.

[10] Jeffrey S. Danforth, Elizabeth Harvey, Wendy R. Ulaszek, and Tara Eberhardt McKee. 2006. The outcome of group parent training for families of children with attention-deficit hyperactivity disorder and defiant/aggressive behavior. *Journal of Behavior Therapy and Experimental Psychiatry* 37, 3: 188–205. https://doi.org/10.1016/j.jbtep.2005.05.009

[11] Milad Dehghani and Ki Joon Kim. 2019. The effects of design, size, and uniqueness of smartwatches: perspectives from current versus potential users. *Behaviour and Information Technology* 0, 0: 1–11. https://doi.org/10.1080/0144929X.2019.1571111

[12] Victor Dibia. 2016. FOQUS: A smartwatch application for individuals with ADHD and mental health challenges. *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS)*: 311–312. https://doi.org/10.1145/2982142.2982207

[13] Christopher Frauenberger, Julia Makhaeva, and Katharina Spiel. 2017. Blending Methods: Developing Participatory Design Sessions for Autistic Children. *Proceedings of the 2017 Conference on Interaction Design and Children - IDC '17*: 39–49. https://doi.org/10.1145/3078072.3079727

[14] Franca Garzotto, Mirko Gelsomini, Vito Matarazzo, Nicolo Messina, and Daniele Occhiuto. 2018. Designing Wearable Immersive "Social Stories" for Persons with Neurodevelopmental Disorder Franca. In *International Conference on Universal Access in Human-Computer Interaction*, 517–529. https://doi.org/10.1007/978-3-319-92049-8

[15] M. Gisladottir and E. K. Svavarsdottir. 2017. The effectiveness of therapeutic conversation intervention for caregivers of adolescents with ADHD: a quasi-experimental design. *Journal of Psychiatric and Mental Health Nursing* 24, 1: 15–27. https://doi.org/10.1111/jpm.12335

[16] Amanda C. Gulsrud, Laudan B. Jahromi, and Connie Kasari. 2010. The Co-regulation of emotions between mothers and their children with autism. *Journal of Autism and Developmental Disorders* 40, 2: 227–237. https://doi.org/10.1007/s10803-009-0861-x

[17] Gillian R. Hayes, Lamar M. Gardere, Gregory D. Abowd, and Khai N. Truong. 2008. CareLog: A selective Archiving Tool for Behavior Management in Schools. In *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08*, 685. https://doi.org/10.1145/1357054.1357164

[18] Eric Horvitz. 1999. Principles of Mixed-Initiative User Interfaces. In *the SIGCHI conference*, 159–166. Retrieved from http://portal.acm.org/citation.cfm?doid=302979.303030%5Cnpapers2://publication/doi/10.1145/302979.303030

[19] M. L. Kaiser, M. M. Schoemaker, J. M. Albaret, and R. H. Geuze. 2015. What is the evidence of impaired motor skills and motor control among children with attention deficit hyperactivity disorder (ADHD)? Systematic review of the literature. *Research in Developmental Disabilities* 36: 338–357. https://doi.org/10.1016/j.ridd.2014.09.023

[20] Julie A. Kientz, Sebastian Boring, Gregory D. Abowd, and Gillian R. Hayes. 2005. Abaris: Evaluating automated capture applied to structured autism interventions. *Lecture Notes in Computer*

Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 3660 LNCS: 323–339.

[21] Kostadin Kushlev, Jason Proulx, and Elizabeth W. Dunn. 2016. "Silence Your Phones": Smartphone Notifications Increase Inattention and Hyperactivity Symptoms. In *Proceedings of the 2016 CHI conference on human factors in computing systems*, 1011–1020. https://doi.org/10.1145/2858036.2858359

[22] Leah Kuypers. 2011. *The Zones of Regulation: A Curriculum Designed to Foster Self-Regulation and Emotional Control*. Social Thinking, San Jose, CA.

[23] Lauren M. Little, Evan Dean, Scott Tomchek, and Winnie Dunn. 2018. Sensory Processing Patterns in Autism, Attention Deficit Hyperactivity Disorder, and Typical Development. *Physical and Occupational Therapy in Pediatrics* 38, 3: 243–254. https://doi.org/10.1080/01942638.2017.1390809

[24] Richard E.A. Loren, Aaron J. Vaughn, Joshua M. Langberg, Jessica E.M. Cyran, Tara Proano-Raps, Beverly H. Smolyansky, Leanne Tamm, and Jeffery N. Epstein. 2015. Effects of an 8-Session Behavioral Parent Training Group for Parents of Children With ADHD on Child Impairment and Parenting Confidence. *Journal of Attention Disorders* 19, 2: 158–166. https://doi.org/10.1177/1087054713484175

[25] Christine Kerres Malecki and Michelle Kilpatrick Demaray. 2002. Measuring perceived social support: Development of the Child and Adolescent Social Support Scale (CASSS). *Psychology in the Schools* 39, 1: 1–18. https://doi.org/10.1002/pits.10004

[26] Gloria Mark, Mary Czerwinski, and Shamsi T. Iqbal. 2018. Effects of individual differences in blocking workplace distractions. *Conference on Human Factors in Computing Systems - Proceedings* 2018-April: 1–12. https://doi.org/10.1145/3173574.3173666

[27] Johnny L. Matson and Jessica A. Boisjoli. 2009. The token economy for children with intellectual disability and/or autism: A review. *Research in Developmental Disabilities* 30, 2: 240–248. https://doi.org/10.1016/j.ridd.2008.04.001

[28] Megan McClelland, John Geldhof, Fred Morrison, Steinunn Gestsdóttir, Claire Cameron, Ed Bowers, Angela Duckworth, Todd Little, Jennie Grammer, and 1. 2018. Self-Regulation. In *Handbook of Life Course Health Development*. Springer, 275–298.

[29] Alison M. McManus, Rich S.W. Masters, Raija M.T. Laukkanen, Clare C.W. Yu, Cindy H.P. Sit, and Fiona C.M. Ling. 2008. Using heart-rate feedback to increase physical activity in children. *Preventive Medicine* 47, 4: 402–408. https://doi.org/10.1016/j.ypmed.2008.06.001

[30] Florence D. Mowlem, Mina A. Rosenqvist, Joanna Martin, Paul Lichtenstein, Philip Asherson, and Henrik Larsson. 2019. Sex differences in predicting ADHD clinical diagnosis and pharmacological treatment. *European Child and Adolescent Psychiatry* 28, 4: 481–489. https://doi.org/10.1007/s00787-018-1211-3

[31] D. W. Murray and K Rosanbalm. 2017. Promoting Self-Regulation in Adolescents and Young Adults: A Practice Brief. *OPRE Report #2015-82. Washington, DC: Office of Planning, Research, and Evaluation, Administration for Children and Families, U.S. Department of Health and Human Services.*: 1–6.

[32] Don Norman. 2013. The Paradox of Wearable Technologies. *MIT Technology Review*. Retrieved from https://www.technologyreview.com/s/517346/the-paradox-of-wearable-technologies/

[33] Laura Pina, Kael Rowan, Paul Johns, Asta Roseway, Gillian Hayes, and Mary Czerwinski. 2014. In Situ Cues for ADHD Parenting Strategies Using Mobile Technology. In *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare*. https://doi.org/10.4108/icst.pervasivehealth.2014.254958

[34] Anthony J. Plienis, Frank R. Robbins, and Glen Dunlap. 1988. Parent adjustment and family stress as factors in behavioral parent training for young autistic children. *Journal of the Multihandicapped Person* 1, 1: 31–52. https://doi.org/10.1007/BF01110554

[35] Daniel S. Quintana, Adam J. Guastella, Tim Outhred, Ian B. Hickie, and Andrew H. Kemp. 2012. Heart rate variability is associated with emotion recognition: Direct evidence for a relationship between the autonomic nervous system and social cognition. *International Journal of Psychophysiology* 86, 2: 168–172. https://doi.org/10.1016/j.ijpsycho.2012.08.012

[36] Ujjwal P. Ramtekkar, Angela M. Reiersen, Alexandre A. Todorov, and Richard D. Todd. 2010. Sex and age differences in Attention-Deficit/Hyperactivity Disorder symptoms and diagnoses: Implications for DSM-V and ICD-11. *Journal of the American Academy of Child & Adolescent Psychiatry* 49, 3: 217–228. https://doi.org/10.1016/j.cortex.2009.08.003.Predictive

[37] Reza Rawassizadeh, Blaine A. Price, and Marian

Petre. 2015. Wearables: Has The age of smartwatches finally arrived? *Communications of the ACM* 58, 1: 45–47. https://doi.org/10.1145/2629633

[38] Blaine Reeder and Alexandria David. 2016. Health at hand: A systematic review of smart watch uses for health and wellness. *Journal of Biomedical Informatics* 63: 269–276. https://doi.org/10.1016/j.jbi.2016.09.001

[39] Robert Reid, Alexandra L. Trouth, and Michalla Schartz. 2005. Self-regulation Interventios for Children with Attention Deficit/Hyperactivity Disorder. *Concil for Exceptional Children* 71, 4: 362–377.

[40] Erin Schoenfelder, Megan Moreno, Molly Wilner, Kathryn B. Whitlock, and Jason A. Mendoza. 2017. Piloting a mobile health intervention to increase physical activity for adolescents with ADHD. *Preventive Medicine Reports* 6: 210–213. https://doi.org/10.1016/j.pmedr.2017.03.003

[41] Kristen Shinohara and Jacob O. Wobbrock. 2011. In the shadow of misperception: Assistive technology use and social interactions. In *Conference on Human Factors in Computing Systems - Proceedings*, 705–714. https://doi.org/10.1145/1978942.1979044

[42] Will Simm, Maria Angela Ferrario, Adrian Gradinar, Marcia Tavares Smith, Stephen Forshaw, Ian Smith, and Jon Whittle. 2016. Anxiety and Autism: Towards Personalized Digital Health. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, 1270–1281. https://doi.org/10.1145/2858036.2858259

[43] Dorothé Smit and Saskia Bakker. 2015. BlurtLine: A Design Exploration to Support Children with ADHD in Classrooms. In *INTERACT*, 456–460. https://doi.org/10.1007/978-3-319-22723-8

[44] Tobias Sonne, Jörg Müller, Paul Marshall, Carsten Obel, and Kai Grønbæk. 2016. Changing family practices with assistive technology: MOBERO improves morning and bedtime routines for children with ADHD. *Conference on Human Factors in Computing Systems - Proceedings*: 152–164. https://doi.org/10.1145/2858036.2858157

[45] Tobias Sonne, Carsten Obel, and Kaj Grønbæk. 2015. Designing Real Time Assistive Technologies: A Study of Children with ADHD. In *OzCHI*, 34–38. https://doi.org/10.1007/978-3-319-32270-4

[46] Katta Spiel, Christopher Frauenberger, O. S. Keyes, and Geraldine Fitzpatrick. 2019. Agency of autistic children in technology research - A critical literature review. *ACM Transactions on Computer-Human Interaction* 26, 6. https://doi.org/10.1145/3344919

[47] Kenji Suzuki, Taku Hachisu, and Kazuki Iida. 2016. EnhancedTouch: A Smart Bracelet for Enhancing Human- Human Physical Touch. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, 1282–1293. https://doi.org/10.1145/2858036.2858439

[48] Victoria Ting and Jonathan A. Weiss. 2017. Emotion Regulation and Parent Co-Regulation in Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders* 47, 3: 680–689. https://doi.org/10.1007/s10803-016-3009-9

[49] Juan C. Torrado, Javier Gomez, and Germán Montoro. 2017. Emotional self-regulation of individuals with autism spectrum disorders: Smartwatches for monitoring and interaction. *Sensors (Switzerland)* 17, 6. https://doi.org/10.3390/s17061359

[50] Omri Weisman, Yael Schonherz, Tal Harel, Martin Efron, Maya Elazar, and Doron Gothelf. 2018. Testing the efficacy of a smartphone application in improving medication adherence, among children with ADHD. *Israel Journal of Psychiatry* 55, 2: 59–64.

[51] Erik G. Willcutt. 2012. The Prevalence of DSM-IV Attention-Deficit/Hyperactivity Disorder: A Meta-Analytic Review. *Neurotherapeutics* 9, 3: 490–499. https://doi.org/10.1007/s13311-012-0135-8

[52] Hui Zheng and Vivian Genaro Motti. 2018. Assisting Students with Intellectual and Developmental Disabilities in Inclusive Education with Smartwatches. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*: 1–12. https://doi.org/10.1145/3173574.3173924

[53] Hui Zheng and Vivian Genaro Motti. 2017. WeLi. *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility - ASSETS '17*, October 2017: 355–356. https://doi.org/10.1145/3132525.3134770

[54] Hui Zheng, Vivian Genaro Motti, Kudirat Giwa-lawal, Anna Evmenova, and Heidi Graff. 2019. Evaluating WELI: A Wrist-Worn Application to Assist Young Adults with Neurodevelopmental Disorders in Inclusive Classes Hui. In *INTERACT*, 114–134. https://doi.org/10.1007/978-3-030-29384-0