From Research to Practice: Informing the Design of Autism Support Smart Technology

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ABSTRACT
Smart technologies (wearable and mobile devices) show tremendous potential in the detection, diagnosis, and management of Autism Spectrum Disorder (ASD) by enabling continuous real-time data collection, identifying effective treatment strategies, and supporting intervention design and delivery. Though promising, effective utilization of smart technology in aiding ASD is still limited. We propose a set of implications to guide the design of ASD-support technology by analyzing 149 peer-reviewed articles focused on children with autism from ACM Digital Library, IEEE Xplore, and PubMed. Our analysis reveals that technology should facilitate real-time detection and identification of points-of-interest, adapt its behavior driven by the real-time affective state of the user, utilize familiar and unfamiliar features depending on user-context, and aid in revealing even minuscule progress made by children with autism. Our findings indicate that such technology should strive to blend-in with everyday objects. Moreover, gradual exposure and desensitization may facilitate successful adaptation of novel technology.

Authors' Keywords
Autism; Smart Technology; Children; Adolescents; Wearable Devices; Smartphone.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

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INTRODUCTION
In recent years autism has become prevalent worldwide. According to data collected in 2012, Centers for Disease Control and Prevention (CDC) reported that 1 in 68 children in the United States has been diagnosed with Autism Spectrum Disorder (ASD) [21]. A recent survey by CDC (published in November 2015) estimated an increase in children with autism, reporting a diagnosis of 1 in 45 [122]. Based on data collected in 2012, globally, 62 out of 10000 people were reported to be on the spectrum [29]. However, this lower number was attributed to a lack of evidence from low and middle-income countries [29].

With the emergence of smart technologies (wearable and mobile devices), researchers and technology designers are increasingly utilizing these to address challenges pertaining to autism. Issues with social communication and social interaction, repetitive behaviors, hyperactivity, impulsivity (acting without thinking), short attention span, aggression, and self-injury are common in children with autism (we use 'children' to refer to infants, kids, and adolescents, or individuals between the ages of 1 and 18). Smart technologies show great promise in improving social and communication effectiveness [36–38, 105, 110], enhancing learnability [53], and detecting and managing repetitive and problematic behaviors [3, 72, 125]. Smart technologies also enable continuous monitoring of children with autism, recording internal physiological states, external behavioral sequelae, [52, 57, 95] and surrounding context [69], which could inform the design and delivery of just-in-time interventions. In addition, children with autism show a preference for interactive technologies [5, 25, 46, 58, 60, 80], indicating that smart technologies may be an effective choice for the design of ASD-support technology.

Our research goal is to investigate how to best design smart technologies to aid children with autism. Our definition of smart technologies include wearable sensors and devices (e.g., biosensors, wrist and chest band, smart watch, glasses and gloves), sensors (e.g., GPS, EDA, Gyroscope), robots embedded with sensors, virtual reality (VR) realized using wearables (e.g., google cardboard) and smartphones.

Several researchers focused on eliciting requirements for designing ASD-support technology [11, 87, 108]. Boucenna et al. explored studies involving interactive technologies for children with autism, specifically focusing on ICT applications and robots [11]. Ramdoss et al. analyzed studies that used computer-based interventions (CBI) and provided a guideline for improving the efficacy of CBI [87]. Virnes et al. focused on research that involved computer as the underlying technology [108]. Unlike these research, we focus on research utilizing emerging smart technologies as these devices show tremendous promise in addressing many challenges pertaining to autism.

Another relevant thread of research focused on specific types of smart technologies such as facial emotion recognition [44, 118], gait analysis with wearable sensors [20], eye tracking [81], robot [27], VR [9, 83], and websites and mobile applications [26]. Unlike these research, we aim to uncover the best design practices involving any types of smart technologies. We believe that to gain a deeper understanding of the challenges and opportunities in designing ASD-support smart technologies, it is imperative to investigate these technologies collectively.

To achieve our research goal, we reviewed 149 articles collected using an extensive systematic search on three prominent databases - ACM Digital Library (ACM DL), IEEE Xplore, and PubMed. To understand current trends, challenges, and effectiveness pertaining to smart technologies and to elicit design guidelines, we coded and analyzed these articles. Our findings reveal that while utilization of smart technologies is becoming more common, at present these technologies are not utilized to their fullest potential. Also, some areas of ASD are well-represented (e.g., affect detection, social interaction, and repetitive and problem behaviors) while others are severely underexplored (e.g., independent living, engaging and maintaining long-term relationships). A vast majority of research in this area focused on the developed countries and as such provided limited insight to design technology that will be effective globally. We propose a set of guidelines driven by our analysis and are also grounded on assistive technology research, and our experience of working with different stakeholders (children with autism and their families, therapists, and educators).

In this paper, we make the following contributions:

- We conduct an extensive systematic literature review on smart technologies aiming to support children with autism. Our analysis reveals trends in ASD-research, strategies and technologies considered effective, and challenges in utilizing such technologies.
- We provide a set of guidelines which are grounded on findings from existing literature and inspired by our experience of working with children with autism and related stakeholders. We hope that these guidelines would inspire researchers and technology developers to design better ASD-support smart technologies.
- We identify areas that received little attention from researchers and technology designers but have tremendous potential to positively influence the lives of children with autism and relevant stakeholders, such as parents, teachers, and therapists.

RESEARCH METHODOLOGY

Data collection / Search Strategy

We conducted a systematic keyword-based search on three major databases, ACM DL, IEEE Xplore, and PubMed, in May 2017. Figure 1 presents the search string:

(wearabl* **OR** smartwatch **OR** "activity tracker" **OR** Band **OR** smartphone **OR** "mobile phone" **OR** "cell phone" **OR** android **OR** ios **OR** iphone **OR** ipad)

AND

(child **OR** child* **OR** adolescent **OR** boy **OR** girl **OR** kid)

AND

(autis* **OR** asperger **OR** “pervasive developmental disorder” **OR** ASDs **OR** PDD-NOS **OR** ASD)

Figure 1. Search string used to collect research articles

We used an asterisk (*) after a keyword to include all words beginning with that word. We did not apply any date restriction in our search. The keywords used to search relevant articles were compiled by discussing with all members of the research team. We tried to use all possible combinations of the key terms to extract as many relevant articles as possible. However, we might miss some relevant articles for the following reasons: (a) IEEE Xplore restricts the maximum number of keywords (N=15) that can be used in a search. As a result, we had to remove some keywords (e.g., band, Android, iOS, iPhone, iPad, and PDD-NOS) while searching IEEE Xplore database; (b) the word “mobile” is widely used to indicate mobility of an object/person in addition to indicate “cell phone” and as such we intentionally used “mobile phone” instead of “mobile” in our search query; (c) we focused on children and as such did not include articles that focused on adults with autism. However, we later found a few articles that not only focused on adults but also offered insights about adolescents (who in our definition are children). For instance, [13] was not retrieved in our search but is relevant to our research; and (d) we did not include “neurodevelopmental disorder” and “neurodiversity” in our search query, which may result in additional relevant articles. In a later search, we included these two keywords, which resulted in 17, 10, and 0 new articles on IEEE Xplore, PubMed, and ACM DL respectively. While these 27 articles focus on ASD, they did not meet our inclusion criteria, as they did not focus on smart technologies.

Selection Criteria

Our keyword-based search resulted in 524 papers, which were imported into Mendeley (www.mendeley.com). After duplicate removal (N=10), three reviewers (co-authors of this paper) independently reviewed the titles and abstracts of the remaining 514 articles to determine relevance. An article was considered relevant if it fulfilled the following four criteria: 1) the article must be written in English; 2) the article focused on smart technology; 3) the article focused on children (infant, kids, teens, or adolescents); and 4) the article focused on any form of autism (Asperger, pervasive developmental disorder). In case of disagreement or confusion about the relevancy of an article, a fourth reviewer reviewed the title and abstract, and all confusion was resolved based on group discussion. By using the selection criteria, we identified 168 relevant articles for full-text review. In this phase, we discarded 19 articles (8 articles were irrelevant, for one article title and abstract were in English but the body was in a different language, and 10 articles were inaccessible), resulting in our final corpus of 149 articles (Figure 2 highlights this process).

Data Extraction and Coding

149 articles were selected for open coding [66] by using Atlas.ti (http://atlasti.com). Initially, we randomly selected a small subset from these 149 articles and collectively identified 34 initial codes (e.g., methodology, collected data type, wearable type, research assumption) to answer our primary research question (*how to best design smart technologies to aid children with autism*). Each research team member coded two to four articles per week. During this process, we identified relevant new codes (e.g., study duration, location, inclusion criteria) and discussed these codes in weekly brainstorming sessions. Upon agreement, we included these new codes to the original code list and re-coded all previously coded articles with the final code list. In total, our list contained 109 codes; however, in this paper, we reported findings pertaining to a subset of these codes (directly relevant to our primary research question).

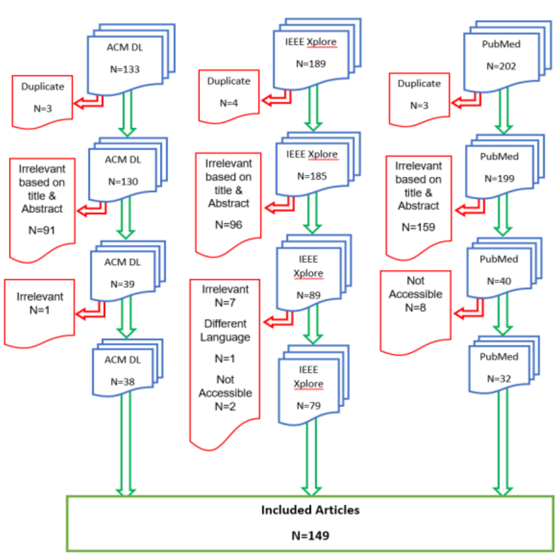

Figure 2: Flow diagram of article selection process

Technology	# of Papers
Smartphones	58
Wearables (smart glass, smartwatch, wristband, chest band, biosensors, eye tracker, smart gloves, camera)	51
Robot (realized using embedded sensors and/or smartphone)	14
VR (realized using wearable technology)	11
Other technologies (games, sensor embedded in toys, in-home sensors)	28

Table 1: Categorization of papers based on types of technology utilized

We used our primary research question as a guide to cluster codes into multiple broad categories (e.g., Technology type, Problem Areas Addressed, Target Stakeholders). After comparing these categories and consolidating them, we finalized themes, which we will discuss in the next three sections (Findings, Do's and Don'ts in Designing Effective ASD-Support Technology, and Discussion).

FINDINGS

Technology

In our research, we focused on smart technologies (see Table 1 for a summary of technology used). The total number of papers is more than 149 as several papers used multiple smart technologies. In addition, while reporting important findings pertaining to the design of ASD-support technology, we excluded proposal papers and meta-reviews.

Wearable Technologies

Wearable technologies are available in different forms such as smartwatches, wrist/chest/ankle bands, head-mounted displays, and cameras. Wearable technologies were used for early detection of autism [16, 115], monitoring affect [68, 69, 114], enhance social interaction, engagement [24, 99], and awareness [51], detect repetitive and problem behavior [3, 72, 125], and teach important life skills [121, 125].

Some common types of wearables such as gyroscope, accelerometer, and magnetometer were used along with sensors embedded in small toys. To detect physiological data, affect (emotion, distress) and activity, ECG (electrocardiogram), EEG (electroencephalogram), EDA (electrodermal activity), EMG (electromyogram), and skin temperature were primarily used [10, 19, 23, 52, 57, 64, 95, 97, 113]. Recently, researchers started investigating the efficacy of therapeutic clothing embedded with sensors as a tool for collecting physiological data [113] and for providing haptic feedback [28, 102], especially for children with autism [26]. Physiological biosensors, eye trackers, and head-mounted devices were commonly used to collect attention and affect [68, 69, 114]. In addition, wearable cameras were used to capture the surrounding environment to provide awareness as well as training children with autism to recognize socio-emotional context [52].

Research utilizing wearables pointed out their tremendous potential as ASD-support technology. We found that the usage and evaluation of such technology were limited to pilot studies where they were used in controlled environments and/or for a brief period. Many wearables possess limited processing power, storage, and battery life - rendering them unsuitable for complex calculation and data processing [114]. Some wearables, especially, chest band and smart glasses were considered burdensome even when used for a couple of hours [102, 109, 112, 125] - raising concerns about their effectiveness as a continuous data collection, monitoring, and intervention tool. Appearance of wearables played a critical role as conspicuous wearables made children with autism visibly different from others - increasing the likelihood of social discrimination [69, 76].

Smartphone, iPad, Tablet, and Mobile-based Applications

Smartphone, iPad, tablet, and mobile-based applications (apps) were used extensively to teach important life skills to children with autism. These devices were primarily used for improving speech and communication skills [1, 31, 40, 62], teaching appropriate social behavior [49, 105, 110], and as location-monitoring tools [104]. Other areas where mobile phones and similar technology were used are game-based learning and skill-acquisition [12, 17, 45, 74]. The wide availability of smartphones and related devices, people's familiarity with them, and their low-cost made them the preferred platform for developing many ASD-support apps in both developed and developing countries. Despite their wide availability, smartphone and similar technology-centric apps, especially the free apps, often suffer from usability issues such as lack of feedback, no support for error recovery, and lack of customization, which limit their effectiveness [54].

Robots

Robots, augmented by smartphones, were utilized extensively as assistive technology in many areas of ASD-research. Robots were used to help children with autism to become more socially engaged [46], to train complex social behavior (e.g., recognizing personal space, adaptability, control, communication, turn-taking, and gross motor skills) [41, 64, 93], and to become skilled in specific tasks such as emotion recognition [25, 64, 73].

Effective design and use of robots as training tools show promise in reducing the burden on therapists and caregivers [25, 80]. Research suggests that a robot's behavior can positively influence children's behavior by incorporating children's affective state, preference, and activity history in ongoing tasks [23, 32]. Robots equipped with sensors can facilitate collecting interaction data (e.g., smile and facing) and real-time sensing of emotion and preferences [32, 46, 80], which can guide the design of robots capable of adapting their behavior in real-time [2, 64, 70, 71]. Robots can be programmed to record interactions and mark key moments for later analysis by a therapist or caregiver, reducing the burden of analyzing the massive volume of video and interaction data. Such interaction history can inform the design of effective interventions [38, 46].

Overall, robots show tremendous opportunities to elicit, observe, and influence behaviors of children with autism and act as an aide for them as well as for the therapists and caregivers. However, two potential issues may hinder widespread use of robot-based ASD-support technology - first, at present robots are expensive, and second, effective use of robots often requires supervision by a technician - a scarce resource in many parts of the world [73].

Virtual Reality (VR)

Expressing emotion is challenging for many children with autism, who may require the presence of a family member or trained therapist to understand (and communicate) their affective condition [47]. However, such recognition is subjective and prone to human-bias. Commercially available wearable VR hardware with eye-tracking technology shows promise in automated detection and quantification of anxiety levels [5, 6, 8, 38, 58–60]. Such objective quantification shows great potential in helping children with autism to engage in social interactions effectively. However, similar to robots, VRs also suffer from relatively high cost and a lack of trained professionals who are capable of using such technology effectively.

Problem Areas Addressed by Autism Research

This section discusses problem areas that ASD researchers explored and summarizes challenges and opportunities in addressing these problems from a technology point of view.

Early Detection of Autism

Early detection of autism is critical to attaining successful treatment outcome. Experts heavily rely on clinical observations and standardized development questionnaire answered by parents, family members, and educators - which are subjective and prone to human error. Early detection has received tremendous attention from researchers [15, 16, 98, 100, 115]. Poor eye contact is a common feature observed in many children with autism. As a result, eye trackers or wearable cameras were widely used to detect gaze peculiarities [68, 114], to identify and quantify a child's engagement level, and to detect the eye's physiological responses [58–60] - aiding in the autism detection process.

Researchers also used wearable sensors to detect the kinematics of the upper and lower limbs of infants [15, 16], which can predict the probability of an infant becoming autistic in later stages of life. A recent research developed an inexpensive skin conductance device that can help in the diagnosis process by measuring galvanic skin conductance [77]. Other efforts in this thread of research have focused on facilitating data collection and note taking, which can be used in the diagnosis process [41, 84].

Real-time Affect Detection and Emotion Recognition

Affect recognition has received tremendous attention from ASD researchers. Children with autism often experience difficulty regulating and expressing their emotions - making them vulnerable in social situations. Researchers utilized different types of biosensors to detect physiological states [10, 18, 19, 23, 35, 52, 57, 64, 95, 101, 120]. VR with eye trackers are also used to detect anxiety from eye-gaze data (e.g., gaze coordinates, fixation duration, pupil diameter, and pupil major axis) [5, 6]. Several researchers utilized robots to identify the affective states of children with autism and adapted the robots' behavior to help children with autism to cope with anxiety and stress [2, 64, 65]. For specific contexts such as playing video games [7] or engaging in social situations [112], sensor-based affect detection systems were developed. Children with autism often struggle to recognize facial expressions (i.e., happy, sad), which makes it difficult for them to properly engage in social interactions. Smart glasses and wearable cameras were used to automatically detect, recognize and communicate facial expressions of others [109, 114]. While widely used, sensor-based affect detection and emotion recognition research faced three main challenges: i) data loss due to malfunctioning of sensors, ii) lack of synchronization with other devices, and iii) lack of effective data preprocessing/analysis tools [10].

Improving Social Skills

Children with autism experience difficulty in learning social boundaries and engaging in appropriate social interaction. Several research studies focused on enabling children with autism to become social [30, 33, 112] and engaging them in socially appropriate interaction [51, 99, 102]. Smart technology were used to subtly (using haptic or visual feedback) inform children with autism about appropriate social behavior [41, 80, 93, 105]. For example, robots were found effective in encouraging children with autism in group activities and social play. Automated or selective noise cancellation systems were found effective in engaging children with autism in social events [112].

Repetitive and Stereotypical Behavior

Many children with autism engage in stereotypical or self-stimulatory behavior which may include visual (e.g., staring at lights, repetitive blinking, and hand flapping), auditory (e.g., tapping ears and making vocal sounds), or tactile senses (e.g., rubbing the skin and scratching). Researchers showed that wearable technology can be used to automatically detect such stereotypical behavior [3, 72, 82, 85, 125], which can facilitate intervention design targeted to decrease such behavior. Commercially available smartwatches (e.g., LG watch, Moto 360) may also serve the same purpose [4, 124]. Gonçalves et al. proposed two methods using Kinect sensor and eZ430-Chronos watch to automatically detect stereotypical hand flapping movements [42]. It is important to recognize that calibration is critical to effectively use wearables for detecting and measuring repetitive behavior [90]. Smartphones were used to detect stereotypical behavior and potential environmental factors that may trigger such behavior [22]. Research in this area shows promise in assisting children with autism to self-regulate stereotypical behavior [125].

Life Skill Acquisition and Improvement

Researchers utilized smartphone-based technology to help children with autism to perform their routine tasks independently. For example, apps can help to improve bedtime routine [94] and maintain personal hygiene [121] and daily routine [117]. Another area of research focused on helping children with autism to communicate their basic needs [1, 48, 61]. A relevant research thread focuses on the design of education support tools. As children with autism possess different skills and capabilities, special applications and technology are needed to teach them effectively [14, 53, 97]. Researchers found that VR-based storytelling tools help children to remain engaged and facilitate learning [36–38]. iPads and similar technologies are also widely used to educate children with autism [1, 89].

Target Stakeholders

The main goal of ASD research is to improve the lives of children with autism and as such majority of the research conducted in this area focuses on designing technology for these individuals. However, researchers acknowledge that to improve the lives of children with autism, technology needs to be designed for all relevant stakeholders (e.g., parents and family members, doctors/therapists, educators, and caregivers). Several researchers focused on developing systems for parents to monitor their children via wearable camera [69] and to locate their children [104] for ensuring safety, to improve morning and bedtime routines [94], and to improve teaching skill of the parents [107]. TOBY, an iPad app, was developed as a complement to conventional early intensive behavioral interventions (EIBI), enabling parents to become co-therapists [43]. Researchers also developed systems for doctors and therapists to aid in autism detection [41, 77, 115].

DO'S AND DON'TS IN DESIGNING EFFECTIVE ASD-SUPPORT TECHNOLOGY

In this section, we discuss factors that need careful consideration when designing ASD-support technology.

Adaptive Behavior of Technology Driven by Real-time Recognition of Affective States is Key

Children with autism showed prolonged engagement and better task performance when interactive technologies were designed to adapt their behavior based on children's preference and activity history [23, 32]. At present, smart technology has the capability of real-time recognition of affective states [64]. If assistive technology can be designed to adapt its behavior (change the tasks, motion, audio) based on children's ongoing affective state, it may have greater potential in keeping the children engaged, help them to learn, or attain mastery in specific tasks.

Technology can Play an Imperative Role in Intervention Design

Therapy is one of the most effective ways of improving the skills of children with autism [109]. However, depending on the level of impact (children with autism are often described as high functioning vs. low functioning) and complexity and severity of the associated challenges (speech disability, non-verbal vs. selectively non-verbal), variable intensity and content of therapy may be needed to make sufficient progress towards addressing core clinical issues. Collection of behavioral data is critical to the design of evidence-based interventions as treatment plans are driven by data. In addition, one of the most important motivating factors for parents and caregivers to continue therapy sessions is to appreciate the degree of progress achieved by therapeutic interventions. Communicating about small progress may be challenging for the therapists, and may be difficult to comprehend by the parents and caregivers [126]. Technology can aid in capturing real-time interaction data to create a rich history, which can reflect progress by highlighting (even minuscule) changes over time. Therapists can use these captured histories to explain their process, outcome, and challenges observed during these therapy sessions.

Incorporation of Familiar and Unfamiliar Features should be driven by Context

Children with autism, in general, show a low preference for novel contexts including new faces, interactions, and situations [10, 80]. Emotion recognition becomes easier for children with autism when they use cartoons instead of photographs of real faces [91]. Research showed that children with autism enjoyed playing the role of their favorite protagonists in a virtual environment where they could interact with story characters and elements using eye-focus and head movements [38]. Research also suggests that using the voice of instructors or caregivers lead to better performance [124, 125]. These findings may inspire the use of known faces and voices in assistive technologies. Interestingly, while evaluating the effectiveness of known-face, unknown-face, and robots for teaching emotion recognition, researchers found that unknown-faces yielded the best result. Their findings indicate that emotion shown by known people (in an image) who are co-located may lead to confusion [25]. Also, audio-recorded instructions that used instructor's voice were found effective for training children with autism to self-manage problem behaviors in a classroom only when instructors were not visibly present in the room [125]. These findings indicate that for designing ASD-support technology the choice of known vs. unknown features (image, voice) should be context-driven.

Gradual Exposure and Desensitization is Imperative for Successful Introduction and Use of Novel Technology

While children with autism often show low tolerance towards novel technology, devices or contexts, research suggests that repetitive exposure helps to improve their tolerance [10, 38, 125]. Introduction of new technologies may require several attempts to get children with autism comfortable and accepting. As a result, researchers trying to evaluate the effectiveness of a new technology should plan for desensitization sessions, which will help children with autism become familiar with, and accepting of the target technology. A recent article (published after May 2017) echoed similar sentiments, stating that a ramp-up mode (systematic desensitization process) is needed to make new technology acceptable to children with autism [51]. For technology designers, behavioral design strategies over visceral [79] may offer better results, as novelty may not lead to preference for children with autism.

Going Beyond Capture and Replay to Detect, Mark, and Highlight Points-of-Interest

Smart technologies show tremendous potential in aiding the therapy process. First, visual and other feedback from wearable technology during therapy sessions can inform therapists about the physiological and affective states of their clients, enabling them to adapt their treatment strategy in real-time. Second, having access to the interaction history of the therapy sessions can assist in the design of personalized treatment plans by providing access to the preferences and performance of children with autism. Traditionally, video and audio recordings along with device interactions can be captured to facilitate therapy. However, reviewing massive amounts of video and audio data can be a daunting task and may not be the best use of a therapist's time [55, 109]. Finally, algorithms could be designed to enable smart devices such as robots and other wearables to not only capture interactions but also identify points-of-interest for review and analysis. These marked interactions will not only reduce the burden on the therapists but also help them to gain a deeper understanding of the preferences and capabilities of children with autism.

Technology should Blend-in and not Stand Out

One of the significant findings reported by ASD researchers is a need for pervasive but invisible technology. For many children with autism, the utilized technology becomes a major source of distraction and discomfort, interfering with their ongoing tasks [10, 95, 125]. For children with attention deficit disorder, best results were obtained when the utilized technology mimicked familiar devices such as wristwatch, glasses, or bracelets, and was hidden from the view (e.g., covered with socks). Additionally, such design did not attract unwanted attention from others - a feature desired by many individuals with autism [69, 76]. While familiar design enhances the likelihood of success, careful consideration is needed to ensure that such devices use subtle interactions (e.g., vibration, sense of touch) as interventions (e.g., messages, alarms) can also become a source of distraction [42, 117, 125]. In addition, technology designers need to consider long-term wearability issues such as weight, size, and temperature as seemingly comfortable technology such as smart glasses can become uncomfortable only after 20 minutes of use [52, 114]. Special consideration is warranted while designing VR-based technology, which is prone to induce motion sickness [36]. To ensure long-term use, designers should strive to design inconspicuous and comfortable technology.

Simplicity and Robustness in Design is Imperative

ASD-support technologies do not have to be complex and may perform better if they are robust from both hardware and software point of view. For example, bracelets that light up when touched [99] or amber-alert like alarms for enabling active and passive monitoring of children with autism when they go beyond a pre-defined safe zone [104] were considered effective. On the other hand, wearables, VR, and robots were considered effective, but raised concerns about the perceived burden, intrusiveness, unfamiliarity, and need for special training [69, 73]. In addition, ASD-support technology should have a high tolerance for unanticipated interaction and errors and should be easy to recover from errors of many kinds [95]. Researchers reported loss or corruption of data from support technology due to inappropriate usage - repeated switching off the devices [99], repeated touching [115], and banging, licking or hitting the device [125]. From a design perspective, these devices should be physically robust, easy to set up [95], should hinder making many errors (locked mode to avoid data loss), and include features to frequently transfer data in a secure storage (cloud or web) [114].

For ASD-Support Technology, One Size Fits Just One

Children with autism experience different types of impairments in different developmental areas at different intensity-levels [34, 54]. This makes designing ASD-support technology extremely complex. For example, to accommodate the different levels of information needs of low and high-functioning children with autism in performing the same task (cleaning, cooking, brushing teeth), a system should offer different levels of informational details based on the needs of the child. In addition, with time, a child may become skilled in performing a task and outgrow the need for elaborate instructions, requiring the technology to fit the current needs [6, 103, 125]. Good design principles suggest the use of redundant information cues to facilitate understanding, and as such many ASD-support technologies utilize multiple information sources (e.g., audio, video, haptic, and text) to communicate the same information [56, 103, 109, 114]. While using multiple modalities (e.g., audio, video) and design features (e.g., color, size, and shape) may cater to a broad group of children with autism, it may also increase the possibility of sensory overload, a common condition experienced by many children with autism [75]. Involving children with autism in the design process may alleviate some of these problems as their preference will be reflected in the designed technology [36, 38, 69, 97]. These findings signify the need for customization where children with autism, their families or caregivers can select one or more communication modality, design features, and granularity of presented information, which can help them to understand and interact with the technology effectively.

Country-Type	Number of articles
Developed	119
Developing	24

Table 2: Categorization of papers based on country
(remaining papers are meta-reviews or focused on algorithm)

Culture-driven Design of Technology

ASD is prevalent in both developed and developing countries [129–131] (economy-based country classification by UN [135]). Research on autism is largely focused on the developed countries (see Table 2). This disparity in research coverage is intensified by the fact that many developing countries are still lacking in trained doctors and therapists, resulting in misdiagnosis and mistreatment [96]. The limited amount of research conducted in developing countries suggests that designing ASD-support technology presents unique challenges pertaining to socio-economic condition, social norms and values, religious beliefs, and culture [69]. For instance, Nazneen et al.'s research in Pakistan revealed that for countries where the joint-family structure is common, technology has to be designed for the entire family including grandparents, uncles, and aunts [76]. Moreover, technology should be sensitive to the religious and cultural values of these people (for example, capturing images of women may be considered inappropriate) and easy to operate to accommodate various skill levels.

To improve the social skills of children with autism, researchers focus on encouraging them to make direct eye contact with anyone speaking to them. In western countries (e.g., USA, European countries), looking directly at others' eyes is considered as the appropriate social behavior. However, in many countries (e.g., India, Bangladesh), looking elders directly in the eye is considered disrespectful. It is critical to consider the cultural upbringing of the child during therapy as looking behavior is highly culture-dependent [59, 63]. Since people tend to be sensitive to culture and religion, it is important to consider cultural and religious factors during design [76].

Cost of Technology is Broadening the Digital Divide

Cost of ASD-support technology may discourage a vast majority of users from adopting and utilizing a given technology despite the benefits it may offer. For example, Lau and Low reported that 25% of the parents in their study were not interested in using technology due to limited availability of hardware and facilities at home [61]. In addition, cost of technology may also affect the applicability and use of technology. For example, robots are considered effective in teaching children with autism important social skills [132]. However, the average cost of a robot that can help with education and learning is approximately $5000 [132] - an amount well above the average GDP per capita for many developing countries (e.g., average. GDP/capita for India, Bangladesh, Ethiopia, and Niger are $1709, $1359, $706 and $363 respectively [133]). As a result, research involving robots as assistive technology is primarily conducted in the developed countries (86% developed vs. 14% in developing countries). In many developed countries, lower-income families may not afford advanced technology-based treatment. For example, for many families, acquiring a smartphone for treatment may become burdensome [39, 76]. It is encouraging that a few researchers have focused on cost minimization by exploring alternate technology capable of offering needed functionality (Garzotto et al. [36] and Gelsomini [38] used Google Cardboard instead of expensive VR). We should explore alternate low-cost options that can offer the benefits of utilizing effective technology in therapy to bridge this ongoing digital divide.

User Freedom, Privacy of Self, and Privacy of Others: Challenges in Using Smart Technology in the Wild

Smart technologies must balance user-freedom and intervention. For example, to limit sensory overload, speech and noise cancellation systems enable individuals with autism to select who/what they want to listen to (and block) [112]. Another important aspect that deserves careful consideration is the privacy of the individual with autism. Location or affect monitoring systems can be very useful for families and caregivers to monitor and provide help whenever needed but can be intrusive for individuals with autism as they can be constantly tracked and monitored by others [92]. To minimize privacy-invasion, individuals with autism should have some control over how frequently they can be contacted or reached [92]. Alternately, instead of constant monitoring, systems can be designed to actively contact family members or caregivers in times of need. Also, utilizing technology that captures images, audio, or video in the natural environment can be intrusive and violate the privacy of others present in the environment. Research suggests that awareness can generate empathy and social acceptance in these situations when others (general public) were notified of individuals with autism using such technology [50, 78]. However, making such technology visible and/or notifying others about the condition of individuals with autism is a breach to their privacy and may even make them vulnerable by subjecting them to harassment, discrimination, and bullying [51,95]. Further research is needed to investigate effective ways of utilizing such technology in the wild.

Essential Features of ASD-Support Smart Technology

Selecting the most appropriate Physiological Signal is Not Trivial: Different physiological signals (e.g., ECG, Accelerometer, GSR, and EDA) help to infer different affective states. Different types of physiological markers can be used to infer the same affective state. For example, ECG, EDA, and EMG can be used to infer heart rate variation (physiological distress). However, research suggests that ECG and EDA might be more effective in stress detection than EMG [23]. As each additional sensor and smart device increases user burden, researchers need to carefully select which signals they need to use to infer a specific affective state.

Capturing Interaction History is Important for Designing Personalized Treatment Plans: History of interaction with different types and modalities of information (e.g., text, audio, and video) may highlight the strengths, weaknesses, and preferences of a child with autism [126] and can enable therapists and/or caregivers to customize the design of therapy sessions [38]. Therapists can utilize these interaction histories to explore, analyze, quantify, and communicate the progress of individuals with autism, which can be difficult to accomplish otherwise [38, 126].

Designing Appropriate Feedback Mechanism is Imperative: Feedback plays an important role to motivate and improve performance and works as a learning tool for individuals with autism. For example, audio and visual feedback are reported to motivate children with autism to engage in various tasks such as social interaction (touching and turn-taking) [93, 99, 114] and be attentive while playing games [15, 36]. In addition, feedback can be effectively used to convey even subtle progress of the children with autism to their parents and caregivers [101]. However, to be effective, feedback should be customizable and context-sensitive. For example, for public environments such as classrooms, haptic feedback is more appropriate for its discreteness [95]. Visual feedback can be more appropriate for providing positive reinforcement [93, 99] while audio feedback can be used to provide instructions [124, 125].

DISCUSSION

Technology should Focus on Enhancing the Natural Capabilities (and Not Only Focus on Deficits)

To date, ASD research primarily focused on designing technology to assist children with autism to overcome challenges, primarily in the areas of social interaction, communication, and restricted interests and repetitive behavior [23, 24, 34, 88]. While it is well-understood that many children with autism show significant strength in areas such as mathematical ability, photographic memory, art, and music [39, 54], research on enhancing/supporting these qualities is practically non-existent. None of the papers in our corpus focused on improving the unique skills and capabilities of children with autism. While it is important to design technology that aids in overcoming deficits, we believe that it is also important to design technology that aims to strengthen the natural capabilities of this population. As the number of children with autism is growing rapidly [130], researchers should look beyond trying only to fix impairments and, rather, additionally seek to tap and nurture the potential of this population.

Utilizing Wearable Devices to Their Fullest Potential

In our corpus, 62 papers utilized one or more wearable devices to gain understanding about the physiological condition (stress, anxiety, preference), attention (eye tracking, pupil size), and motion and activity detection (hand flapping, head banging). Wearable devices show tremendous potential by enabling collection of real-time, continuous, and objective data. Traditionally, therapists try to understand emotion and affect by observing children with autism. However, their understanding is subjective and prone to human error, and collection of such data is limited to therapy sessions. Long-term observation of children with autism in the wild can improve the quality of therapy but requires continuous co-presence, which is very expensive, if not impossible. Only seven research articles utilized wearable devices to collect data from the field or specific environment (e.g., school, therapist's office), and only one research paper collected longitudinal data - indicating that researchers are currently not utilizing these devices for collecting longitudinal data from the field. Utilizing wearables in the lab or other controlled environments enables collection of high-quality data for a short period. However, it rarely embodies the complexities of real-life (e.g., the presence of other people, noise level, lack of control over ongoing situations), which greatly influences the behavior and experience of individuals with autism. Research in the area of mHealth highlights the feasibility of collecting such data from the field ([86] reported the feasibility of collecting 11 hours/day of data from a month-long study). We believe the next step in autism research is to investigate optimal ways of utilizing wearable devices in advancing our knowledge about autism and finding ways of utilizing them in therapy and daily life.

Designing Technology for All Stages of Life

Autism Spectrum Disorder persists lifelong. As such, it is critical to design technology that can provide support at different stages of life [24, 32, 67]. A vast majority of ASD research and relevant technology focused on challenges experienced in early childhood [39, 116, 123] - focusing on detection and diagnosis of autism [16, 41, 77] and relevant symptoms such as managing repetitive and/or problem behavior [3, 72, 119, 125], emotion recognition [98, 109], enhancing attention span [38], and automated affect detection [10, 64, 95, 120]. However, challenges (e.g., dating, independent travel, or part-time or full-time employment) primarily faced by adolescents (and later in their lives as adults) with autism are underrepresented [103]. In our corpus of 149 papers, only three papers focused on challenges pertaining primarily to adolescents or later stages of life – employability [39], independent living [103] and independent travel [92]. As we only reviewed papers focusing on children and adolescents, we conducted a secondary search to explore if these areas have been adequately explored by adding “adult” as part of the search query. This secondary search also revealed that research and supporting technology for the later stages of life as well as important real-life problems (e.g., employability, long-term relationship) is sparse. Our search on ACM DL, IEEE Xplore, and PubMed returned 23, 22, and 22 new papers respectively. However, only eight of these papers were relevant. Future research should explore how to design assistive technology for these underexplored areas to provide continuing support to improve the experience of individuals with autism across the lifespan.

Challenges with Technology Evaluation

Nature of Autism: Individuals with autism face different challenges at different stages of their lives. For example, children with autism face challenges involving social interaction in a group setting, expressing their emotions and needs, while adults with autism face challenges associated with independent living, employability, etc. None of the research we reviewed evaluated their proposed technology or method with individuals with autism from different age groups, limiting the generalizability of reported results.

Small Sample Size: Of the 149 reviewed articles, 34 did not report involving any users and an additional 73 involved less than 10 users. In addition, the small sample used for evaluating proposed technology often included a combination of individuals with autism, therapists, family members, educators, and/or people not on the spectrum. It is difficult to understand whether and how the reported findings will generalize to individuals with autism.

Limited Study Duration: When evaluating technology, study duration and use of multiple sessions are very important as individuals with autism are less tolerant of novel technology and true influence of a proposed technology may not be understood without repeated exposure. Notably, only a few articles [38, 64, 69, 97, 125] utilized multiple sessions or studied the influence of a proposed technology/method for more than two months, which offered a better understanding of the experience of the individuals with autism. We hope that future research will focus on investigating the true impact of the proposed technology by utilizing longitudinal studies.

Study Environment: Children with autism, in general, are greatly influenced by their surrounding context and it is extremely difficult to predict how they will react to a new context [127]. A vast majority of the ASD research evaluated proposed technology in the controlled or semi-controlled environment, which are void of complexities present in real life. While we acknowledge the challenges in conducting a field study involving individuals with autism, we want to emphasize that it is critical to evaluate ASD-support technology in the target environment due to the greater influence of context on individuals with autism.

Selection of Study Participants: Ideally, studies investigating the efficacy of ASD-support technology should involve not only target users (individuals with autism) but also their families, educators, and/or therapists, especially for individuals with social and communication deficits. Without involving these relevant stakeholders, it may be difficult to elicit natural behavior of the study participants or correctly interpret the influence of the proposed technology on the participants. Several researchers also evaluated their proposed technologies with typical users, and we are unsure how lessons learned in these studies will translate to individuals with autism.

Increased Social Awareness May Positively Impact Autism Research

The prevalence of individuals with autism has significantly increased in recent years in both developed and developing countries [129–131]. However, recruiting individuals with autism for research is still challenging, often impacting the generalizability of reported results [58–60]. Although budget and time constraints may hinder recruitment of large study samples, our experience of working with families with children with autism, therapists, and educators suggest that social stigma associated with ASD may further limit access to the target user for research. In the developing countries, families with children with autism often experience excessive stress [96, 111], social devaluation, discrimination, and injustice [134]. Many parents in the developed countries also prefer not to disclose their child's condition due to fear of labeling, lack of opportunities to lead a typical life, and social discrimination. In many developing countries, autism detection and diagnosis process is still in its infancy and often erroneous, resulting in misdiagnosis and mistreatment [96]. While technology may contribute to improving the lives of individuals with autism and their families, without social acceptance, it is almost impossible to encourage families to openly take part in research and engage in discussions about their needs. We believe that widespread awareness about autism will help to improve the general conception pertaining to autism and that may encourage more families to come forward and participate in research and other relevant activities. Researchers should think critically about how to design technological and other solutions to help improve social awareness about autism. For example, popular social networking sites such as Facebook can be used to run awareness campaigns globally to increase social awareness. Systematic research is needed to investigate how to utilize such platforms on building awareness about autism.

CONCLUSION

We investigated how to design effective ASD-support smart technologies for children. To uncover needs, challenges and opportunities, we conducted an extensive literature review on ACM DL, IEEE Xplore, and PubMed. Our findings indicate that smart technologies have been utilized to support different areas pertaining to ASD - early detection of autism, gaze and facial expression recognition and understanding, affect detection, identifying and managing repetitive and stereotypical behavior, and improving social, educational, and learning skills. Despite this wide coverage of clinical challenges unique to ASD, we believe smart technologies are still under-utilized. Specifically, such technologies were rarely used for continuous real-time data collection, monitoring, and intervention, in the natural environment and/or for longer periods. We also found that at present ASD-research is primarily conducted in the developed countries. As autism is a global phenomenon and developing countries lack advanced technologies and trained professionals [96, 134], we argue that developing countries deserve the same, if not more, attention from the ASD research community.

We propose a set of actionable guidelines collectively drawing from our findings, research on assistive technology design, and our experience of working with related stakeholders. We believe that to be effective, smart technologies should facilitate real-time collection, detection, and identification of events-of-interest such as the beginning of a lapse episode or distress triggered by a specific context. These technologies should be capable of adapting their behavior in real-time based on user's preference, affective state, and user and environmental context. Smart technologies should also act as analytical tools, facilitating capture, detection, and highlighting even small progress made by children with autism. We argue that to be effective, smart technologies need to be inconspicuous and low-burden. We believe that our findings and insights would lead to better ASD-support smart technologies.

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REFERENCES

1. Muhammad Haziq, Lim Abdullah and Margot Brereton. 2015. MyCalendar: Fostering Communication for Children with Autism Spectrum Disorder Through Photos and Videos. *OzCHI* '15, 1–9.
2. Jordi Albo-Canals, Danielle Feerst, Daniel de Cordoba, and Chris Rogers. 2015. A Cloud Robotic System Based on Robot Companions for Children with Autism Spectrum Disorders to Perform Evaluations During LEGO Engineering Workshops. *ACM/IEEE Human-Robot Interaction Extended Abstracts* (HRI'15 Extended Abstracts), 173–174.
3. Bassem Alhalabi, Clyde Carryl, and Mirjana Pavlovic. 2014. Activity Analysis and Detection of Repetitive Motion in Autistic Patients. *IEEE International Conference on Bioinformatics and Bioengineering*, 430–437.
4. Amir Mohammad Amiri, Nicholas Peltier, Cody Goldberg, Yan Sun, Anoo Nathan, Shivayogi V Hiremath, and Kunal Mankodiya. 2017. WearSense: Detecting Autism Stereotypic Behaviors through Smartwatches. *Healthcare* 5, 1.
5. Pradeep R K B and Uttama Lahiri. 2016. Design of eyegaze-sensitive Virtual Reality Based Social Communication Platform for Individuals with Autism. *Intelligent Systems, Modelling & Simulation*, 301–306.
6. Pradeep R K B, Poojan Oza, and Uttama Lahiri. 2017. Gaze-sensitive Virtual Reality based Social Communication Platform for Individuals with Autism. *IEEE Transactions on Affective Computing* PP, 1.
7. Pedro H F Bacchini, Erlan C. Lopes, Marco Aurélio G. de A. Barbosa, José O. Ferreira, Olegário C. da Silva Neto, Adson F. Da Rocha, and Talles Marcelo G. de A. Barbosa. 2014. Developing an affective Point-of-Care technology. *IEEE CICARE*, 77–84.
8. Esubalew Bekele, Zhi Zheng, Amy Swanson, Julie Crittendon, Zachary Warren, and Nilanjan Sarkar. 2013. Understanding How Adolescents with Autism Respond to Facial Expressions in Virtual Reality Environments. *IEEE Transactions on Visualization and Computer Graphics* 19, 711–720.
9. M. Bellani, L. Fornasari, L. Chittaro, and P. Brambilla. 2011. Virtual reality in autism: state of the art. *Epidemiology and Psychiatric Sciences* 20, 3: 235–238.
10. Mariana Aparicio Betancourt, Laura S Dethorne, Karrie Karahalios, and Jennifer G Kim. 2017. Skin Conductance as an In Situ Marker for Emotional Arousal in Children with Neurodevelopmental Communication Impairments: Methodological Considerations and Clinical Implications. *ACM Transactions on Accessible Computing*. 9, 3: 8:1--8:29.
11. Sofiane Boucenna, Antonio Narzisi, Elodie Tilmont, Filippo Muratori, Giovanni Pioggia, David Cohen, and Mohamed Chetouani. 2014. Interactive Technologies for Autistic Children: A Review. *Cognitive Computation* 6, 4: 722–740.
12. Louanne E. Boyd, Kathryn E. Ringland, Oliver L. Haimson, Helen Fernandez, Maria Bistarkey, and Gillian R. Hayes. 2015. Evaluating a Collaborative iPad Game's Impact on Social Relationships for Children with Autism Spectrum Disorder. *ACM Transactions on Accessible Computing* 7, 1: 1–18.
13. Lou Anne 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. *SIGCHI* '16, 4872–4883.
14. Luke Buschmann, Lourdes Morales, and Sri Kurniawan. 2014. Online Learning System for Teaching Basic Skills to People with Developmental Disabilities. *ACM ASSETS* '14, 271–272.
15. Domenico Campolo, Massimo Molteni, Eugenio Guglielmelli, Flavio Keller, Cecilia Laschi, and Paolo Dario. 2006. Towards Development of Biomechatronic Tools for Early Diagnosis of Neurodevelopmental Disorders. *IEEE Engineering in Medicine and Biology Society*, 3242–3245.
16. D Campolo, F Taffoni, G Schiavone, C Laschi, F Keller, and E Guglielmelli. 2008. A novel technological approach towards the early diagnosis of neurodevelopmental disorders. *IEEE Engineering in Medicine and Biology Society*, 4875–4878.
17. Beryl Charlton, Randy Lee Williams, and T F Mclaughlin. 2005. Educational Games: A Technique to Accelerate the Acquisition of Reading Skills of Children with Learning Disabilities. *The International Journal of Special Education* 20, 202.
18. Theodora Chaspari, Matthew Goodwin, Oliver Wilder-Smith, Amanda Gulsrud, Charlotte A. Mucchetti, Connie Kasari, and Shrikanth Narayanan. 2014. A non-homogeneous poisson process model of Skin Conductance Responses integrated with observed regulatory behaviors for Autism intervention. *IEEE ICASSP*, 1611–1615.
19. Theodora Chaspari, Andreas Tsiartas, Leah I. Stein Duker, Sharon A. Cermak, and Shrikanth S. Narayanan. 2016. EDA-gram: Designing electrodermal activity fingerprints for visualization and feature extraction. *IEEE EMBC*, 403–406.
20. Shanshan Chen, John Lach, Benny Lo, and Guang-Zhong Yang. 2016. Toward Pervasive Gait Analysis With Wearable Sensors: A Systematic Review. *IEEE Journal of Biomedical and Health Informatics* 20, 1521–1537.
21. Deborah L. Christensen, Jon Baio, Kim Van Naarden Braun, Deborah Bilder, Jane Charles, John N. Constantino, Julie Daniels, Maureen S. Durkin, Robert T. Fitzgerald, Margaret Kurzius-Spencer, Li-Ching Lee, Sydney Pettygrove, Cordelia Robinson, Eldon

Schulz, Chris Wells, Martha S. Wingate, Walter Zahorodny, and MarshalynYeargin-Allsopp. 2016. Prevalence and Characteristics of Autism Spectrum Disorder Among Children Aged 8 Years — Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2012. *MMWR. Surveillance Summaries* 65, 3: 1–23.
22. M Chuah and M Diblasio. 2012. Smartphone Based Autism Social Alert System. *Mobile Ad-hoc and Sensor Networks (MSN)*, 6–13.
23. Karla Conn, Changchun Liu, Nilanjan Sarkar, Wendy Stone, and Zachary Warren. 2008. Affect-sensitive assistive intervention technologies for children with autism: An individual-specific approach. *RO-MAN 2008 - IEEE Robot and Human Interactive Communication*, 442–447.
24. Antonio Coronato and Giovanni Paragliola. 2014. Towards a Personal Health Records system for patients with Autism Spectrum Disorders. *IEEE Computational Intelligence in Healthcare and e-health*, 90–97.
25. Sandra Costa, Filomena Soares, Ana Paula Pereira, Cristina Santos, and Antoine Hiolle. 2014. Building a game scenario to encourage children with autism to recognize and label emotions using a humanoid robot. *The 23rd IEEE International Symposium on Robot and Human Interactive Communication*, 820–825.
26. Antonina Dattolo and Flaminia L Luccio. 2017. A Review of Websites and Mobile Applications for People with Autism Spectrum Disorders: Towards Shared Guidelines. In *Smart Objects and Technologies for Social Good*, Springer International Publishing, Cham, 264–273.
27. Joshua J Diehl, Lauren M Schmitt, Michael Villano, and Charles R Crowell. 2012. The clinical use of robots for individuals with Autism Spectrum Disorders: A critical review. *Research in Autism Spectrum Disorders* 6, 1: 249–262.
28. Julia C Duvall, Lucy E Dunne, Nicholas Schleif, and Brad Holschuh. 2016. Active "Hugging" Vest for Deep Touch Pressure Therapy. *UbiComp* '16, 458–463.
29. Mayada Elsabbagh, Gauri Divan, Yun-JooKoh, Young Shin Kim, Shuaib Kauchali, Carlos Marcín, Cecilia Montiel-Nava, Vikram Patel, Cristiane S Paula, Chongying Wang, Mohammad Taghi Yasamy, and Eric Fombonne. 2012. *Global Prevalence of Autism and Other Pervasive Developmental Disorders. Autism Research* 5, 3: 160–179.
30. Angelica Escalona, Tiffany Field, Jacqueline Nadel, and Brenda Lundy. 2002. Brief Report: Imitation Effects on Children with Autism. *Journal of Autism and Developmental Disorders* 32, 2: 141–144.
31. Charles Fage, Léonard Pommereau, Charles Consel, Emilie Balland, and Hélène Sauzéon. 2016. Tablet-Based Activity Schedule in Mainstream Environment for Children with Autism and Children with ID. *ACM Trans. Access.Comput.* 8, 3: 9:1--9:26.
32. David Feil-Seifer and Maja J. Mataric. 2008. B3IA: A control architecture for autonomous robot-assisted behavior intervention for children with Autism Spectrum Disorders. *RO-MAN 2008 - The 17th IEEE International Symposium on Robot and Human Interactive Communication*, 328–333.
33. Tiffany Field, Tory Field, Chris Sanders, and Jacqueline Nadel. 2001. Children with autism display more social behaviors after repeated imitation sessions. *Autism: the international journal of research and practice* 5, 3: 317–323.
34. Andrés M Figueroa and Reyes Juárez-Ramírez. 2014. Towards a User Model for the Design of Adaptive Interfaces for Autistic Users. *IEEE Computer Software and Applications Conference Workshops*, 264–269.
35. Richard R Fletcher, Kelly Dobson, Matthew S. Goodwin, Hoda Eydgahi, Oliver Wilder-Smith, David Fernholz, Yuta Kuboyama, Elliott Bruce Hedman, Ming-ZherPoh, and Rosalind W. Picard. 2010. iCalm: Wearable Sensor and Network Architecture for Wirelessly Communicating and Logging Autonomic Activity. *IEEE Transactions on Information Technology in Biomedicine* 14, 215–223.
36. Franca Garzotto, Mirko Gelsomini, Francesco Clasadonte, Daniele Montesano, and Daniele Occhiuto. 2016. Wearable Immersive Storytelling for Disabled Children. *AVI* '16, 196–203.
37. M Gelsomini, F Garzotto, D Montesano, and D Occhiuto. 2016. Wildcard: A wearable virtual reality storytelling tool for children with intellectual developmental disability. *IEEE EMBC*, 5188–5191.
38. Mirko Gelsomini. 2016. An Affordable Virtual Reality Learning Framework for Children with Neuro-Developmental Disorder. *ACM SIGACCESS Conference on Computers and Accessibility*, 343–344.
39. Tony Gentry, Richard Kriner, Adam Sima, Jennifer McDonough, and Paul Wehman. 2015. Reducing the need for personal supports among workers with autism using an iPod Touch as an assistive technology: delayed randomized control trial. *Journal of autism and developmental disorders* 45, 3: 669–684.
40. Cindy Gevarter, Mark F O'Reilly, Michelle Kuhn, Laci Watkins, Raechal Ferguson, Nicolette Sammarco, Laura Rojeski, and Jeff Sigafoos. 2016. Assessing the acquisition of requesting a variety of preferred items using different speech generating device formats for children with autism spectrum disorder. *Assistive Technology* 0, 0: 1–8.
41. Julie Golliot, Catherine Raby-Nahas, Mark Vezina, Yves-Marie Merat, Audrée-Jeanne Beaudoin, Mélanie Couture, Tamie Salter, Bianca Côté, Cynthia Duclos, Maryse Lavoie, and François Michaud. 2015. A Tool to Diagnose Autism in Children Aged Between Two to

Five Old: An Exploratory Study with the Robot QueBall. ACM/IEEE Human-Robot Interaction Extended Abstracts (HRI'15), 61–62.

42. Nuno Gonçalves, José L. Rodrigues, Sandra Costa, and Filomena Soares. 2012. Automatic detection of stereotyped hand flapping movements: Two different approaches. *2012 IEEE RO-MAN: IEEE Robot and Human Interactive Communication*, 392–397.
43. Joanna Granich, Alena Dass, Margherita Busacca, Dennis Moore, Angelika Anderson, Svetha Venkatesh, Thi Duong, Pratibha Vellanki, Amanda Richdale, David Trembath, Darin Cairns, Wendy Marshall, Tania Rodwell, Madeleine Rayner, and Andrew J O Whitehouse. 2016. Randomised controlled trial of an iPad based early intervention for autism: TOBY playpad study protocol. *BMC Pediatrics* 16: 167.
44. Madeline B Harms, Alex Martin, and Gregory L Wallace. 2010. Facial Emotion Recognition in Autism Spectrum Disorders: A Review of Behavioral and Neuroimaging Studies. *Neuropsychology Review* 20, 3: 290–322.
45. Nazih Heni and Habib Hamam. 2016. Design of emotional educational system mobile games for autistic children. *Advanced Technologies for Signal and Image Processing* (ATSIP), 631–637.
46. Masakazu Hirokawa, Atsushi Funahashi, Yadong Pan, Yasushi Itoh, and Kenji Suzuki. 2016. Design of a robotic agent that measures smile and facing behavior of children with Autism Spectrum Disorder. *IEEE International Symposium on Robot and Human Interactive Communication* (RO-MAN), 843–848.
47. Stefan G Hofmann and Jasper A J Smits. 2008. Cognitive-Behavioral Therapy for Adult Anxiety Disorders: A Meta-Analysis of Randomized Placebo-Controlled Trials. *The Journal of clinical psychiatry* 69, 4: 621–632.
48. Gemma Hornero, David Conde, Marcos Quilez, Sergio Domingo, María Peña Rodríguez, Borja Romero, and Oscar Casas. 2015. A Wireless Augmentative and Alternative Communication System for People With Speech Disabilities. *IEEE Access* 3, 1288–1297.
49. Juan Pablo Hourcade, Stacy R Williams, Ellen A Miller, Kelsey E Huebner, and Lucas J Liang. 2013. Evaluation of Tablet Apps to Encourage Social Interaction in Children with Autism Spectrum Disorders. *SIGCHI* '13, 3197–3206.
50. Giovanni Iachello, Khai N Truong, Gregory D Abowd, Gillian R Hayes, and Molly Stevens. 2006. Prototyping and Sampling Experience to Evaluate Ubiquitous Computing Privacy in the Real World. *SIGCHI*' 06, 1009–1018.
51. Xinlong Jiang, Lou Anne E Boyd, Yiqiang Chen, and Gillian R Hayes. 2016. ProCom: Designing a Mobile and Wearable System to Support Proximity Awareness for People with Autism. *UbiComp* '16, 93–96.
52. Rana el Kaliouby and Matthew S Goodwin. 2008. iSET: Interactive Social-emotional Toolkit for Autism Spectrum Disorder. *Interaction Design and Children* (IDC '08), 77–80.
53. M. F. Kamaruzaman and M. H. H. Azahari. 2014. Form design development study on autistic counting skill learning application. *International Conference on Computer, Communications, and Control Technology* (I4CT), 70–74.
54. Sehrish Khan, Mutahira N. Tahir, and Arif Raza. 2013. Usability issues for smartphone users with special needs - Autism. *International Conference on Open Source Systems and Technologies*, 107–113.
55. Julie A. Kientz, Gillian R. Hayes, Tracy L. Westeyn, Thad Starner, and Gregory D. Abowd. 2007. Pervasive Computing and Autism: Assisting Caregivers of Children with Special Needs. *IEEE Pervasive Computing* 6, 28–35.
56. Helen Koo. 2014. 'TellMe': Therapeutic Clothing for Children with Autism Spectrum Disorder (ASD) in Daily Life. *ACM International Symposium on Wearable Computers: Adjunct Program* (ISWC '14 Adjunct), 55–58.
57. Azadeh Kushki, Ajmal Khan, Jessica Brian, and Evdokia Anagnostou. 2015. A Kalman Filtering Framework for Physiological Detection of Anxiety-Related Arousal in Children With Autism Spectrum Disorder. *IEEE Transactions on Biomedical Engineering* 62, 990–1000.
58. Uttama Lahiri, Esubalew Bekele, Elizabeth Dohrmann, Zachary Warren, and Nilanjan Sarkar. 2013. Design of a Virtual Reality Based Adaptive Response Technology for Children With Autism. *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 21, 55–64.
59. Uttama Lahiri, Zachary Warren, and Nilanjan Sarkar. 2011. Design of a Gaze-Sensitive Virtual Social Interactive System for Children With Autism. *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 19, 443–452.
60. Uttama Lahiri, Zachary Warren, and Nilanjan Sarkar. 2011. Dynamic gaze measurement with adaptive response technology in Virtual Reality based social communication for autism. *International Conference on Virtual Rehabilitation*, 1–8.
61. B T Lau and T K Low. 2010. A mobile communicator with meta communicator for children with Asperger Syndrome. *IEEE Conference on Industrial Electronics and Applications*, 2227–2232.
62. Gianluca De Leo and Gondy Leroy. 2008. Smartphones to Facilitate Communication and Improve Social Skills of Children with Severe Autism Spectrum Disorder: Special Education Teachers As Proxies. *Interaction Design and Children* (IDC '08), 45–48.

63. Han Z Li. Culture and Gaze Direction in Conversation. Retrieved September 18, 2017 from https://goo.gl/EQYKwC
64. Changchun Liu, Karla Conn, Nilanjan Sarkar, and Wendy Stone. 2007. Affect Recognition in Robot Assisted Rehabilitation of Children with Autism Spectrum Disorder. *IEEE International Conference on Robotics and Automation*, 1755–1760.
65. Changchun Liu, Karla Conn, Nilanjan Sarkar, and Wendy Stone. 2008. Online Affect Detection and Robot Behavior Adaptation for Intervention of Children With Autism. *IEEE Transactions on Robotics* 24, 883–896.
66. Donna R. Long. 1993. Basics of qualitative research: Grounded theory procedures and techniques.
67. Catherine Lord and Sarah J Spence. 2006. Autism Spectrum Disorders: Phenotype and Diagnosis. *Understanding autism: From basic neuroscience to treatment*, 1–23.
68. Silvia Magrelli, Basilio Noris, Patrick Jermann, François Ansermet, François Hentsch, Jacqueline Nadel, and Aude G. Billard. 2014. A Wearable Camera Detects Gaze Peculiarities during Social Interactions in Young Children with Pervasive Developmental Disorders. *IEEE Transactions on Autonomous Mental Development* 6, 274–285.
69. Gabriela Marcu, Anind K Dey, and Sara Kiesler. 2012. Parent-driven Use of Wearable Cameras for Autism Support: A Field Study with Families. *UbiComp* ’12, 401–410.
70. Daniele Mazzei, Lucia Billeci, Antonino Armato, Nicole Lazzeri, Antonio Cisternino, Giovanni Pioggia, Roberta Igliozzi, Filippo Muratori, Arti Ahluwalia, and Danilo De Rossi. 2010. The FACE of autism. *Robot and Human Interactive Communication*, 791–796.
71. Daniele Mazzei, Alberto Greco, Nicole Lazzeri, Abolfazl Zaraki, Antonio Lanata, Roberta Igliozzi, Alice Mancini, Francesca Stoppa, Enzo Pasquale Scilingo, Filippo Muratori, and Danilo De Rossi. 2012. Robotic Social Therapy on Children with Autism: Preliminary Evaluation through Multi-parametric Analysis. *Privacy, Security, Risk and Trust and 2012 International Conference on Social Computing*, 955–960.
72. Cheol-Hong Min and Ahmed H. Tewfik. 2011. Semi-supervised event detection using higher order statistics for multidimensional time series accelerometer data. *IEEE Engineering in Medicine and Biology Society*, 365–368.
73. Mohd A. Miskam, Syamimi Shamsuddin, Hanafiah Yussof, Ilmi M. Ariffin, and Abdul R. Omar. 2015. A questionnaire-based survey: Therapist’s response on emotions gestures using humanoid robot for autism. *International Symposium on Micro-Nano Mechatronics and Human Science* (MHS), 1–7.
74. Melissa Morgenlander, Allison D’Eugenio, and Deidre Witan. 2015. uChoose by InteractAble: Learning Social Skills via Game Play. *Interaction Design and Children* (IDC ’15), 403–405.
75. Brenda Smith Myles, Winnie Dunn, Louann Rinner, Taku Hagiwara, Matthew Reese, Abby Huggins, and Stephanie Becker. 2004. Sensory Issues in Children with Asperger Syndrome and Autism. *Education and Training in Developmental Disabilities* 39, 4: 283–290.
76. Nazneen, F, A Boujarwah, A Rozga, G D Abowd, R I Arriaga, R Oberleitner, and S Pharkute. 2012. Towards in-home collection of behavior specimens: Within the cultural context of autism in Pakistan. *Pervasive Health and Workshops*, 9–16.
77. B. Nehme, R. Youness, T. A. Hanna, W. Hleihel, and R. Serhan. 2016. Developing a skin conductance device for early Autism Spectrum Disorder diagnosis. *3rd Middle East Conference on Biomedical Engineering* (MECBME), 139–142.
78. David H Nguyen, Gabriela Marcu, Gillian R Hayes, Khai N Truong, James Scott, Marc Langheinrich, and Christof Roduner. 2009. Encountering SenseCam: Personal Recording Technologies in Everyday Life. *UbiComp* ’09, 165–174.
79. Don Norman. 2013. *The design of everyday things: Revised and expanded edition*. Basic Books (AZ).
80. Eleuda Nunez, Soichiro Matsuda, Masakazu Hirokawa, Junichi Yamamoto, and Kenji Suzuki. 2016. An approach to facilitate turn-taking behavior with paired devices for children with Autism Spectrum Disorder. *IEEE Robot and Human Interactive Communication* (RO-MAN), 837–842.
81. Eleni A Papagiannopoulou, Kate M Chitty, Daniel F Hermens, Ian B Hickie, and Jim Lagopoulos. 2014. A systematic review and meta-analysis of eye-tracking studies in children with autism spectrum disorders. *Social Neuroscience* 9, 6: 610–632.
82. Giovanni Paragliola and Antonio Coronato. 2013. Intelligent Monitoring of Stereotyped Motion Disorders in Case of Children with Autism. *Intelligent Environments*, 258–261.
83. Sarah Parsons and Peter Mitchell. 2002. The potential of virtual reality in social skills training for people with autistic spectrum disorders. *Journal of Intellectual Disability Research* 46, 5: 430–443.
84. Lorenzo Piccardi, Basilio Noris, Olivier Barbey, Aude Billard, Giuseppina Schiavone, Flavio Keller, and Claes von Hofsten. 2007. WearCam: A head mounted wireless camera for monitoring gaze attention and for the diagnosis of developmental disorders in young children. *RO-MAN 2007 - Robot and Human Interactive Communication*, 594–598.
85. Nastaran M. Rad, Seyed M. Kia, Calogero Zarbo, Giuseppe Jurman, Paola Venuti, and Cesare Furlanello. 2016. Stereotypical Motor Movement Detection in

Dynamic Feature Space. *IEEE International Conference on Data Mining Workshops*, 487–494.
86. Md Mahbubur Rahman et al. 2014. Are we there yet?: Feasibility of continuous stress assessment via wireless physiological sensors. *ACM Conference on Bioinformatics, Computational Biology, and Health Informatics*, 479–488.
87. Sathiyaprakash Ramdoss, Russell Lang, Austin Mulloy, Jessica Franco, Mark O'Reilly, Robert Didden, and Giulio Lancioni. 2011. Use of Computer-Based Interventions to Teach Communication Skills to Children with Autism Spectrum Disorders: A Systematic Review. *Journal of Behavioral Education* 20, 1: 55–76.
88. N. M. Rani, R. Legino, N. Mudzafar, and M. F. Kamaruzaman. 2014. Embedded visual schedule application towards autistic children development: A preliminary study. *IEEE ICEED*, 129–132.
89. Nancy Rasche, John Pourcho, Shuang Wei, Cheryl Zhenyu Qian, and Victor Yingjie Chen. 2013. Literacy LABELS: Emergent Literacy Application Design for Children with Autism. *SIGGRAPH* '13, 24:1--24:1.
90. L. Ricci, D. Formica, E. Tamilia, F. Taffoni, L. Sparaci, O. Capirci, and E. Guglielmelli. 2013. An experimental protocol for the definition of upper limb anatomical frames on children using magneto-inertial sensors. *IEEE EMBC*, 4903–4906.
91. Delphine B. Rosset, Cecilie Rondan, David Da Fonseca, Andreia Santos, Brigitte Assouline, and Christine Deruelle. 2008. Typical emotion processing for cartoon but not for real faces in children with autistic spectrum disorders. *Journal of autism and developmental disorders* 38, 5: 919–925.
92. Rune Roswall and Thanos Panousis. 2009. Views on service individualization and support for autistic people. *Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology*, 432–437.
93. Tamie Salter, Neil Davey, and François Michaud. 2014. Designing & developing QueBall, a robotic device for autism therapy. *Robot and Human Interactive Communication*, 574–579.
94. Tobias Sonne, Jörg Müller, Paul Marshall, Carsten Obel, and Kaj Grønbæk. 2016. Changing Family Practices with Assistive Technology: MOBERO Improves Morning and Bedtime Routines for Children with ADHD. *SIGCHI* '16, 152–164.
95. Tobias Sonne, Carsten Obel, and Kaj Grønbæk. 2015. Designing Real Time Assistive Technologies: A Study of Children with ADHD. *OzCHI* '15, 34–38.
96. T. R. Soron. 2015. Autism, stigma and achievements of Bangladesh. *Journal of Psychiatry* 2015.
97. Katharina Spiel, Julia Makhaeva, and Christopher Frauenberger. 2016. Embodied Companion Technologies for Autistic Children. *Tangible, Embedded & Embodied Interaction* (TEI '16), 245–252
98. Kenji Suzuki. 2015. Social Imaging Technology to Identify and Represent Social Behaviors. *UbiComp/ISWC*'15 Adjunct, 907–908.
99. Kenji Suzuki, Taku Hachisu, and Kazuki Iida. 2016. EnhancedTouch: A Smart Bracelet for Enhancing Human-Human Physical Touch. *SIGCHI* '16, 1282–1293. https://doi.org/10.1145/2858036.2858439
100. Fabrizio Taffoni, Valentina Focaroli, Domenico Formica, Eugenio Gugliemelli, Flavio Keller, and Jana M. Iverson. 2012. Sensor-based technology in the study of motor skills in infants at risk for ASD. *IEEE RAS & EMBS International Conference on Biomedical Robotics and Biomechatronics* (BioRob), 1879–1883.
101. Yuji Takano and Kenji Suzuki. 2014. Affective Communication Aid Using Wearable Devices Based on Biosignals. *Interaction Design and Children* (IDC '14), 213–216.
102. Fei Tang, Ryan P. McMahan, and Tandra T. Allen. 2014. Development of a low-cost tactile sleeve for autism intervention. *IEEE Haptic, Audio and Visual Environments and Games* (HAVE) Proceedings, 35–40.
103. Ziying Tang, Jin Guo, Sheng Miao, Subrata Acharya, and Jinjuan H Feng. 2016. Ambient Intelligence Based Context-Aware Assistive System to Improve Independence for People with Autism Spectrum Disorder. *HICSS*, 3339–3348.
104. Lisa Thomas, Pam Briggs, and Linda Little. 2010. The Impact of Using Location-based Services with a Behaviour-disordered Child: A Case Study. *NordiCHI* '10, 503–510.
105. L Tian, M Chuah, and E Cappellini. 2015. A Hybrid Solution for Monitoring Conversational Skills of Children with Special Needs. *Wireless Health* (WH '15, 3:1--3:6.
106. Zelai S de Urturi, Amaia M Zorrilla, and Begoña G Zapirain. 2011. Serious Game based on first aid education for individuals with Autism Spectrum Disorder (ASD) using android mobile devices. *Computer Games* (CGAMES), 223–227.
107. Svetha Venkatesh, Dinh Phung, Thi Duong, Stewart Greenhill, and Brett Adams. 2013. TOBY: Early Intervention in Autism Through Technology. *SIGCHI* '13, 3187–3196.
108. Marjo Virnes, Eija Kärnä, and Virpi Vellonen. 2015. Review of Research on Children with Autism Spectrum Disorder and the Use of Technology. *Journal of Special Education Technology* 30, 1: 13–27.
109. Catalin Voss, Peter Washington, Nick Haber, Aaron Kline, Jena Daniels, Azar Fazel, Titas De, Beth McCarthy, Carl Feinstein, Terry Winograd, and Dennis Wall. 2016. Superpower Glass: Delivering Unobtrusive

Real-time Social Cues in Wearable Systems. *Ubicomp*'16, 1218–1226.
110. Bimlesh Wadhwa and Clarence Cai Jianxiong. 2013. Collaborative Tablet Applications to Enhance Language Skills of Children with Autism Spectrum Disorder. *Asia Pacific Conference on Computer Human Interaction* (APCHI '13), 39–44.
111. Peishi Wang, Craig A Michaels, and Matthew S Day. 2011. Stresses and coping strategies of Chinese families with children with autism and other developmental disabilities. *Journal of autism and developmental disorders* 41, 6: 783–795.
112. Xi Wang, Xi Zhao, O Gnawali, K A Loveland, V Prakash, and Weidong Shi. 2013. A real-time selective speaker cancellation system for relieving social anxiety in autistics. *Pervasive Computing Technologies for Healthcare and Workshops*, 420–423.
113. Steve Warren, Punit Prakash, David Thompson, Bala Natarajan, Charles Carlson, Kim Fowler, Ed Brokesh, Jack Xin, Wayne Piersel, Janine Kesterson, and Steve Stoffregen. 2016. Design projects motivated and informed by the needs of severely disabled autistic children. *IEEE EMBC*, 3015–3018.
114. Peter Washington, Catalin Voss, Nick Haber, Serena Tanaka, Jena Daniels, Carl Feinstein, T. Winograd, and Dennis Wall. 2016. A Wearable Social Interaction Aid for Children with Autism. *SIGCHI EA* '16, 2348–2354.
115. Mohammad Wedyan and Adel Al-Jumaily. 2016. Upper limb motor coordination based early diagnosis in high risk subjects for Autism. *IEEE SSCI*, 1–8.
116. Michael L Wehmeyer and Kristine W Webb. 2012. *Handbook of adolescent transition education for youth with disabilities*. Routledge.
117. Orad Weisberg, Ayelet Gal Oz, Ruth Berkowitz, Noa Weiss, Oran Peretz, Shlomi Azoulai, Daphne Kopleman Rubin, and Oren Zuckerman. 2014. TangiPlan: Designing an Assistive Technology to Enhance Executive Functioning Among Children with Adhd. *IDC* '14, 293–296.
118. Jonathan A Weiss, Kendra Thomson, and Lisa Chan. 2014. A Systematic Literature Review of Emotion Regulation Measurement in Individuals With Autism Spectrum Disorder. Autism Research 7, 6: 629–648.
119. Karla C Welch. 2012. Physiological signals of autistic children can be useful. *IEEE Instrumentation & Measurement Magazine* 15, 28–32.
120. Tracy Westeyn, Peter Presti, and Thad Starner. 2006. ActionGSR: A Combination Galvanic Skin Response-Accelerometer for Physiological Measurements in Active Environments. *10th IEEE International Symposium on Wearable Computers*, 129–130.
121. Wijayasingha and Lo. 2016. A wearable sensing framework for improving personal and oral hygiene for people with developmental disabilities. *IEEE Wireless Health* (WH), 1–7.
122. Benjamin Zablotsky, Lindsey I. Black, Matthew J. Maenner, Laura A. Schieve, and Stephen J. Blumberg. 2015. Estimated prevalence of autism and other developmental disabilities following questionnaire changes in the 2014 National Health Interview Survey. Retrieved September 18, 2017 from https://stacks.cdc.gov/view/cdc/38790
123. Dianne Zager and Nancy Shamow. 2005. Teaching students with autism spectrum disorders. *Autism spectrum disorders: Identification, education, and treatment* 3: 589.
124. Camellia Zakaria and Richard C Davis. 2016. Demo: Wearable Application to Manage Problem Behavior in Children with Neurodevelopmental Disorders. *MobiSys '16 Companion*, 127.
125. Camellia Zakaria, Richard C Davis, and Zachary Walker. 2016. Seeking Independent Management of Problem Behavior: A Proof-of-Concept Study with Children and Their Teachers. *IDC* '16, 196–205.
126. Ambreen Zaman and Moniruzzaman Bhuiyan. 2014. Usability evaluation of the MumIES (Multimodal Interface based Education and Support) system for the children with special needs in Bangladesh. 2014 *ICIEV*, 1–4.
127. Special Learning. Retrieved September 18, 2017 from https://www.special-learning.com/
128. AAC speech communicator - Android Apps on Google Play. Retrieved September 18, 2017 from https://play.google.com/store/apps/details?id=com.epfl.android.aac_speech
129. Autism on the rise in India - Chennai - The Hindu. Retrieved September 18, 2017 from http://www.thehindu.com/news/cities/chennai/'Autism-on-the-rise-in-India'/article14985745.ece
130. Autism Spectrum Disorder (ASD) - Data &Statistics. Retrieved from https://www.cdc.gov/ncbddd/autism/data.html
131. Autism facts and history. Retrieved September 18, 2017 from http://www.autism.org.uk/about/what-is/myths-facts-stats.aspx
132. Autism Therapy From a Robot? Medpage Today. Retrieved September 18, 2017 from www.medpagetoday.com/pediatrics/autism/50386
133. GDP per capita (current US$) | Data. Retrieved September 18, 2017 from data.worldbank.org/indicator/NY.GDP.PCAP.CD
134. Autism awareness in Bangladesh and its challenges | theindependentbd.com. Retrieved September 18, 2017 from https://goo.gl/cGVejA
135. UN. Country Classification, https://goo.gl/ftvvCo