



Information & Communication Technologies use by Children & Youth with Autism Spectrum Disorder: Promise and Perils

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Abstract

The current era of Information and Communication Technologies (ICTs) has led to new means of and scope for social interactions and interconnectedness, with potential impacts on the development and quality of interpersonal relationships. Many individuals with Autism Spectrum Disorders (ASD) prefer computer-based interactions and could benefit from the social opportunities offered through this medium. This paper provides a systematic review on ICT use for social and communication purposes in individuals with ASD. Our review suggests that research in this area is extremely limited but that ICT use may present both risk and protective factors in ASD. We highlight gaps in the existing research literature and provide a conceptual framework for future investigation.

Received: Dec 14, 2020

Accepted: Jan 28, 2021

Published Online: Feb 02, 2021

Journal: Journal of Psychiatry and Behavioral Sciences

Publisher: MedDocs Publishers LLC

Online edition: <http://meddocsonline.org/>

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Introduction

Information and Communication Technologies (ICTs) refers to the technology used for providing access to information, including those used for socialization and communication purposes [1]. The current era of ICTs has evoked new means of social connections and interactions with significant impact on the development of interpersonal relationships [2-7]. ICT use can meet the need for companionship and social engagement, supplement face-to-face contact with friends, and help to strengthen existing friendships [8-12]. Greater connectedness through ICTs has been associated with improved social engagement, increased perceptions of social support, closer relationships, decreased depression/loneliness, and enhanced

self-esteem and well-being [10,12,13]. Further, ICTs may be an appealing and compensatory alternative for individuals with social difficulties [14].

Many individuals with Autism Spectrum Disorder (ASD), for whom face-to-face exchanges can be challenging, prefer computer-based interactions and could benefit from the social opportunities offered through this medium [15,16]. While there is evidence that individuals with ASD engage heavily with media and computer-related activities [15-17], there is limited research regarding patterns of ICT use in this population and their potential benefits and risks. This paper provides a system-



Cite this article: Macoun SJ, Bedir B, Runions K, Barker LE, Halliday D, et al. Information & Communication Technologies use by Children & Youth with Autism Spectrum Disorder: Promise and Perils. *J Psychiatry Behav Sci.* 2021; 4(1): 1047.

atic review on the use of ICTs in individuals with ASD, while also highlighting gaps in the research and presenting a conceptual framework for future investigation.

Problems initiating and maintaining relationships due to social-communication challenges define ASD and persist across the lifespan [18] as demonstrated in recent reviews of the nature of friendships and social risks in ASD [19,20]. Individuals with ASD have limited social interactions when compared with their typically developing peers [19,21,22]. This includes restricted social support networks, fewer satisfying relationships and less reciprocal relationships [23,24]. Within the friendships that do exist, they report less companionship, security, intimacy, support, and lower social status [19,25]. In spite of their social challenges, many individuals with ASD desire social interactions and friendships and experience distress around social isolation [26,27]. Those with ASD who have broader social networks experience less loneliness, a greater sense of self-worth, and improved mental health [28,29]. In other words, having a network of friends appears to mitigate against some of the negative effects of social-communication challenges in ASD [30,31]. ICTs hold promise for expanding social networks and building social connections.

A recent exploration of media and ICT use among youth with ASD found that 98% of adolescents with ASD used computers for an average of five hours per day [32]. Their most frequent online activities were solitary, including watching cartoons/video clips, engaging in single-player videogames, and visiting computer game information websites [32]. Further, youth with ASD spent fewer hours per day (0.2 hours) using social media compared to typically developing youth (1 hour) and those with other developmental disabilities (i.e. learning, communication, and intellectual disabilities; [33]). Youth with ASD who used computers for social purposes, including visiting social networking sites and emailing with friends/family, reported more positive relationships than who did not use the computer socially [32]. Youth with ASD also had more of an appreciation for the structural aspects of ICTs (textual, self-paced communication) than their typically developing peers [34]. Interestingly, those with more severe autistic symptoms who used ICTs more frequently demonstrated lower satisfaction with their lives outside of ICTs. These findings are mixed, but suggest that while there may be a benefit to using ICTs for social engagement in individuals with ASD, many individuals with ASD may not naturally gravitate towards using ICTs for social purposes.

Dimensions of ICT use and its social potential has been only minimally examined among individuals with ASD. Bahiss and colleagues [35] explored the use of social media websites (e.g., Facebook, Orkut) as a promising accessible and appropriate means for communication in youth with ASD and found that individuals with ASD experienced these sites as boring or confusing, lacking dynamic interactivity or interface, and were unmotivated to use them for social communication. Burke and colleagues [36] explored use of ICTs among youth and adults with ASD, documenting both promises and barriers to developing friendships *via* the Internet. Their respondents reported many benefits of ICTs, including reduced stress from nonverbal signals, the ability to find people with similar interests, and pre-defined interaction mechanisms. However, while they felt that ICTs helped them to initiate interactions, ICTs were not seen as conducive to maintaining interactions or friendships. Many interactions that were initiated online did not develop into lasting

friendships, as respondents did not know who to trust (e.g., by drawing on previous cyber and traditional bullying experiences), how much personal information to disclose, or the unwritten rules of communication through ICTs (e.g., how face-to-face interaction translates to internet communication).

It is unclear as to whether the inherent structural and functional qualities of ICTs place individuals with ASD on a more equal social 'playing field' and mitigate some of their social-communication difficulties or put them at higher risk. Online communication is different from face-to-face or even telephonic communication in important ways. Runions and colleagues [37] provide a conceptual framework detailing these differences as they pertain to cyber-aggression and cyber-victimization among typically developing youth, although this same theoretical approach can be applied to an exploration of benefits and risks of ICT use in ASD [37]. This framework maps the structural properties of ICTs onto Social Information Processing Theory [38] and describes ways in which the features of ICTs may alter certain core aspects of social information processing and social response, either working in favor or against youth with ASD. The first key communication difference with ICTs is the absence or paucity of non-verbal (facial expressions, gestures, and emotions) and paralinguistic (vocal prosody and speech intonation) cues in favor of text-only communication, or text augmented by photos. Secondly, ICT communication is asynchronous, where lags and delays in interaction are normative. A third communicative difference lies in the permanence of digital data. The fourth difference between communications on- and off-line is the pervasive social nature of communication (i.e., social networks) presenting an unquantifiable potential audience. Each of these technologically-based communicative affordances may pose particular risks and benefits for individuals with ASD.

In this systematic review, we review existing data on the use of ICTs for mainly social and communication purposes in ASD. We consider the potential benefits and risks afforded by ICTs as reported in the small body of extant literature regarding on the online experiences of individuals with ASD. Finally, we outline a framework through which to investigate potential benefits and risks of ICTs in ASD [37].

Methods

Data sources and searches

A comprehensive search of the electronic data bases PsychInfo and ERIC was conducted in January 2019 and then updated in July 2019. Keyword search terms included Autism, Autism Spectrum Disorder (ASD), Asperger's, or Pervasive Developmental Disorder AND Information and Communication Technologies (ICT), computer mediated communication, internet use, online communication, online gaming, social media, social networking, and cyber-aggression/bullying/ victimization. In total, 1600 records were identified through database searches and 13 records were identified through the references sections of articles. 1486 records were identified after duplicates were removed. Forty-seven abstracts were screened, and 23 full text articles were reviewed after applying the exclusion criteria. Two of these 23 articles were removed as they did not meet the criteria, and 21 articles are included in this systematic review (Figure 1). No limits (i.e. publication date or age range) were imposed on the database search due to the limited research in this area. The reference lists of included papers were also screened for additional relevant publications.

Study selection criteria

For this review, we were interested in identifying how and in which ways individuals with ASD use ICTs for social and communication purposes. Inclusion criteria comprised any studies that examined how children, youth and adults diagnosed with ASD use any type of ICTs. Given the expanded date range for this systematic review, studies were included if their samples of individuals with ASD were diagnosed based on either the Diagnostic and Statistical Manual of Mental Disorders Fourth Edition (DSM-IV/TR up to 2013; American Psychiatric Association, 2000) or the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition [19,39] criteria. For the purposes of this review, ICTs were operationalized as any type of computer, tablet or phone use of ICTs for communication, socialization and/or leisure purposes including social media, chat rooms, forums, blogs and online gaming. Exclusion criteria included studies that used ICTs for specific intervention purposes (i.e. educational applications or ICTs specifically designed to remediate cognitive, social, language or other skills).

Data extraction

Two independent examiners screened results for eligibility by title and abstract. When there was a disagreement, a third independent examiner was introduced to make a decision. Eligible studies were selected based on the examiners' reviews of the abstracts. Then, key data were extracted by two reviewers (DH and BB). Key data were extracted from a total number of 23 studies; however, two of these studies were excluded as they were direct intervention studies.

Quality review

Studies were subsequently reviewed for quality, based on measures suggested by Zeng and colleagues [40]. The majority of the included studies were cross-sectional and employed data derived from surveys. For these studies, the Agency for Healthcare Research and Quality (ARHQ) methodology checklist was used [41]. Most of the studies that were included employed measures with reliable psychometric properties. Additionally, studies that used less well-known surveys and questionnaires reported on the internal consistency of their measures. Recruitment strategies for ASD participants within studies varied, but typically recruitment occurred through targeting ASD groups, health care practitioners, and in some cases, databases available through major hospitals or research centers. The majority of studies included participants who were identified as having ASD on the basis of self- or parent-reported diagnosis, and nearly all studies failed to report on the presence of potential comorbid conditions that may have impacted interpretation of the findings (e.g., social anxiety, ADHD). Two of the included studies conducted reviews and we examined these for quality

using the second edition of the Assessment of Multiple Systematic Reviews (AMSTAR-2) measurement tool [42]. Although the description of the individual studies and the synthesis of findings in each of these reviews were well-conducted, there were methodological shortcomings in both studies with respect to the reported strategies for study search and inclusion, as well as assessment for risk of bias. One case study was included and was examined for quality using the Newcastle-Ottawa Scale [43]. Quality in this study based on the Newcastle-Ottawa scale was high.

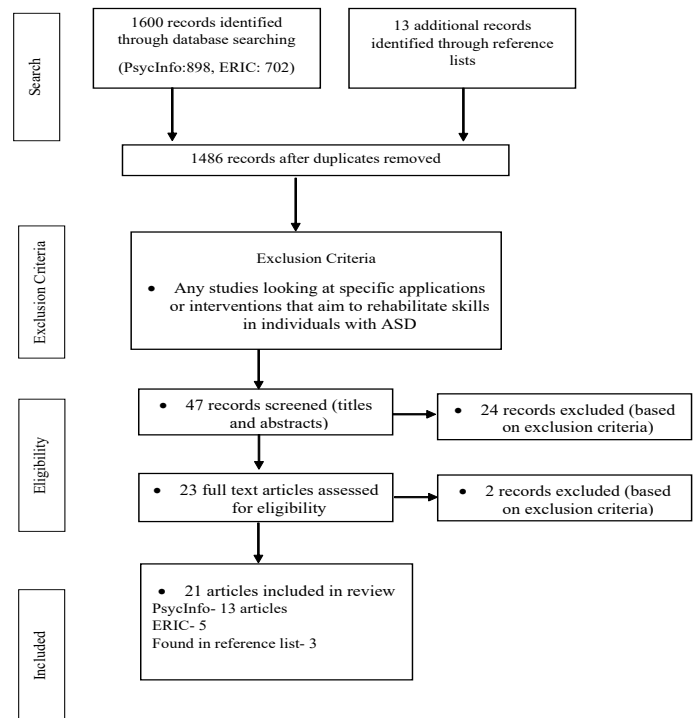


Figure 1: Electronic search and screening methods.

Results

A total of 21 studies are included in the current systematic review. Key methodological characteristics of these studies are presented in Table 1. The included studies consist of one case study, one dissertation, two reviews, and 17 cross-sectional or observational studies. The studies reviewed include samples ranging from only one participant to 920 participants diagnosed with ASD. The included studies were conducted mainly in USA (n= 12) and Europe (n= 6), one in Japan, and two reviews. Given the novelty of the topic of interest, a variety of study types were used in the current systematic review. To summarize, study results are summarized in two parts: ICT use in individuals with ASD and risks and benefits of ICT use in individuals with ASD (Table 1).

Table 1

First Author	Year	Country	Sample size	Age range	Diagnosis	Study Design	Study Objective	Outcome
Benford	2008	England	138	16 and older	Diagnosis of Asperger's or high functioning ASD (HFA)	Cross-sectional	Identify the users of internet and the patterns of internet and social media use	Most participants (91%) are internet users. Most popular reasons for using internet were enjoying this form of communication and have contact with others.
Benford	2009	England	23	16 and older	Diagnosis of Asperger's or HFA	Cross-sectional	Identify whether internet based communication helps or hinders the communicative approach characteristics of autism	4 subthemes under the communication theme emerged: control, clarity, role of nonverbal communication and social role of communication

Boucenna	2014	France	N/A (Review)	N/A	Diagnosis of ASD	Review	Identify the uses of ICT for education of individuals with ASD	4 reasons why ICT is used: Interactive environments, virtual environments, avatars for serious games, telerehabilitation for ASD
Burke	2010	USA	16	17-37	Diagnosis of ASD including Asperger's, HFA and PDD-NOS	Cross-sectional	Identify the communication needs of adults with ASD, and how well current ICTs meet these needs	5 difficulties emerged: initiating contact, problems maintaining contact, knowing whom to trust, how much to disclose, understanding CMC specific norms
Gillespie-Lynch	2014	USA	602	18 and older	Diagnosis of ASD and control participants	Cross-sectional	Identify whether ICTs provide qualitative different communicative benefits to adults with ASD compared to without ASD	ASD participants enjoyed meeting others online for reasons of increased comprehension and control over communication, access to similar people, and the opportunity to express who they are
Iglesias	2019	Spain	181	10 to 25	Individuals with intellectual disability (ID), with ASD and controls	Cross-sectional with a case-control	Examine how young people with ID or ASD use ICTs and social media compared to typically developing peers	Individuals with Asperger's syndrome use social media the least; however, there were no differences in cyberbullying rates.
Kowalski	2011	USA	42	10 to 20	Youth diagnosed with ADHD and/or Asperger's syndrome	Cross-sectional	Identify patterns of traditional and cyber bullying in youth with ADHD and Asperger's	High rates of traditional (57%) and cyberbullying (21%) reported in the past 2 months.
Kuo	2014	USA	91	12 to 18	Previous diagnosis of ASD	Cross-sectional	Identify how adolescents with ASD use media, and examine factors associated with media use	98% of all adolescents in this study used computers. Adolescents with ASD who visited social networking websites or received emails from friends reported more positive friendships
MacMullin	2016	Canada	311	Parents of youth between 6 and 21	Typically developing youth and youth diagnosed with ASD	Cross-sectional	Identify the experiences of electronics use between controls and youth with ASD	Individuals with ASD use electronics more, and had more compulsive internet and video game use compared to those without ASD. Parents of children with ASD reported electronics use as more problematic.
Mazurek	2012	USA	920 with ASD	13-17	Special education ASD students	One wave of data taken from longitudinal study	Identify the prevalence and correlates of screen-based media in youth with ASD	Majority of participants with ASD (64.2%) used screen based media for non-social media purposes, and only 13.2% used screen based media for social media purposes
Mazurek	2013	USA	381	8 to 18	Parent-reported diagnosis of ASD	Cross-sectional	To characterize the amount and intensity of tv, video game, and social media use among children with ASD and their typically developing siblings	Children with ASD spend more time watching tv and playing video games (62% more) than all other non-screen activities combined. Parents reported more problematic video game use in the ASD group participants. Children with ASD use internet less for social media and socially interactive video games.
Mazurek	2013	USA	108	18-62	Clinical diagnosis of ASD	Cross-sectional	Identify and examine the patterns and social-emotional correlates of social media use in adults with ASD	79.6% of participants with ASD use social networking sites (SNS) for social connection purposes. Adults who used SNS were more likely to have close friends, and reported closer friendships.
Shane	2008	USA	89	18 and younger	Diagnosis of ASD	Cross-sectional	Identify the viewing patterns and habits for television and computers for children with ASD	Children with ASD mostly use internet for websites that feature primarily animated content (e.g. cartoons).
Shane-Simpson	2016	USA	66 (33 with ASD, 33 typically developing)	18-37	Diagnosis or self-identification of ASD	Cross-sectional	To investigate the difference between Compulsive Internet Use (CIU) between samples	There were no differences in compulsive internet use between ASD and neurotypical students.
Stendal	2016	Norway	1	14-69	Individual diagnosed with ASD	Case study	To explore the virtual worlds of people with ASD	This individual's experience indicated that he enjoyed using a virtual world, and virtual methods of communications may be more preferable.

Sundberg	2018	Sweden	156	14-69	Diagnosis of ASD	Cross-sectional	Investigate the links between online gaming, loneliness and friendship in adolescents and adults with and without ASD	Individuals with ASD who play online video games have more friends than those who do not. Additionally, online games were linked with less loneliness in this group.
Van der Aa	2016	Netherlands	183	18 and older	Diagnosis of ASD and control participants	Cross-sectional	To understand and compare CMC use between adults with and without ASD	Individuals with ASD spend more time on computer-mediated communication methods more than controls, and are positive about their experiences. They also reported high levels of online social life satisfaction.
Van der Aa	2017	USA	100	12 to 19	Diagnosis of ASD and control participants	Cross-sectional	To investigate patterns of social media use, friendship quality and level of anxiety in adolescents	Social media use is associated with friendship quality in participants with ASD.
Wainer	2010	USA	N/A	N/A	Individuals with ASD	Cross-sectional	Examine the use of computer programs focused on social skills to individuals with ASD	Computer programs may be effective in developing language, emotion recognition, social skills in individuals with ASD.
Ward	2018	USA	106	Adults	Self-report of ASD	Cross-sectional	To explore and understand the relationship between social media use and happiness in adults	Adults with ASD who used social media (particularly Facebook) reported greater subjective happiness than those who did not.
Watabe	2015	Japan	158	20-39 (all male)	Asperger's diagnosis, schizophrenia and control participants	Cross-sectional	To investigate the usage of Internet communication among individuals with ASD and schizophrenia	Individuals with ASD prefer anonymous media, and believe they can communicate better online than face-to-face.

Patterns of ICT use in individuals with ASD

Amount of ICT use in individuals with ASD

Eleven of the 21 studies reviewed (52%) reported on the time spent on ICT use in individuals with ASD. Results indicate that those with ASD appear to spend more time using ICTs than typically developing populations of the same age [34]. Findings also suggest that individuals with ASD use electronics (i.e. computers, laptops, smart phone or tablet) more and engage in more compulsive internet use as evidenced by longer electronics use and more time spent using Internet [15,33]. Taken together, these studies found that many individuals with ASD engage heavily with ICTs and computer-related activities. One study [44] surveyed individuals with ASD aged 16 and older and found that 95% of their participants used computers and 91% were regular Internet users.

Type of ICT use in individuals with ASD

Thirteen of 21 studies (62%) described the specific ways that individuals with ASD engage with computers and other ICTs for leisure purposes. Even though most individuals with ASD use computers and Internet, the purpose of this use, and how it is used for social and communication purposes, varied depending on the study.

Seven of 21 studies (33%) found that participants with ASD primarily used ICTs in a social manner, such as for interacting with others [44]. It was found that 83% of their ASD sample (ages 16 and older) used internet to communicate with others through email, online groups and online forums [33]. Another study similarly found that majority of ASD participants within their sample (ages 18 to 62; 79.6%) used social networking (i.e., blogs) for social connection purposes. Of note is that four of 21 studies reported that the individuals with ASD who were using social media and social networking sites reported having more close friends and higher friendship quality than those ASD who

were using ICTs for non-social purposes [33,45-47].

In contrast, four of the 21 studies reviewed reported different ICT use patterns in individuals with ASD compared to their typically developing peers, which tended to be less social and communicative in nature. These studies found that individuals with ASD generally used ICTs in a solitary manner. Specifically, Iglesias, Saanchez and Rodríguez found that individuals diagnosed with Asperger's Syndrome (DSM-IV) used social media much less than other special needs groups (i.e., intellectual disability) and typically developing individuals [45]. Others found that even though 98% of adolescents with ASD used computers daily, playing video games and exploring websites were their most common activities [15,45] It was documented that those with ASD used electronics more and exhibited more compulsive internet and video game use compared to those without ASD [32]. Finally, others Noted that 64.2% of youth with ASD were using screen-based media for non-social purposes whereas only 13.2% were using screen-based media for social purposes.

Reasons for ICT use in individuals with ASD

Eight of the 21 studies (38%) reported on why individuals with ASD use ICTs, primarily from the perspective of the individual diagnosed with ASD [32,33,44,45,48-51]. Overall, reasons cited for using ICTs included taking part in online groups to make contact with others with similar interests, advocating for themselves through media blogs, communicating with others without the pressure of in-person interactions (eye contact, immediate response etc.), expressing who they are in a 'safe' medium, and exploring websites focused on their areas of interest. The most common theme was that individuals who used ICTs for social networking did so in order to access other individuals who shared similar interests [48]. summarized first person reports from individuals with ASD who stated that their reasons for using ICTs/screen-based media included more control and comfort in online interactions, clearer communication

online, the absence of nonverbal communication, and socialization purposes (to keep in touch and have relationships with others). Overall, these results suggest that individuals with ASD are using ICTs and screen-based media frequently; however, the purpose and the patterns of ICT use are variable, and more research is clearly needed to understand how ICT's are being used and for what purposes in individuals with ASD of various ages.

Benefits and Risks of ICT use in individuals with ASD

There are specific benefits and risks associated with ICT use [52-54] that may be even more pronounced in individuals with ASD compared to those without. Sixteen of 21 studies (76%) commented upon the potential benefits and risks associated with ICT use in individuals with ASD.

Benefits

Ten of 21 studies (48%) reported on perceived benefits of ICTs in individuals with ASD. The themes that emerged were that ICT use may have social and mental health benefits in ASD. Seven of the 10 studies that reported on potential ICT benefits described specific social benefits, such as contacting others who share the same interests with them, having closer relationships and more friends, and experiencing higher friendship quality [33,44,45-47,50,51].

Three of the 10 studies that described benefits of ICT use in ASD, reported on the mental health benefits of ICT use, such as decreased loneliness through having friends [46,55] and greater happiness in life [56].

Finally, three of the 10 studies reported on other potential benefits of ICTs specific to ASD. First, individuals with ASD reported communication benefits in ICTs such that they prefer online communication because it provides more control and clarity in social interactions [48]. Second, it was also found that leisure use of ICTs could be leveraged to develop language and communication skills, and may be potentially effective for teaching social skills and social understanding [57]. Verbal imitation was reported to occur after exposure to ICTs, which could support development of social language and communication skills in individuals with ASD [16].

Risks

Despite the potential benefits of ICTs considered above, it is important to recognize that the online social context might not support net gains in social and emotional wellbeing. For instance, the same negative processes that predispose youth with ASD to social communication difficulties and bullying in face-to-face contexts may also be present in the ICT medium [58-60]. Overall, 6 of the 21 studies (29%) reported on the potential risks of ICT use in individuals with ASD. The main themes that emerged from these studies included the risk of cyberbullying, stress and anxiety caused by ICT use, perceived social risks, failures of ICT and compulsive internet use. First, two of the 6 studies that reported on potential risks of ICTs in ASD, highlighted the potential of cyberbullying in individuals with ASD [61,62]. Cyberbullying is defined as an intentional act of aggression or bullying that occurs through electronic forms of contact such as email, instant messaging or social networking sites [63]. Individuals who are bullied experience a significant impact on their health, and experience a range of negative psychological effects including anxiety, depression and low self-esteem [62,64,65]. Those with special needs are at a heightened risk of being bullied compared to others [62,66-68]. It was reported that 21%

of individuals with ASDs (Asperger's Disorder) had experienced cyberbullying in the past two months characterized by experiencing aggression through instant messaging and social networking sites [61]. It was found that there were no significant differences in cyberbullying rates between individuals with ASD, ID and typically developing individuals. However, given the particularly high risk of bullying in ASD when compared with other special needs groups [68,69], cyberbullying remains a significant risk factor of ICT use in individuals with ASD.

Three of the 6 studies that cited ICT risks reported on potential mental health risks of using ICTs for individuals with ASD [34,49]. These risks included higher levels of anxiety and depression experienced by individuals with ASD due to cyberbullying [62] and concerns around whether to trust others online. Risks also included experiencing loneliness [49] and poorer life satisfaction [34]. Interestingly, [34] noted that although their sample with ASD reported positive feelings around their ICT use and relatively high levels of online life satisfaction, ICT use was negatively associated with general life satisfaction in this group. This may be because individuals with ASD who spend more time using ICTs have fewer in-person interactions, thus lowering general life satisfaction. Another possibility is that individuals with ASD who are less satisfied with their lives may turn to ICTs and spend more time online to build connections.

Three of the 6 studies citing potential risks reported on compulsive ICT/computer use in individuals with ASD [15,33,55]. These studies found that individuals with ASD tend to use ICTs more compulsively and for a longer duration than those without ASD. In one study, parents of children/youth with ASD (ages 6 to 21) reported more problematic ICT use in their children compared to parents of typically developing children/youth [15]. Similarly, children with ASD spend more time playing video games and watching TV compared to all other non-screen activities combined [33], which can lead to compulsive computer use [33]. It was argued that these behaviours may be particularly problematic because compulsive ICT use reduces the frequency of non-screen-based activities such as physical exercise, reading or spending time with friends. Additionally, problematic videogame play, as evidenced by prolonged time playing video games, may lead to other unfavorable behaviours such as thinking about video games when not playing, getting upset or angry when not able to play or having difficulty disengaging from playing video games. Alternately, another study defined compulsive internet use as experiencing "loss of control" when using Internet and experiencing withdrawal symptoms when not able to use Internet [70]. This study reported that there were no significant differences in compulsive internet use between college students with ASD and typically developing students [70]. However, they did identify unique patterns of Internet use around special interests in ASD, such as frequenting certain websites focused on circumscribed interests.

One study of 6 reported on the perceived social risks and failures of ICT use in individuals with ASD [49]. This study indicated that individuals with ASD used ICTs to initiate contact with others and to work around problems maintaining contact with others. However, they also reported some risks for ICT use in individuals with ASD, including not knowing whom to trust in online relationships, not knowing how much to disclose in online interactions, and concerns around being deceived in online relationships. Individuals with ASD reported not knowing how much information to share or how much to disclose with people they meet online and not understanding the norms of comput-

er medicated communication (CMC). Additionally, individuals in this study reported difficulties maintaining contact with people they had met online, leading to negative feelings such as feelings of loneliness and having no one to talk to.

Discussion

This study set out to explore dimensions of ICT use in individuals with ASD ranging from childhood through to adulthood. The limited body of research found suggests the majority of individuals with ASD are using ICTs for social (i.e. communicating with others through ICTs) and non-social (i.e. visiting websites, playing videogames) purposes. Compared to the typically developing population, individuals with ASD are spending more time using ICTs and seem to be more prone to using ICTs compulsively [15,33]. Further, those with ASD are using ICTs in a less social and communicative way (such as playing video games or exploring websites) compared to their typically developing counterparts [61]. Although an understudied area, there do appear to be potential benefits and risks of ICT use in ASD. The benefits of ICTs include ease/comfort of meeting and interacting with others, less pressure in social interactions, better friendship quality, increased happiness, and fewer mental health problems (e.g., low self-esteem and depression). The risks of ICT use include the potential for cyberbullying, compulsive Internet/computer use (i.e., spending prolonged periods of time using ICTs), problematic ICT use (i.e. not engaging in other non-screen-based activities) and limited understanding of the nature of online interactions (i.e., not knowing whom to trust or how much information to disclose, thus increasing stress).

Current literature on ICT use in ASD is limited, making it difficult to form firm conclusions based on age or gender, and it is clear that more systematic research is needed. Based on the systematic review conducted, several themes emerged. First it appears that children/youth (aged between 6 and 21) with ASD are using ICTs more compulsively than their peers. We could not find literature on compulsive ICT use for adults with ASD and more research is needed to determine whether compulsive ICT use is also an issue in adulthood. Second, youth and adults with ASD who use ICTs reported better mental health outcomes and higher online life satisfaction. They also reported enjoying meeting others online due to feeling more comfortable and having clearer communication in the online medium [33,47,48,56]. Third there is some data on cyberbullying experiences in ASD from childhood through early adulthood (ages 10-25; [61,62], but we could not find any information on cyberbullying experiences after age 25. Finally, in terms of trends based on gender, it appears that females with ASD may use internet and ICTs for socialization/communication purposes more so than males [44]. Additionally, a higher number of males use ICTs to play video games (i.e. in non-social ways) compared to females [15].

It is clear that research on ICTs in ASD is in its infancy and fraught with limitations. First, the few studies that do exist rely on convenience samples rather than the broader community of individuals with ASD and do not differentiate between experienced and inexperienced ICT users. Key factors such as severity of ASD, gender, and age have not been explored, despite the known impact of these variables on communication, social function, and dimensions of ICT use. Studies in youth have often gathered information from a parent-only perspective [15,16], which may not accurately mirror children, youths or adults' experiences [19]. When studied from a first-person view, researchers have typically used self-report measures and surveys of emotional and social experiences and perceptions. However,

these are difficult to interpret in ASD, given challenges with communication and social-emotional understanding [71]. Even less is known about the impact of ICTs on social-communication and friendships in ASD. Questions regarding how ICTs actually influence social functioning, either on- or off-line, and how this extends to relationships, mental health, and quality of life outside of the online medium and across the lifespan are unanswered. The literature regarding the risks of ICT use in ASD and relative vulnerability of children with ASD is similarly scant. In part, these limitations relate to the absence of a strong theoretical basis from which to generate hypotheses regarding the anticipated impact of ICTs in this population. Structuring this research in a clear theoretical framework [37], provides a basis for generating hypotheses considering how the specific structural and functional properties of ICTs might operate for people with ASD, to either benefit or hinder communication and socialization.

A theoretically informed approach to investigating benefits and risks of ICTs in ASD

Runions and colleagues [37] provide a conceptual framework detailing the differences between on-line and face to face communication as they pertain to cyber-aggression and cyber-victimization among typically developing youth. However, this same theoretical approach, which maps the structural and functional properties of ICT's onto social information processing theory, can be applied to explore of benefits and risks of ICT use in ASD. Below we review how four unique features of ICTs (paucity of nonverbal cues, asynchronous communication, permanence of digital data, and the virtual audience afforded by ICTs) might be used to investigate specific benefits/risks of ICT use in ASD.

Paucity of paralinguistic and nonverbal cues

Online communication is characterized by a lack of paralinguistic and nonverbal cues. Nonverbal affective displays, expressed through facial expression, eye contact, emotional expression, and body language are absent [72], as are verbal cues such as tone of voice, vocal inflection, and breathing patterns. In non-ICT communication, these cues help to clarify intentions and the emotional meaning behind words. In ASD, problems with understanding facial expressions, reading body language, identifying emotions in others, and interpreting vocal intonation [18,73] result in ambiguity and problems with accurately gauging others' intentions. The converse is also true in that individuals with ASD have difficulty producing appropriate nonverbal and paralinguistic cues, similarly leading to communication breakdowns. Online, verbal and nonverbal social cues are absent, creating the same ambiguity about the intent or meaning of the words for all users. While this may present risks for increased cyber-aggression amongst non-ASD youth [37], it may 'level the communicative playing field' for those with ASD through reducing the number of communication channels to attend to, streamlining or simplifying social interactions, and minimizing social misperceptions [74,75]. Further, communicative conventions such as emoticons have arisen in response to the ambiguity and lack of nonverbal cues during ICT communication. Emoticons assign emotional content to text-based communications and clarify message content that could potentially be misunderstood. While emoticons have the potential to be misunderstood and can create ambiguity (e.g., when a negative statement is followed by a positive emoticon; [76]), they generally help to assign meaning and tag emotions to communications in a literal manner. In ASD, these emoticons may provide

a concrete symbol scaffolding understanding of the emotional tone of a communication or its intent. Indeed, our systematic review indicates that adults with ASD report feeling more clarity and less stress during online communication, because they don't have to attend to or interpret nonverbal cues [34,48,49].

Asynchronous nature of on-line communication

ICT communication is asynchronous, where lags and delays in interaction are normative. When communicating *via* ICTs there is less expectation for uninterrupted, continuous engagement and it is understood that a friend may not be able to reply immediately. This normative lag may present opportunities for users with ASD who have difficulty with real-time reciprocal back-and-forth communication [18,73,77]. Rather than requiring a contextually-appropriate response to be generated in real-time, online communication permits a more deliberated response. This could allow for more control over the pacing of conversations, which may be helpful for those with ASD [34,48]. Further, conventions such as waiting for others to finish speaking before talking, turn-taking turns, and knowing how to enter and exit a conversation are less of an issue within an asynchronous medium. Indeed, the 'slower pacing' of internet communication has been perceived by ASD ICT users as advantageous, affording more time to process the message, practice social interactions, and formulate a response [48].

Online communication creates permanent records

When we communicate *via* digital ICTs, most of our communications are permanent and shareable. Much theorizing on the impact of this has focused on the negatives arising from sharing of private images or communications (e.g., cyberbullying and sexting). For those with ASD, however, permanent records may allow them to review at their own pace, to re-visit/re-examine communications and multimodal social cues (text, pictures, emoticons), and to plan response options. This provides time to apply a problem solving approach and shifts communication from abstract to more concrete. The permanence of digital data may provide an opportunity for to consult with others on response options or to clear up misunderstandings. This greater control over social interactions and opportunity to review is not present in most other modes of communication [48]. Indeed, those with ASD have noted that conversations *via* ICTs feel more predictable and structured, individually paced, and less stressful [34].

Online communication is simultaneously public and private

A key difference between communications on- and off-line is the pervasive social nature of communication (i.e., social networks) presenting an unquantifiable potential audience. Although one-to-one text messaging remains popular, online communication is increasingly in 'one-to-many' modes (i.e., one individual communicating with an audience). The prevalence of sites like Facebook, Twitter and Instagram linking social networks means that communication *via* ICTs is increasingly conducted with a potentially unlimited audience, which affords both benefits and risks. The public nature of ICTs may increase risks for victimization as they make bullying acts easier to initiate and disseminate [37]. Further, the potential for a larger audience witnessing these acts intensifies their negative impact [78]. On the other hand, the one-to-many mode afforded through ICTs could be beneficial to those with ASD in that it permits users to participate in a group context and feel part of a larger 'community.' The one-to-many mode can

also serve to broaden one's social network, allowing initiation of social interactions with a greater number of individuals and increasing the likelihood of finding those with shared interests. Research suggests that individuals with ASD use ICTs to expand their social networks and connect with individuals who share similar interests [48,50]. In addition to expanding one's social network, knowing that one is engaging successfully "in front" of an audience, even if a virtual one, may also support self-efficacy in youth with ASD. Many individuals with ASD exhibit social anxiety and discomfort, due to a long history of aversive social experiences and successful online socialization could mitigate against that [79,80].

Although in front of an audience, ICTs also hold a degree of anonymity for the user. This has been cited as a risk factor for cyberbullying and victimization in that perpetrators may be more likely to initiate (due to their own anonymity) and maintain (due to anonymity of the recipient) bullying behavior [37]. However, for individuals with ASD, being able to initiate interactions without revealing one's identity may allow social practice in a less 'threatening' manner thus reducing social discomfort [81]. Online anonymity allows people to experiment with their identity and express ideas they may not be comfortable communicating in face-to-face interactions [81]. Because of the anonymity afforded through ICTs, individuals self-disclose personal information more quickly than in face to face interactions, leading to greater perceived closeness to others and faster development of friendships [13,81-83].

It is also important to recognize that the online social context might not support net gains in social and emotional wellbeing for individuals with ASD. It may be that the same negative processes that predispose those with ASD to social communication difficulties and bullying in face-to-face contexts are also present online. First, in order to reap the potential social benefits of ICTs, one needs to use ICTs for social purposes. Problematic internet use and a fixation on passive entertainment in some youth with ASD in addition to lower motivation to engage socially on line may limit on-line socialization opportunities [15,48]. Even among those willing to use ICTs for socializing, there is insufficient evidence as to whether the social practice that occurs through this medium has a downstream positive effect on real life social skills, friendships, and wellbeing [36,84]. Further, time spent socializing or developing superficial relationships online may come at the expense of quality, real world relationships which are protective for mental health in youth with ASD [i.e., time spent with family [85]. Finally, there is insufficient evidence as to whether ICTs truly compensate for some of the fundamental social problem-solving, perspective-taking, and communication deficits seen in individuals with ASD. Even within ICTs, individuals with ASD have difficulty understanding figures of speech and handling inappropriate requests [86]. The same pattern of deficits may exist when communicating both through ICT and non-ICT mediums, and the net gain of socializing in this manner may be negligible.

It may also be that ICT mediated socialization also poses a risk of direct harm for individuals with ASD. The same properties of ICTs that place typically developing individuals at greater risk of victimization [37] may hold true for those with ASD. First, while individuals with ASD may be more likely to self-disclose in an ICT medium, a valid concern acknowledged by individuals with ASD is knowing when and how much to disclose to others, posing the risk of too much self-disclosure of private information [48]. Further, for non-ASD youth with developmental and

intellectual disabilities, there is evidence of relatively high rates of cyberbullying, with a significant positive correlation between the use of technology and the prevalence of being bullied [87]. Indeed, preliminary research suggests that youth with ADHD and ASD may have higher rates of victimization *via* cyberbullying than typically developing youth, manifesting in increased anxiety, depression, and lower self-esteem [61].

Conclusion

Similar to their typically developing peers, individuals with ASD are regularly engaging with ICTs. However, there is limited knowledge on the true benefits and risks of socializing and communicating in this medium. Ultimately, to answer questions of whether and how ICTs might improve life for individuals with ASD theoretically informed studies are required. We believe that the conceptual framework outlined above [35] provides a clear structure for investigating how the unique structural properties of ICTs map onto social and communicative differences in individuals with ASD, thus conferring either benefit or risk when socializing in this manner. Future studies should explore both the quality and quantity of friendships on- and off-line, how these are associated with and mediated by ICT use, and their broader impact on mental health and quality of life. In this endeavor, investigations of specific types of ICTs in relation to outcomes will be particularly enlightening, with a possible emphasis on how the use of socially-oriented multiplayer games or virtual formats, of particular appeal to the ASD population, might enhance social engagement and gains [33].

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