Investigation into Stress Triggers in Autistic Adults for the Development of Technological Self-Interventions

John J. Mcgowan
Edinburgh Napier University
j.mcgowan@napier.ac.uk

Iain Mcgregor
Edinburgh Napier University
i.mcgregor@napier.ac.uk

ABSTRACT

Adults with autism spectrum disorder (ASD) face daily challenges dealing with stress, for example, at work, or in public spaces, which can be overwhelming in terms of coping with sensory overload. Technological interventions have been created in order to attempt to counter symptoms of stress, through improving cognition and functioning of target users. Mobile devices, virtual reality (VR) and augmented reality (AR) applications have demonstrated the ability to support and improve clinical practices through sensory based technologies. In this paper, we present the initial phase of research concerning an online survey conducted with over 200 autistic participants and caregivers. We report on the identification of currently used technological preferences, triggers associated with stress, issues regarding sensitivity and perception, the needs of caregivers, as well as the perceived potential for new technologies. The study has identified that sensitivity to sound and light remain key stress triggers for those on the autism spectrum. Headphones and mobile devices were considered to be suitable methods of accessing multi-sensory stimuli to help manage stress. Augmented Reality and VR were identified by autistic participants as technologies that might aid in the reduction of unpredictable stress-related events. The insights gained from the research will inform future research regarding the design of technological self-interventions for stress management in autistic adults.

CCS CONCEPTS

• **Human-centered computing** → Accessibility; Accessibility technologies; Interaction design; Empirical studies in interaction design.

KEYWORDS

Autism, Stress Triggers, Stress Management

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1 INTRODUCTION

This research is concerned with the identification of stress triggers along with the use and adoption of technologies amongst autistic people. Data will be used as initial requirements for the design and development of a stress management augmented reality tool (SMART). A potential application could monitor real-time biometric data from autistic users and employ audio-visual entrainment to help manage end-users' stress. Mobile technologies have been designed to help autistic people and their caregivers overcome a number of challenges, for example, in communication, social interaction, and living independently [13]. Previous research has indicated that technology was a major strength and interest for those on the autism spectrum [14]. However, software designers need to be more aware that the creation of future technology-based products for people with autism requires to go beyond being merely effective, but also to meet important user goals and align with individual users' interests and strengths.

1.1 Autism and Stress

Autism Spectrum Disorders (ASDs) are a group of developmental disorders that have related deficits in communication [1], perceptual processing [2], and/or social interaction [3]. Autistic people can easily become anxious and stressed in different situations, in particular when senses become over-stimulated, for example, when exposed to a new environment [4]. Autism is associated with hypersensitivity and/or hyposensitivity, which in turn can directly affect cognitive processes through sensory overload [5–7]. Low functioning adults with ASD, clinically referred to as *profound autism* [8], are said to lack other-awareness, and can be non-verbal, which severely restricts opportunities for peer collaboration [9]. High-functioning adults with autism may lead more independent lives, face daily challenges with hyper/hyposensitivity, for example, tasks performed at work, or in dealing with public spaces, which can be overwhelming in terms of coping with sensory overload. Adults may use camouflaging, masking or compensating of autistic characteristics in social situations, which is hypothesized as a common social coping strategy for adults with ASD. Camouflaging may impact diagnosis, quality of life, and long-term outcomes [10], which may be especially prevalent amongst women, according to a 2020 review by Hull et al. [11]. Autistic characteristics can make everyday activities more difficult for those on the spectrum, leading to an inability to cope with certain situations, poorer social functioning compared to neurotypicals (NTs), and a more stressful life in general. The consequences of stress need to be addressed in order to deal with the immediate and long terms effects on the autistic population through development of appropriate technological interventions [12–14].

People with ASD can have trouble focusing on specific visual cues from a distance, indicating a more distinct spatial gradient of attention [15]. In particular, autistic visual experience is typically marked by superior perception of local details and inefficient integration of information across a broader space [16]. Robertson et al. [16] suggested this forms the presence of a form of tunnel vision, likened to studies relating to stress in emergency services, where both visual and auditory stimuli decreased significantly under stress [17, 18]. From an audio perspective, decreased sound tolerance (DST) is the most common sensory difficulty experienced by autistic people [19]. Loud, sudden, and high-pitched sounds are commonly cited as causing stress and anxiety, leading to reduced social abilities, challenging behaviors, and difficulties throughout autistic individuals' lives [20].

Difficulties have been further exacerbated by the recent impact of the COVID-19 pandemic, where studies found a notable increase in depression and anxiety in autistic adults [21]. In computer-mediated communications, autistic adults have been shown to use coping strategies to manage stress, including moderating their sensory inputs, for example, by adjusting their partners webcam brightness, or engaging in stimming to release nervous energy [22]. In addition, they may create mental models of conversation partners, and attempt to mask their autism by adopting NT behaviors [23]. The use of virtual reality (VR) shows real promise as a means to improve cognition and functioning in autism for young adults [24]. Audiovisual entrainment has been demonstrated to reduce symptoms in those with cognitive disorders including seasonal affective disorder, chronic pain, fibromyalgia, insomnia, post-traumatic stress disorder (PTSD), as well as attentional disturbance [25]. The same study claimed to reduce stress and increase socialization amongst college students. Audio-based research has demonstrated that listening to soft music with repetitive slow rhythms can indeed provide an effective method of calming children with autism [26].

1.2 Current Interventions for Stress

Interventions designed to reduce stress for autistic people aim to provide a better quality of life by facilitating interaction with media, encouraging engagement in exercise, participating in recreational activities, and by generally providing a means to live healthy independent lives [27, 28]. Successes have been identified for both occupational therapy and music therapy as interventions for stress, for those on the autism spectrum [29]. Occupational therapies aimed at developing fine, gross motor and daily living skills, have garnished substantial support for their effectiveness in improving play, language, social interaction, independent functioning, and self-management skills [30]. Music therapy consisting of listening to or performing music, often as a group, has received evidence for its ability to improve social tolerance, flexibility, and engagement, but also emotional responsiveness, attention span, along with reduction of stress [31].

Alonso-Esteban et al. [32] highlighted the use of smartphones, video modeling (simulation of social activities), teleassistance, virtual/augmented reality, or the use of robots, as means to support and improve clinical practice regarding the use of cognitive behavioral therapy (CBT) for addressing anxiety in autism spectrum disorders. Findings from a 2021 study into the use of sensory-based technologies, suggested an effective improvement of auditory and visual recognition, and other behavioral outcomes, such as attention in children with ASD [33]. A prototype mixed reality (MR) system called *Tea Room* was successfully tested with autistic children aged between 6 and 10 as a means of reducing stress through interactive simulation [34]. Extended reality (XR) autism research has typically focused on socio-emotional capabilities and high functioning target populations. However, Bauer et al. [35] suggested that XR could better support practitioners' existing interventions, and that further study may help to define improved design guidelines, thereby benefitting a greater number of individuals on the spectrum. The report suggested further development to widen the scope of usage, for example, via machine learning (ML). Carlier et al. [36] presented a small-scale study (n=3) investigating the feasibility of empowering children with ASD, and their parents, via the use of sensory and meditative-based mini-games to foster relaxation techniques. The results showed potential for stress and anxiety reduction. Some employers are currently utilizing digital technologies, including AR, as a means of addressing the needs of autistic employees, by reducing stress, and adding to the wellness of their organizations [37]. However, further research needs to be undertaken regarding how autistic people experience and perceive technology. Computer mediated communication can intensify problems of trust, disclosure, inflexible thinking, and perspective-taking, making it difficult for some to maintain relationships [38] studies have looked at inclusive sensory ethnography and how internal senses shape and are shaped by mediated relationships, practices, and intimacies [39], for example, shared use of technology with parents and children which can facilitate opportunities for close physical contact.

2 METHOD

The broad aim of the study was to identify common stress-inducing triggers of autistic adults and establish knowledge gaps to be addressed empirically. This initial investigation will affect the design of semi-structured interviews, to investigate further areas of interest, drawing upon established research practice. The data collected will relate to: [1] common triggers and sensory information recognized within people with ASD, as well as from carers who may identify catalysts; and [2] reflections on current assistive technologies along with where potential may lie in using alternative applications as a means of assisting high functioning autistic adults.

2.1 Participants

Two hundred and two participants participated: 31% identified as male, 61% female, 6% non-binary, and 2% as other. Three incomplete responses were deleted from the survey, due to omitted informed consent forms that were required to confirm permission to use the results as part of the ethical approval process. The majority of participants reported having a formal autism diagnosis (76%), whilst 23% indicated that they were caregivers. Three participants chose not to answer the question related to formal diagnosis. These participants indicated whether they were caregivers or not, and answered related questions based on this response. There was a small overlap of participants who indicated that they were both autistic and caregivers. Ages ranged from 18 to 70 with a mean of 44. Fifty one percent of caregivers responded that people in

their care had Asperger Syndrome (n = 45), with 47% reporting Autistic Disorder (one of which also had Pervasive Developmental Disorder). The predominance of people under their care ranged in ages between 18 and 34 years (44% at 18-24 years, 40% at 25-34 years, n = 45). Sixty six percent of the people being cared for identified as *male*, while the remaining 34% identified as *female* (n = 45).

The University's ethical approval process prevented participants under 18 or over 70 taking part, and age was the only compulsory question within the survey. Eighty six percent of participants had no known form of hearing impairment, 8% had mild hearing loss, with 3% experiencing moderate hearing loss and the remainder either severe or did not provide a response. Eighty eight percent of participants had no known form of visual impairment, 3% had low visual acuity, with the remainder either wearing corrective glasses or choosing to omit the query. These data were captured due to the desire to use visual and auditory channels in the final output of the research, that is, a working prototype designed to be evaluated by the target group. Eleven countries were represented, with 85% of participants located in Europe, 14% from the Americas, and 1% from Asia. Participants were recruited through Autism-related organizations including Autistica [40] and Sense Scotland [41], as well as via social media platforms such as LinkedIn [42] and Twitter [43], amongst others. Recruitment information highlighted that participants should have a formal autism diagnosis or be a carer for someone who has a formal diagnosis, be aged between 18 and 70 years. No inducement was made to take part in the study.

2.2 Materials and Design

An online survey was developed in English, to collect demographic information, identify stress triggers, sensory effects, and technological preferences concerning stress management, from both autistic people and their caregivers. Questions were designed following a related PhD study regarding the design of a therapeutic audiovisual intervention for autistic users within music therapy sessions [44], and were derived from publications regarding sensitivity in autism and its challenges (see section 1.1). The survey questions which formed the basis of this study can be found online [45]. The PhD study involved developing survey and interview questions for autistic participants, and carers of people with autism [46]. In this study, a web-based questionnaire allowed for access to a potentially larger group of autistic participants and caregivers, as well as ease of participant response [47]. Depending on the target group each respondent identified with, autistic participants answered 15 questions related to the identification of stress, seven questions on current uses of technology, and five questions concerning uses of games and preferences. The remaining questions included four relating to technologies used to manage stress (including technologies that help manage personal sensitivity issues), and seven questions regarding the potential for new technologies. Caregivers were asked 21 related questions regarding the same topics, but from an observational perspective. The majority of the questions were formatted as multiple choice, alphabetized, some with accompanying images, and a few with comments sections available for additional information. Five-point ratings scales were also employed for some questions to allow two negative and two positive options, as well as a neutral option. These scales are recognised as allowing for a wider range of responses but without over complicating potential responses for autistic participants [48]. The survey was hosted by NoviSurvey [49], following which, the data was downloaded as Excel spreadsheets for analysis [50].

2.3 Procedure

Ethical approval was granted by the University's ethics committee, and participant consent was inbuilt at both the start and end of the survey to ensure approval to utilize the responses. Participants were invited to take part through a number of media and charitable outlets including the Autistica mailing list, and the authors' professional networks. The survey was online for approximately 12 months. Raw data were downloaded from NoviSurvey into an Excel spreadsheet for analysis. NVivo [51] was used to code open-ended questions and participant comments, with Excel [50] being used for calculating percentages, graphing, and tabulating data. Coding was conducted, based on a qualitative Grounded Theory type approach [52]. Codes were allocated to quotations using an open approach where interpretation of quotations suggested appropriate codes, as opposed to pre-defining codes and assigning quotations. The results were divided into five sections using the second pass transcript codes as headings for each section, which included Needs of Caregivers, Sensitivity and Perception, Stress Triggers, Current Uses of Technology, and Potential for New Technology. The five derived code descriptions, reviewed by both authors, are described below followed by detailed findings from the data (see Table 1). Instances refers to the coding procedure and how many times the derived themes were identified by the coder within the open-ended comments. The autistic participants are referred to within the results as A01, A02, and so on, while caregivers are referred to as C01, C02, etc. for the purposes of anonymization.

2.4 Results

The highest number of instances for a single code was *Current Uses of Technology* with 474. Nine questions, with opportunities for participant comments, were answered by 63% of the respondents. The majority of autistic respondents used some form of technology, typically mobile devices, laptops and PCs. Additional technologies were identified including noise cancelling headphones, radio, and portable music players, and though AR was not used by the majority, 37% of respondents expressed interest in its use. The purpose of this study was to investigate factors that may trigger stress in autistic people. Thirteen questions where participants could leave feedback related to *Stress Triggers* and *Sensitivity and Perception* codes (612 combined instances), which were commented on by 94% of the participants. Some of the external factors associated with triggering stress, included unfamiliar surroundings and people. Having limited or no access to technology also created stressful effects. In general terms, autistic participants indicated that sensitivity to noise with unfamiliar people and surroundings were also stressful. Optional comments, related to the *Needs of Caregivers'* 18 questions, were left by 87% of respondents. Feedback indicated that people in their care needed both emotional (one-to-one) and family support (familial social interaction), as well as assistance with advice and advocacy. Finally, *Potential for New Technology*

Table 1: Code and Descriptions for Open-Ended Questions and Comments

Code	Descriptions	Instances
Current Uses of Technology	Personal choices and functionality of current technology to help manage stress	474
Stress Triggers	Recognizing external factors that may be a catalyst for stress	367
Sensitivity and Perception	How sensory influences affect perception and stress levels	245
Needs of Caregivers	Observations on the needs of caregivers to help them manage people in their care	104
Potential for New Technology	Opinions on the potential for new technologies to address personal needs and requirements regarding stress management	44

Table 2: Scale regarding levels of sensitivity as reported by caregivers (1 = hyposensitive, 5 = hypersensitive)

	n	Mean	Std dev	Count and % Rating 1	Count and % Rating 2	Count and % Rating 3	Count and % Rating 4	Count and % Rating 5	NA option
Light	46	3.9	0.7	1 (2%)	0 (0%)	9 (20%)	29 (63%)	7 (15%)	0 (0%)
Sound	45	4.6	0.5	0 (0%)	0 (0%)	1 (2%)	17 (38%)	27 (60%)	0 (0%)
Touch	45	3.9	1	0 (0%)	4 (9%)	11 (24%)	15 (33%)	15 (33%)	0 (0%)
Smell	45	3.4	0.9	0 (0%)	5 (11%)	24 (53%)	7 (16%)	9 (20%)	0 (0%)
Taste	45	3.3	1	2 (4%)	4 (9%)	25 (56%)	5 (11%)	9 (20%)	0 (0%)
Pain	44	2.8	1.2	4 (9%)	19 (42%)	10 (22%)	5 (11%)	6 (13%)	1 (2%)
Key:	*Hypersensitive* responses: 0-20% , 20-40% , >40%								
	Neutral responses: 0-20% , 20-40% , >40%								
	Hyposensitive responses: 0-20% , 20-40% , >40%								

presented three questions with options for participant comments, to which 38% responded. There were a variety of responses from commonly used technology like smartphones, use of AR headsets, and ways to reduce sensitivity issues, for example, via noise cancelling headphones. Detailed results from each code are presented below, divided into two sections: first, from carers of individuals diagnosed with ASD; and second, from participants who have been diagnosed with ASD.

2.5 Carers of Individuals Diagnosed with ASD

2.5.1 Sensitivity. Caregivers were queried about how hyposensitive [1] or hypersensitive [5] those they were caring for were, regarding their senses. Sixty three percent (n = 46) were identified as tending towards hypersensitivity to *light* (level 4). Regarding *sound*, 38% and 60% tended towards hypersensitivity at levels 4 and 5 respectively. Respondents identified *touch* across a wider range, tending towards hypersensitivity, with the majority at level 5 (33%). *Smell* was identified as more neutral with 53% at level 3, with *taste* in a similar position of 56% at level 3. Finally, *pain* tended towards the hyposensitive side (51.1 %) with 22% as neutral but 42% at level 2 (see Table 2).

2.5.2 Stress Triggers. Caregivers were asked how stressed the person they care for is, within certain locations, where 1 on a 5-point scale represented *very calm,* and 5 *highly stressed.* Of the 23% response rate, feedback indicated subjects experience anxiety across all specified locations ranging 7% to 58%. A range of moderate stress was reported from 7% to 42%, while responses to being highly stressed ranged from 4% to 56%. Caregivers responded that a majority of 48% (n = 46) were calm at *home*, with 28% very calm. Twenty seven percent were reported as anxious in the *office*, while 31% were anxious in *University/College*. Thirty eight percent were reported as calm in the *park*, with a wider spread of scores regarding the *street,* with 35% and 26% at levels 3 and 4 respectively. Fifty six percent were reported as anxious within a *café/restaurant*, 34% and 29% as stressed or highly stressed in a *bar*, while most people were reported with higher levels of stress on *public transport* with the majority at level 4 (40%). Indications were that most people felt relatively calm (65% at level 2) within a *private car*, however, the majority were at levels 4 and 5 with 16% and 41% respectively regarding *large public events* (see Table 3). Asking how caregivers can tell if the person they are caring for is stressed, *wanting to leave* returned an 89% response (n = 45), whilst *being emotionally withdrawn* indicated an 84% return rate. Both *avoiding eye contact* and *being physically withdrawn,* returned a similar response rate (73% and 75%), with *refusing or ignoring requests* and *seeking isolation* returning 60% and 71% of responses respectively.

2.5.3 Current Uses of Technology. Regarding how effective techniques were for relieving stress for the person they were caring for on a scale of 1 (not effective at all) - 5 (very effective), *take them away from the situation* reported a 48% effective response at level 4, and 30% at level 5. *Putting on headphones* indicated effectiveness for 44% and 20% at levels 4 and 5, while *putting on hearing protection* returned 27% and 24% at levels 3 and 4 respectively. Forty two percent at level 4, reported that *playing music* was effective. *Showing*

Table 3: Scale of levels of stress regarding the people they care for (1 = very calm, 5 = highly stressed)

Matrix row	n	Mean	Std dev	Count and % Rating 1	Count and % Rating 2	Count and % Rating 3	Count and % Rating 4	Count and % Rating 5	NA option
Home	46	1.9	1.1	22 (48%)	13 (28%)	7 (15%)	2 (4%)	2 (4%)	0 (0%)
Office	19	3.4	0.8	0 (0%)	1 (2%)	12 (27%)	3 (7%)	3 (7%)	25 (57%)
University / College	25	3.7	0.9	0 (0%)	0 (0%)	14 (31%)	5 (11%)	6 (13%)	20 (44%)
Park	42	2.6	0.9	3 (7%)	18 (40%)	16 (36%)	3 (7%)	2 (4%)	3 (7%)
Street	46	3.2	1	1 (2%)	11 (24%)	17 (37%)	12 (26%)	5 (11%)	0 (0%)
Café / Restaurant	44	3.4	0.8	1 (2%)	2 (4%)	26 (58%)	10 (22%)	5 (11%)	1 (2%)
Bar	37	3.6	0.9	1 (2%)	1 (2%)	15 (33%)	13 (29%)	7 (16%)	8 (18%)
Public Transport	42	3.9	1	1 (2%)	3 (7%)	7 (16%)	19 (42%)	12 (27%)	3 (7%)
Private Car	45	2.2	0.9	7 (16%)	29 (64%)	4 (9%)	3 (7%)	2 (4%)	0 (0%)
Large Public Event	43	4.4	0.8	0 (0%)	2 (4%)	3 (7%)	12 (26%)	26 (57%)	3 (7%)
Other	8	4.8	0.5	0 (0%)	0 (0%)	0 (0%)	2 (15%)	6 (46%)	5 (39%)
Colour Key:	*Positive* responses: 0-20% , 20-40% , >40%								
	Neutral responses: 0-20% , 20-40% , >40%								
	Negative responses: 0-20% , 20-40% , >40%								

them a video returned a 36% response at level 4, with *singing to or with them* reporting 29% at level 4. Fifty one percent, also at level 3, regarded *listing the things they will be doing that day* as mildly effective. Forty nine percent (n = 45) of respondents reported *getting them to talk* as moderately effective level 3 (see Table 4).

Queried whether caregivers had used any of the suggested technologies for the people they care for, *smartphone* was the most popular answer with 88% response rate (n = 43). *Television* returned 67%, with *PC/Laptop* 58%. Other choices represented 30% and many indicated *using a music player* or *music system*. Referring to other techniques that helped mitigate stress, 84% majority (n = 44) reported *listening to music*. Seventy nine percent indicated that *watching a movie/video* helped, while *playing games, talking to someone* and *fitness routine* returned responses of 61%, 54% and 52%. Asked what they would like the people they care for to have access to, the most popular answers were *headphones to listen to music* at 86%, and *smartphone* at 70% (n = 43). *Headphones for noise cancellation* returned a response of 51%, with *smartwatch* at 37% (see Figure 1). Binaural beats are said to lower stress and are when two tones of slightly different frequencies are played in separate ears simultaneously (usually through headphones), creating a perceived third tone, whose frequency is equivalent to the difference between the two signals being played [53].

2.5.4 Potential for New Technology. Asked what technologies they think might help manage stress for the people they care for, the most popular answer from caregivers was *smartphone* with 79% (n = 42). *Headphones* returned 76%, *portable music player* returned 64%, with *augmented reality headset/glasses* at 52%. *Smartwatch* had a 43% response rate. On a 5-point scale where 1 represented *very unappealing*, and 5 *very appealing*, 51% of caregivers rated virtual reality (VR) technology appealing at level 4 (n = 45) for the people they are caring for. Seventy three percent (n = 45) responded that they felt neutral (level 3) regarding how *not distracting* or *very distracting* VR would be. In a similar manner, using the same 5-point scale, 32%, 16% and 41% of caregivers rated augmented reality (AR) technology appealing at levels 3, 4 and 5 respectively (n = 44). Sixty seven percent (n = 45) responded that they felt neutral (level 3) regarding how *not distracting* (level 1) or *very distracting* (level 5) AR would be. Nine percent chose level 2, with 15% indicating it was distracting.

2.6 Participants with ASD

2.6.1 Sensitivity and Perception. From the suggested list of possible things that could make autistic people feel stressed, the top answers tended towards unfamiliarity and loud sounds, with *unfamiliar people*, *unwanted touch*, and *unfamiliar surroundings* representing 89%, 84% and 83% (n = 151). *Bright light* had similarly high response at 78%, *unwanted music registered 72%, with unwanted smells scoring 71%*. Lack of access to technology was notable with *No access to smartphone* at 60%, and *no access to PC/laptop* at 30% (see Figure 2). When categorized into groups, *unfamiliar stimuli* returned a mean of 77%, *unwanted stimuli* 62%, and *lack of access to technology* 27%.

Regarding the sensitivity of respondents to certain sounds, the majority reported an aversion to undesired human sounds (vocalisations in particular), followed by mechanical sounds, with sounds of nature being the least distressing. Results indicated *people shouting* at 88% (n = 146), with crowds of people at 83%. When categorized into sounds made by people, technology or nature, results suggest that the majority of the sensitivity comes from people (56% mean), technology (45% mean), and then nature (20% mean). People eating registered 58%, repetitive sounds and traffic were chosen by 53% and 52% of respondents respectively. Comments left in the *Other* category made by people included breathing, snorting, singing badly,

Table 4: Scale of effectiveness for relieving stress for the person they care for (1 = not effective at all, 5 = very effective)

Matrix row	n	Mean	Std dev	Count and % Rating 1	Count and % Rating 2	Count and % Rating 3	Count and % Rating 4	Count and % Rating 5	NA option
Give a drink	42	1.9	0.8	15 (34%)	20 (46%)	6 (14%)	0 (0%)	1 (2%)	2 (5%)
Give a toy	35	1.8	1.1	19 (45%)	7 (17%)	6 (14%)	2 (5%)	1 (2%)	7 (17%)
Give some food	42	1.9	1	17 (40%)	16 (37%)	5 (12%)	3 (7%)	1 (2%)	1 (2%)
Get them to talk	45	2.4	1.1	13 (29%)	5 (11%)	22 (49%)	4 (9%)	1 (2%)	0 (0%)
List things they will be doing	43	2.8	1.1	9 (20%)	3 (7%)	23 (51%)	5 (11%)	3 (7%)	2 (4%)
Play music	44	3.5	1.2	6 (13%)	2 (4%)	9 (20%)	19 (42%)	8 (18%)	1 (2%)
Put on a piece of clothing	38	1.3	0.6	29 (67%)	7 (16%)	2 (5%)	0 (0%)	0 (0%)	5 (12%)
Put on hearing protection	38	3	1.3	9 (20%)	2 (4%)	12 (27%)	11 (24%)	4 (9%)	7 (16%)
Put on their headphones	44	3.4	1.4	8 (17%)	4 (9%)	3 (7%)	20 (44%)	9 (20%)	2 (4%)
Put on their sunglasses	36	2.1	1	11 (26%)	14 (33%)	6 (14%)	5 (12%)	0 (0%)	7 (16%)
Show a video	42	2.8	1.3	11 (24%)	4 (9%)	10 (22%)	16 (36%)	1 (2%)	3 (7%)
Sing to, or with	41	2.7	1.5	16 (36%)	2 (4%)	5 (11%)	13 (29%)	5 (11%)	4 (9%)
Talk loudly to them	42	2	1.1	21 (49%)	5 (12%)	12 (28%)	4 (9%)	0 (0%)	1 (2%)
Talk about favourite topic	42	3.2	1.3	7 (16%)	3 (7%)	17 (39%)	6 (14%)	9 (21%)	2 (5%)
Take them away from situation	46	4	0.8	0 (0%)	2 (4%)	8 (17%)	22 (48%)	14 (30%)	0 (0%)
Other	9	4	1	0 (0%)	0 (0%)	4 (36%)	1 (9%)	4 (36%)	2 (18%)
Colour Key:	*Negative* responses: 0-20% , 20-40% , >40%								
	Neutral responses: 0-20% , 20-40% , >40%								
	Positive responses: 0-20% , 20-40% , >40%								

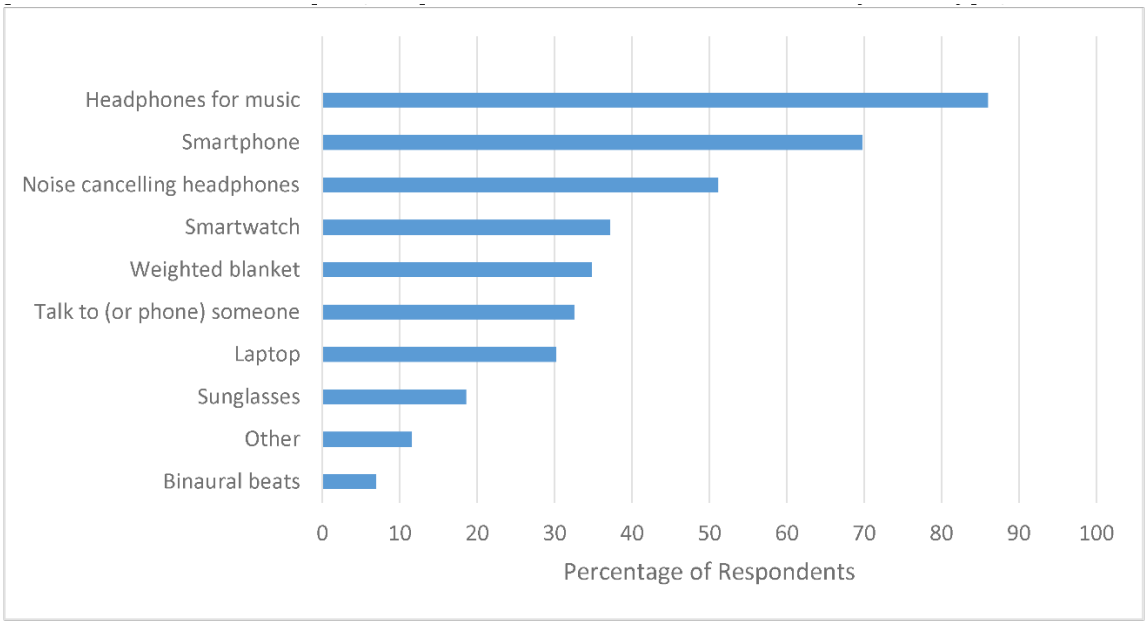

Figure 1: What caregivers would like the people they are caring for to have access to

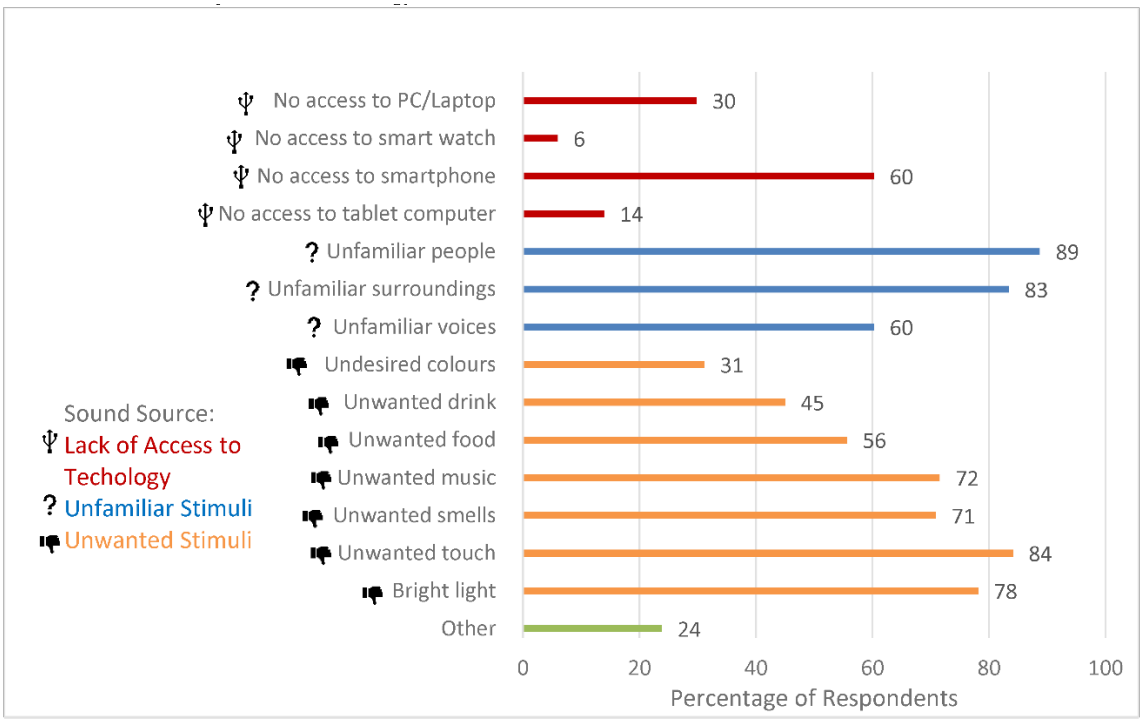

Figure 2: Things identified that could make autistic respondents feel stressed

children screeching, and swearing, whilst technological sounds included emergency vehicle sirens, appliances, tools, buzzing, humming, lawn mowers, vacuums, and TV noise (see Figure 3).

Sensitivity to light was queried, referencing different light sources, where 1 on a 5-point scale represented *really bad (painful to the participant)*, and 5 denoted *really good (pleasing to the participant)*. The majority were inclined towards a positive response for *candlelight* with 26% and 34% (n = 151) indicating levels 4 and 5 respectively, with 30% returning a neutral response. *Compact fluorescent* and *computer screen* light returned a neutral scale level 3 value of 48% and 64%, while most respondents disfavored *fluorescent* lighting with 45% at level 1, 29% at level 2, and 17% at level 3. *Halogen* lights were really bad for 19%, with 30% at level 2 and 40% in a neutral position at level 3. *Incandescent* light sources were also in the central level 3 scale at 59%. Feedback on *LED* lighting was spread across the scale but favored towards neutral with 44% at level 3. *Natural daylight* saw 40% respond positively at level 5, with *sunrise* and *sunset* both spread favorably across levels 3, 4 and 5, with a notable 53% at level 5 for *sunset*. *Smartphone screen* light returned an 68% neutral (3) response (see Table 5).

Asked how regularly participants wore sunglasses for eye protection in different locations, 30% sometimes wore them in the *park*, 32% sometimes wore them in the *street*, with 21% sometimes wore them on public transport. In respect of how colors made participants feel, again where 1 on 5-point scale represented *really bad*, and 5 on the scale represented *really good*, *yellow* tended to be regarded as neutral by 51% (n = 151). The color *red* was neither decidedly positive nor negative for the majority of respondents, however, *blue* tended toward a positive response with 32% at level 5. *Orange* was regarded relatively neutral with 42% at level 3, however, *green* favored more positively with scores of 21%, and 24% at levels 4 and 5, with 32% returning a neutral response. *Purple* returned a somewhat similar response with 38%, 21% and 22% at levels 3,4 and 5. The shade *black* indicated a generally neutral response at 48% at level 3 with *white* similarly indicating 49% at level 3.

2.6.2 Stress Triggers. With regards to how calm or stressed respondents felt in different locations (in a scale of 1 representing *very calm*, 3 corresponding to *anxious*, and 5 denoting *highly stressed*), feedback indicated participants experience anxiety across all locations, ranging from 7% to 30% (level 3). The most stressful place suggested was a *large public event*, with 52% of respondents highlighting they felt highly stressed. The most neutral location suggested was *The Street* with 30%, while the least stressed location was seen as a *Private Car,* with 45% indicating they felt calm (level 2). Sixty percent (n = 150) recording they felt calm at *home* at levels 1 and 2, 24% *highly stressed* in the *office*, 42% stated they were at scale level 2 in the *park*, a combined 79% indicated they were *anxious* or

stressed in the *street*, 29% and 21% stated they were anxious in *cafés* and *bars* respectively (see Table 6).

When asked what things can help feel calm, 74% of respondents identified something. The majority indicated *familiar surroundings* (82%, n = 150). A similar number of replies indicated that *familiar people,* and *access to smartphone* were important, with 80% and 70% respectively. *Preferred clothing, music, food, drink, and familiar voices* were also popular with a mean of 53% of the total responses

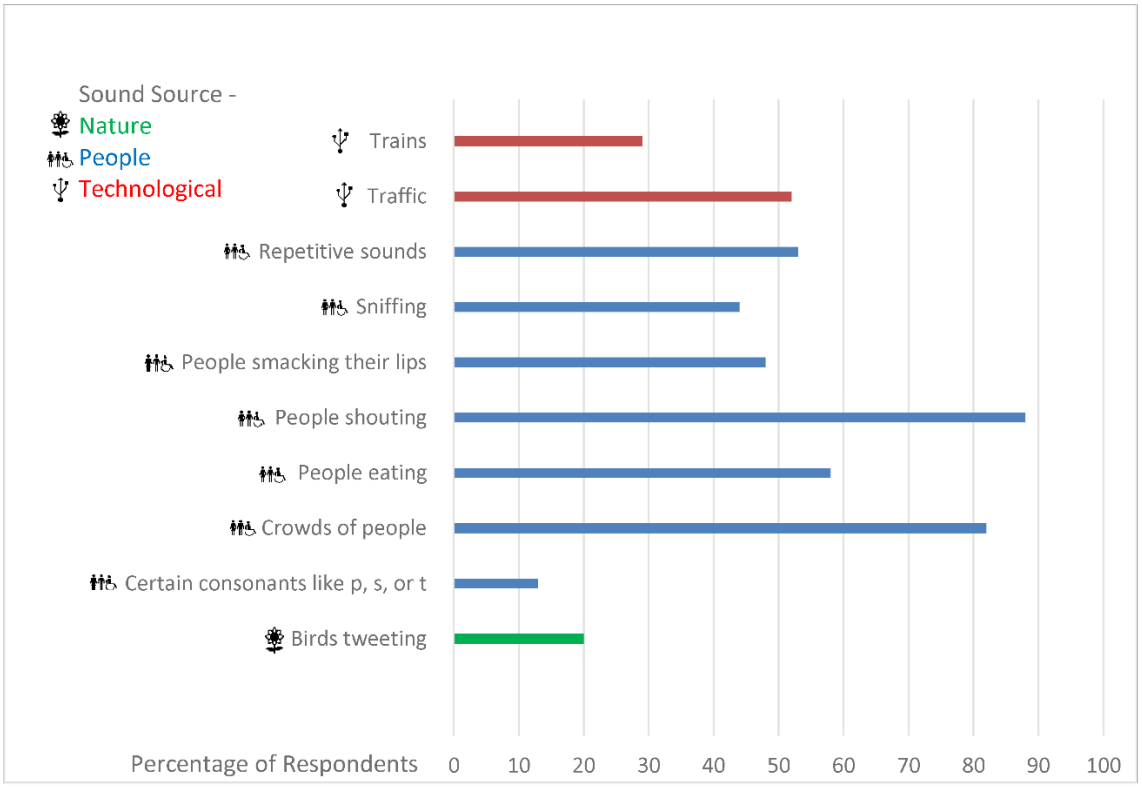

Figure 3: The sensitivity of autistic respondents to certain sounds

(see Figure 4). *Other* responses included references to nature and outdoors – 'quiet countryside' (A36), 'outdoor settings' (A51), 'by or in or on the water' (A62), trees/birds' (A67), 'nature' (A75). Additional answers referred to quiet time – 'silent, calm, lowly lit place' (A74), 'dark quiet rooms' (A136), as well using technology to achieve that – 'noise cancelling headphones' (A86), or via sensory objects, like 'small stim toys' (A54), 'fidget toy' (A59), and 'weighted clothing' (A149).

2.6.3 Current Uses of Technology. Asked about current use of technologies, 76% of all respondents stated that they used some form of technology, with 94% of the autistic participant responses (n = 153) indicating that they used a *smartphone*, 83% used a *laptop*, 66% used a *tablet computer*, while 53% used *noise cancelling headphones* (see Figure 5). Other responses indicated using audio technologies including radio, portable music player, and ear defenders, while other participants commented on using PC's, smartwatches, and portable games consoles.

Regarding familiarity with virtual reality (VR) technology, 33% of participants (n = 151) indicated they were *slightly familiar*, 18% *moderately familiar*, with 31% *not at all familiar*. However, 29% (n = 151) reported that they would be moderately interested in using VR technology, with 22% extremely interested. In terms of augmented reality (AR) technology, although 45% (n = 149) reported being not at all familiar with the technology, 91% (n = 150) expressed some form of interest in using AR. Twenty three percent and 28% reported being slightly interested and extremely interested in using AR technology, with 28% being slightly familiar, and 18% moderately familiar.

Of the respondents who played computer games (76%, n = 153), the majority used a *smartphone* as the platform (68%, n = 123), with 34% using PC/Mac, 31% using tablet computers, and 20% currently using *VR headsets* (see Figure 6). Nineteen percent of *other* responses reported using *Nintendo Switch*.

Of the technologies used to try to help control stress, 75% of responses (n = 127) used a *smartphone*, 46% a *PC or laptop*, while 43% a *TV*. A number of other responses reported using a music system. When asked about techniques used to control stress, 76% (n = 150) employed *listening to music*, 65% described *watching a video/movie*, 63% *stimmed*, 58% performed a *fitness routine*, and 51% *meditation* (see Figure 7). Many comments regarding listening to music described the activity as an 'essential depressor' (A13), as 'meditation' (A20), helping to 'shut out the world' (A30), 'escapism' (A55), as the 'best remedy for stress' (A66), for 'staying calm' (A136), and 'mood regulation' (A144). Participants commented that movies aided relaxation as a 'good distraction' (A63), and as the 'main stress reduction technique' (A148). Comments related to stimming pointed out that it helps reduce stress, 'release nervous energy' (A30), and that it 'works both for staying calm and for identifying stress' (A136). Additional fitness routine comments included several physical activities including, yoga, weightlifting, walking, swimming, running, karate, and horse-riding. In the *other* category,

Table 5: Lighting types rated by autistic respondents (1 = really bad, 5 = really good), approximate intensity and colour temperature

Light Source	Count and % Rating					Intensity (c. Lux)	Colour Temperature (c. Kelvin)
	1	2	3	4	5		
Candlelight	5 (3%)	6 (4%)	45 (30%)	39 (26%)	51 (34%)	50	1800
Compact fluorescent	20 (13%)	41 (27%)	73 (48%)	7 (5%)	6 (4%)	100	5000
Computer screen	6 (4%)	31 (21%)	96 (64%)	12 (8%)	2 (1%)	500	8000
Fluorescent (strip lights)	66 (45%)	43 (29%)	28 (19%)	6 (4%)	3 (2%)	500	3000
Halogen (e.g., spotlights)	30 (20%)	45 (30%)	61 (41%)	10 (7%)	3 (2%)	530	4000
Incandescent (filament bulbs)	13 (9%)	29 (19%)	89 (59%)	12 (8%)	4 (3%)	1700	3000
LED (light emitting diodes)	12 (8%)	34 (23%)	68 (46%)	20 (13%)	10 (7%)	300	4000
Natural daylight	0 (0%)	10 (7%)	32 (21%)	47 (31%)	60 (40%)	10000	5000
Smartphone screen	2 (1%)	22 (15%)	102 (68%)	14 (9%)	4 (3%)	200	8000
Sunrise	2 (1%)	6 (4%)	33 (22%)	42 (28%)	60 (40%)	100	1800
Sunset	0 (0%)	9 (6%)	28 (19%)	30 (20%)	79 (53%)	10	1800
Other	4 (10%)	3 (7%)	9 (21%)	1 (2%)	5 (12%)		
Colour Key:	*Negative* responses: 0-20% , 20-40% , >40%						
	Neutral responses: 0-20% , 20-40% , >40%						
	Positive responses: 0-20% , 20-40% , >40%						

Table 6: Scale levels of calm and stress within different locations reported by autistic respondents (1 = very calm, 5 = highly stressed)

	n	Mean	Std dev	Count and % Rating 1	Count and % Rating 2	Count and % Rating 3	Count and % Rating 4	Count and % Rating 5
Home	145	2.3	1	40 (27%)	50 (34%)	39 (27%)	14 (10%)	4 (3%)
Office	104	3.8	1	2 (1%)	8 (5%)	32 (22%)	29 (20%)	35 (24%)
University/College	72	3.7	1.1	2 (1%)	9 (6%)	22 (15%)	17 (12%)	24 (17%)
Park	146	2.5	1.1	22 (15%)	65 (43%)	33 (22%)	21 (14%)	7 (5%)
Street	143	3.5	1.1	6 (4%)	18 (12%)	45 (30%)	44 (29%)	32 (21%)
Cafe/Restaurant	139	3.6	1.1	3 (2%)	23 (15%)	44 (29%)	34 (23%)	37 (25%)
Bar	122	3.9	1.1	3 (2%)	12 (8%)	33 (22%)	25 (17%)	51 (34%)
Public Transport	129	3.8	1.2	4 (3%)	19 (13%)	24 (16%)	36 (24%)	48 (32%)
Private Car	146	2.3	1	31 (21%)	68 (45%)	33 (22%)	13 (9%)	3 (2%)
Large Public Event	122	4.3	1	3 (2%)	4 (3%)	18 (12%)	21 (14%)	78 (52%)
Other	17	3.5	1.6	4 (15%)	2 (7%)	2 (7%)	3 (11%)	8 (30%)
Colour Key:	*Negative* responses: 0-20% , 20-40% , >40%							
	Neutral responses: 0-20% , 20-40% , >40%							
	Positive responses: 0-20% , 20-40% , >40%							

a few mentioned playing musical instruments (A89), and special interest hobbies (A124) as ways to manage stress.

Few participants (45%, n = 89) reported that they had used any of the listed health or relaxation apps, with 55% of those indicating they use *Headspace*, 39% having used *Calm*, and 26% using *Nature Sounds Relax and Sleep*. Other responses (35%) included *Mindfulness, Tripp (VR app), Binaural Beats, Antistress and Muse.*

Of the 146 respondents, 66% *put on headphones* to help reduce stress. Sixty four percent chose to use a *smartphone*, while 62% *listen to music*, with 51% *watching a video or film, and 48% spoke to a friend or family* to help reduce stress (see Figure 8). When queried about the use of headphones, the majority of participants preferred *Closed-back headphones to listen-through options* (with 24% at level 4, and 34% at level 5 (n = 150), while *earbuds* were generally disliked (28%

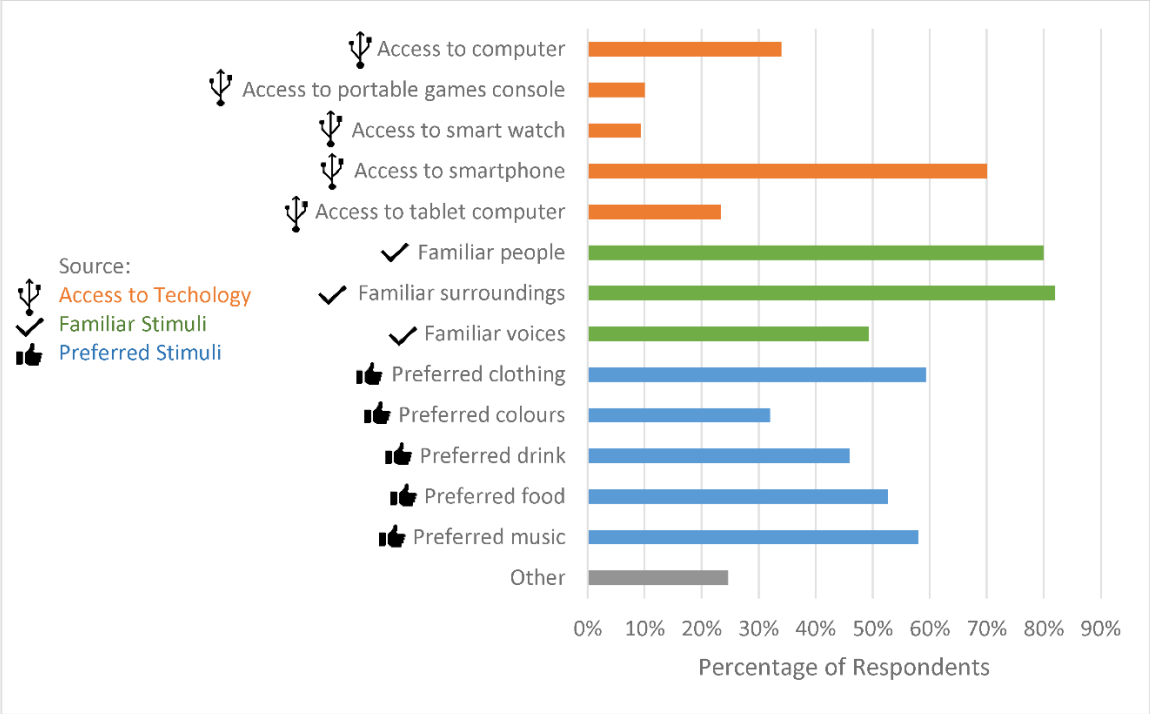

Figure 4: Things identified as helping autistic participants feel calm

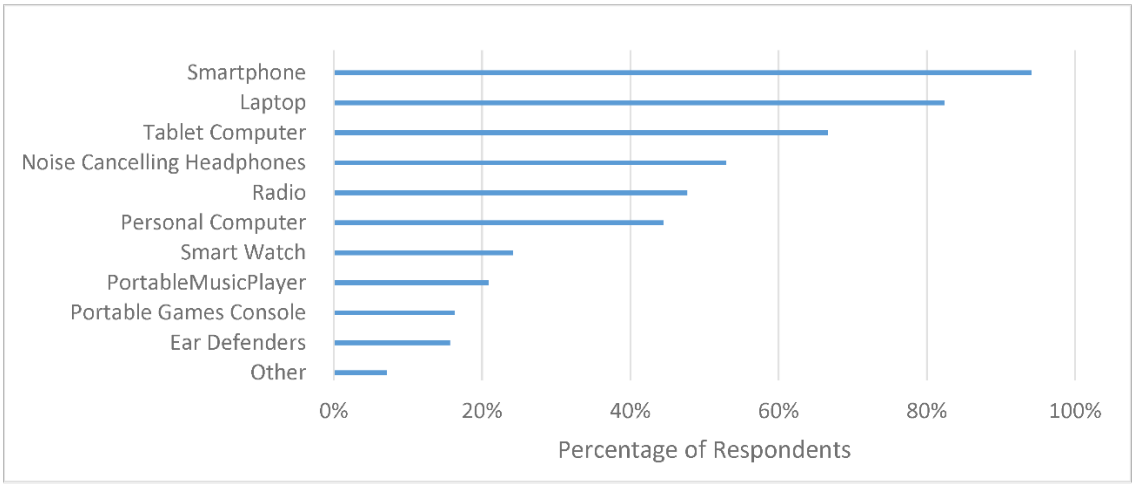

Figure 5: Current use of technology by autistic participants

at level 1, 26% at level 2). Asked if any suggested approaches helped to reduce stress, the largest percentage (53%, n = 120) indicated that *meditation* was successfully used, with 32% and 28% preferring *massage* and *cognitive behavioral therapy* (CBT) respectively.

2.6.4 Potential for New Technology. Asked what they would like to have access to for managing stress, the majority of autistic respondents favored a *smartphone* (68%, n = 146), while 63% indicated they wanted *headphones for noise cancellation,* with *headphones to listen to music* registering 53%. Fifty one percent indicated they would like to use a *weighted blanket* (see

Figure 9). Other comments mentioned 'going outside to regulate stress' (A29), a 'quiet place to recover from meltdowns' (A43), 'timeout' (A74), 'acceptance and understanding' (A129), and 'being alone' (A81).

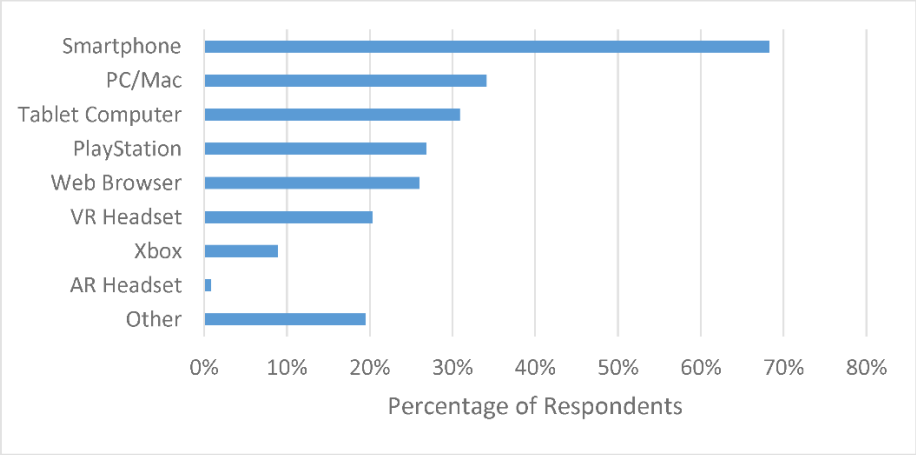

Figure 6: Autistic participants' chosen platforms to play computer games

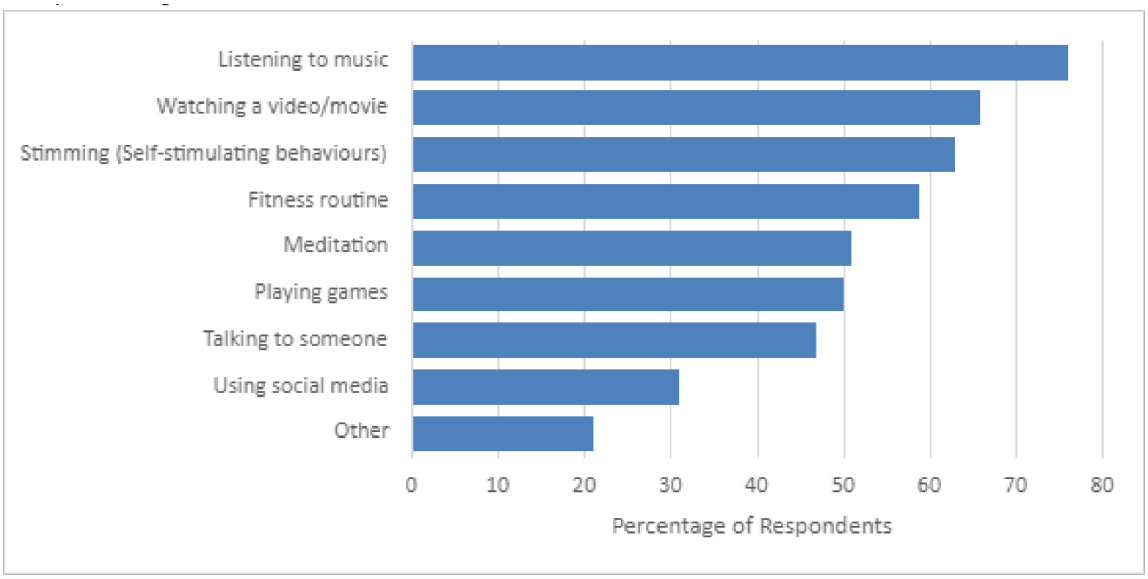

Figure 7: Techniques used by autistic participants to try to help control stress

Regarding what technologies might help participants manage stress, 78% (n = 138) autistic respondents suggested *smartphones*, with 72% suggesting *headphones*, as the most popular answers. Thirty eight percent indicated *augmented reality*, a *laptop* at 36%, with *tablet computer* at 35% and *VR headset* at 33% (see Figure 10). Additional 'other' comments included the use of TV, better noise cancelation, and that 'technologies miss the point – the problem is not in us' (A36).

Asked how appealing VR technology was on a scale of 1 to 5, with 1 *very unappealing* and 5 *very appealing*, 53% provided a positive response, 28% a neutral response, with 20% replying with a negative response. Similarly, asked how appealing AR technology was, 53% returned a positive response, 39% a neutral response, and 15% negatively. Regarding how *distracting* VR technology might be, on a scale of 1 to 5 (where 1 represented *not distracting* and 5 represented *very distracting*), 66% (n = 147) majority responded at level 3, 11% at level 4, 9% at level 5, with 8% at level 1 and the remaining 5% at scale level 2. Responses regarding how *distracting* AR technology might be returned a 60% majority (n = 146) responded at level 3, 16% at level 4, and 3% at level 5, with the remaining 14% and 8% at scale levels 2 and 1 respectively.

3 DISCUSSION

The data from the results suggest that the smartphone should be the most useful platform for any potential application for managing stress, by both autistic users and caregivers, and as the most popular gaming platform. The smartphone screen was reported as being

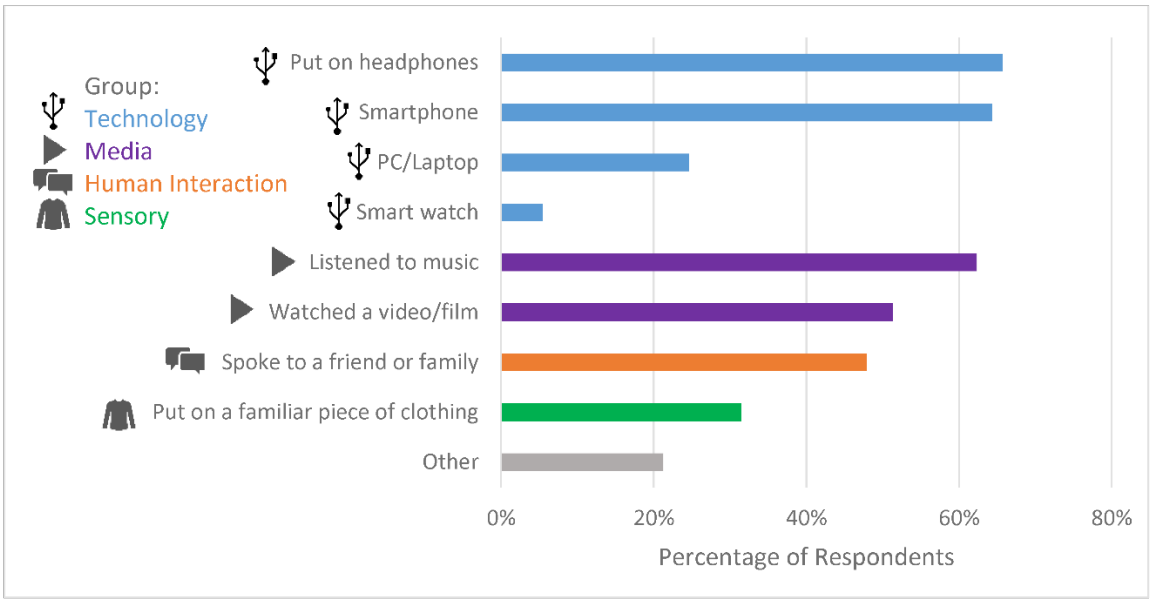

Figure 8: Things identified as helping autistic respondents reduce stress

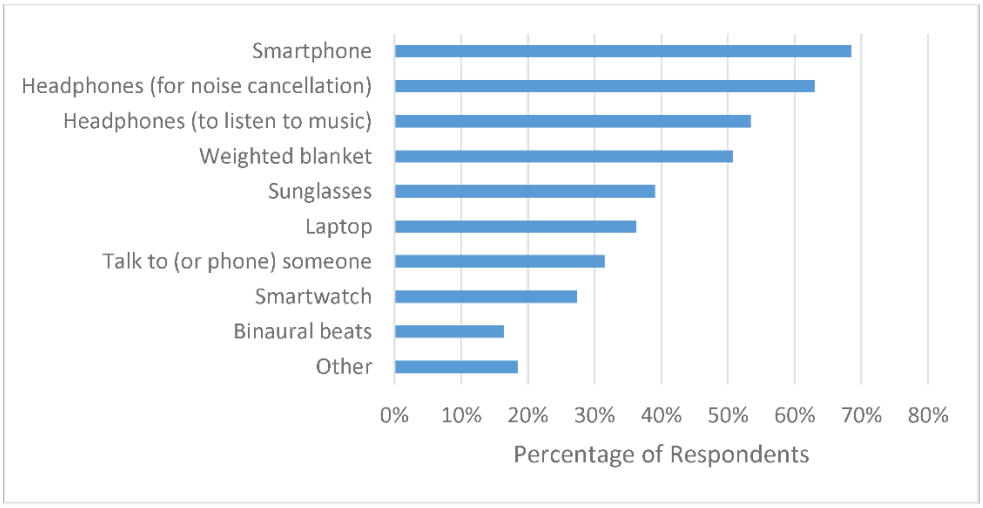

Figure 9: Technological preferences by autistic respondents for managing stress

neutral in terms of its effect on participants and has been commented on as useful technology for listening to music, accessing meditation applications, and as an alternative technology for VR and AR headsets. Recent research has questioned the use of screen exposure in early childhood and its influence on neurodevelopment, including the development of ASD [54]. The authors commented that although there are no definitive conclusions, the issue is complex, and should continue to be further researched. Similarly, Lu et al. [55] looked at the associations between autistic traits and excessive smartphone use in Chinese college students. The authors hypothesized that social interaction anxiety and loneliness mediate the relationship between autistic traits and excessive smartphone use. However, the participants in the study did not have a formal diagnosis regarding ASD, or any other medical conditions.

The present study supports related work, by O'Neill et al., [56] that aimed to understand the needs and experiences of autistic individuals, which reported that the majority of experiences with mobile assistive technologies (AT) were positive. The authors commented that mobile forms of AT, such as tablet and smartphone devices, are particularly powerful forms of technology that may be used to support the development of scheduling and planning, and communication skills. Related AT research, examined in a study by Lian and Sunar [57], suggests researchers should focus on users

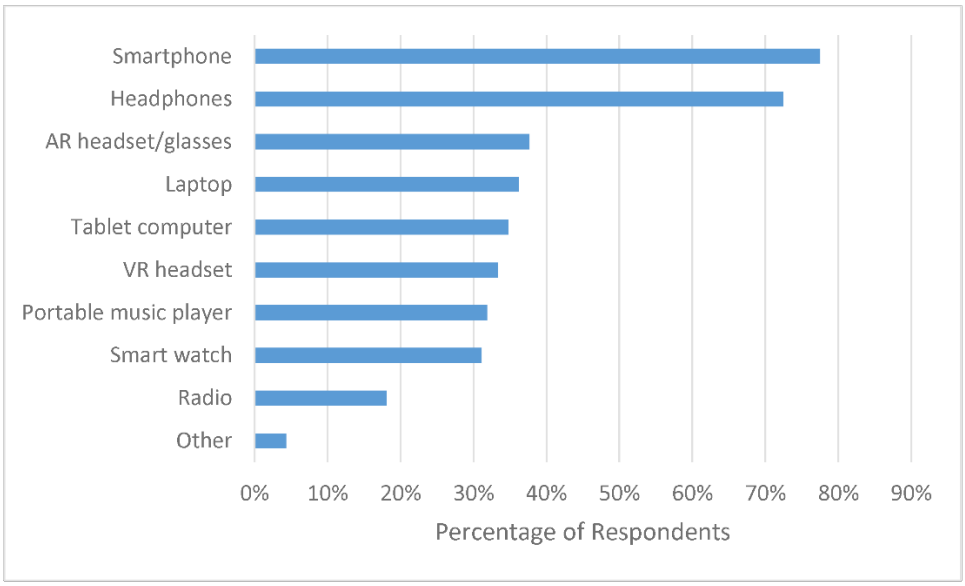

Figure 10: Technologies that might help manage stress as reported by autistic respondents

Table 7: Overview of main findings from results regarding stress management as reported by autistic participants and their carers

Sensitivity and Perception	Triggers	Current Solutions	Potential Solutions
Sound	Large public events, public transport, street, cafes, bars, shouting, crowds, eating, unwanted music	Leaving the situation, ear protection, headphones, familiar voices,	Headphones (for noise cancellation, and for listening to music)
Light	Fluorescent, halogen, compact fluorescent, incandescent, LEDs	Eye protection, natural light (including sunrise and sunset), candlelight	Smartphones, AR, laptop, VR
Touch	Unfamiliar people, unwanted touch	Familiar people	Weighted blanket
Smell	Unfamiliar surroundings, unwanted smells	Familiar surroundings	
Other	No access to smartphone, no access to PC/laptop	Having access to smartphone, listening to music, watching a movie, stimming, fitness routine, playing games	AR, VR

and improve the quality of mobile augmented reality (MAR) applications for autistic people. In addition, more effective research and evaluation methods could be involved in future studies to facilitate the development of MAR intervention applications.

Table 7 below presents an overview of the main findings from the results, regarding the sensitivity and perceptions of participants, associated stress triggers, currently used solutions, and potential solutions.

A common theme highlighted by participants, regarding current coping techniques for stress, was *distraction***.** Meditation and music are two popular activities identified by participants to avoid being overwhelmed by cognitive processing and sensory overload. Additionally, the use of stimming (self-stimulatory behavior), typically viewed in NT discourse as having negative associations, should be appreciated for its benefits [58], further suggesting that the periodicity of movement helps to create a meditative mindset for some. Kapp et al. [59] proposed that researchers further investigate the experiences of autistic people regarding the supposed internal causes of their stims, including sensory (hyper)sensitivities, cognitive inflexibility and emotional dysregulation, along with whether these should be addressed. They further argue the viewpoint of many autistic people, regarding opposition to the NT stance on eliminating all forms of stimming and favor the desire for society to accept non-harmful forms. Recent articles have speculated that some forms of stimming be adopted constructively and managed through time spent in an escape space, perhaps as a form of meditation, rather than being avoided [59, 60, 60]. Lane and Radesky [61] suggested it may be useful to use media like a "stim" toy reinforcer for children

with ASD, intentionally for brief, specific ways, with parent monitoring. Some form of audio-visual distraction techniques could be developed to encourage the use of sound, and music, which may incorporate users' own stimming techniques to meditate and relieve stress in an augmented space. Ragone et al. [62] created a prototype sound generation system for autistic children, based on gestural interaction. A function of a new SMART application could incorporate participant movement in a similar manner, using sound to augment gesture, and aid in reducing stress. Previous studies have identified that many autistic impairments are complicated by a lack of self-awareness [63, 63]. Monitoring heart rate, as well as movements before such times as a user becomes overwhelmed with external stimuli, could help provide a preventative measure, or help reduce the impact of a stressor.

Unfamiliarity, a common theme within the responses, creates stressful situations [64]. Many of the comments indicated sudden or unpredictable noise as one of the main triggers that causes stress within different locations. This corresponds with previous research regarding sensitivity and ASD [65]. Sources highlighted range from human and animal generated noises to any types of mechanical sounds. Equally, respondents suggested nature and its associated sounds as being a desirable means to alleviate stress. Some commented that disorganized sounds are a big stress inducer, not so much loud identifiable, or known sounds, but unexpected ones. Previous reviews reported on the annoyance and pain caused by certain frequencies, for example, computer fans and sirens, as well as the overwhelming nature of multiple sounds, like overlapping voices [66, 67]. In terms of protection against undesired sounds, the adoption of a managed approach to noise cancellation and avoidance of unexpected dynamic changes in sound pressure, would need to be a priority within the SMART application, which can be easily monitored within a smartphone app [67]. Listen through and noise cancelling technology is currently commercially available by several manufacturers, including Apple [68] and Google [69], and has also been used by the military since at least 2014 [70]. These specialist earbuds allow users greater management of potential aural threats, and as such should be considered within a potential stress management application.

Crowds and enclosed spaces have been reported as being highly stressful, with several participants expressing a desire to remove themselves from situations. Some respondents expressed the lack of an escape route as creating stress in itself, highlighting the need for a less stimulating space where they can reduce anxiety levels. Previous work concurs with avoidance and escape as a coping mechanism with ASD [71]. This concept is reinforced in relation to the design of familiar enclosed spaces for autistic children, which have been reported as enhancing feelings of safety and intimacy [72]. Alternatively, nature has also been suggested, with several participants commenting on using outdoor open spaces to reduce stress. Li et al. [72] discuss the benefits, barriers, and caveats, to exposure to nature for autistic people. As it is not always possible for potential users to physically remove themselves from a situation, it is proposed that the potential SMART system could be used to intellectually remove them from stressful scenarios. The application could cognitively transport them, through positive distraction techniques, to a familiar digital space. However, concerns will probably be raised by others about the extent of this form of prosthesis, as evidenced with problematic internet use (PIU), gaming disorder (GD), without fully considering the benefits of avoiding autistic burnout [73].

Using sound and entrainment is an often-cited technique to manage stress and to reduce sensory processing deficits in autistic people [74]. However, there is a lack of research into sound therapies and their success with autistic individuals [75]. Nonetheless, recent studies have sought to investigate the integration of neuroimaging techniques to establish their efficacy [76]. Participants have commented on the use of music, tuning forks, and nature sound videos as relaxants. Many comments in the present study reported the use of personal music hardware systems, or music players, as a means of controlling stress. A recent study by Pino [77] explored the effects of an audio-visual entrainment prototype amongst psychological disorders, including anxiety and depression, where audio-visual content could be entrained with participants affective state to influence the relationship between biological responses and musical stimuli. The implications, from the positive results in the Pino study, could be extended via exploration of a stress management application that employs a comparable approach.

Related research has seen the creation of an interactive VR prototype game designed to address auditory hypersensitivity in autistic adults, by integrating exposure-based therapy techniques into game mechanics and delivering target auditory stimuli to the player rendered via binaural-based spatial audio [78]. The authors continued their research into the use of binaural-based spatial audio as a rendering technique for delivering realistic simulations of adverse stimuli, and its efficacy in reducing auditory hypersensitivity [79]. Results indicated significant reductions in associated negative emotional reactions to target stimuli for participants, with significant improvements experienced by those listening to spatial audio simulations. This suggests the importance of further exploration into the use of spatial audio within an extended reality environment to manage potential stress triggers. Customised example scenarios, based on user input and preferences, could run through a 'familiarisation' mode that would allow the simulation of several narratives to be played out, in preparation for unpredictable events that may cause stress.

The use of robots has also shown a degree of success in regulating the stress levels of autistic children [80], but in most studies they are utilized as a form rehabilitation. Alban et al. [81] advocate the measuring of autistic interactions with social robots to predict "challenging behavior" in order to allow carers to prevent "the progression of unwanted behaviors". The many successful studies with autism and companion animals might lead the way forward in terms of an approach to take in terms of virtual stress management for both those on the spectrum and their carers (82). However, it could be suggested that a virtual companion be a useful way to provide a level of predictive communication for users of a potential application [83]. One way to do this could be via chatbots. Li et al. [84] adopted an open-source chatting corpus to evaluate whether development of an app would be beneficial. Their study indicated interest and potential for the development of a conversation mediated intervention for children with ASD, based on the ability to use an AI system to quickly learn how to communicate with its user, dependent on their individual abilities. A 2022 study has proposed the design of a virtual talking companion to support children

with ASD cope with difficult social situations [85]. The design aims to trigger a breathing exercise function when detection of negative input from the child occurs. In a potential application related to the current study, biometric information, including heart rate, breathing, or verbal input, could trigger appropriate functionality designed to help manage potential stressful situations, as part of a continuous feedback loop.

4 CONCLUSION

The aims of the current study are to establish common stress triggers for autistic people. Participant feedback, and literature reviewed provided qualitative information from potential users and caregivers. Results from a survey, in which over 200 autistic participants or caregivers took part, identified the extent to which people with ASD currently engage with technology, commonly reported stress triggers, sensory issues, as well as the potential for a new tool that may aid in a stress management augmented reality tool (SMART). Overall, the study has identified that sensitivity to sound and light remain key triggers for stress, with current (and potentially new) solutions centered around the use of headphones and mobile devices to help manage stress, with the addition of interest in newer technologies like AR and VR.

Future research should aim to develop for smartphone and headphones as a portable and centralized means to access multi-sensory stimuli, and to use audio noise cancelling or listen-through capabilities when required. Exploration of reactive biometric apps, that can measure and pre-empt the impact of stress through appropriate stimuli, should be developed, including the use of AR apps. The main themes relate to positive distraction, familiarity, and planning to avoid unfamiliarity where possible, through identification of routes and spatial-audio driven scenarios, which could aid in the reduction of unpredictable stress-related events.

The aim of the proposed wider research is to develop an assistive application for high functioning autistic (HFA) adults, by managing levels of stress in a variety of daily scenarios. However, the findings could be utilized by the broader autistic spectrum age group. From an ethical perspective, it is entirely appropriate to begin the research with HFA adults as they are capable of providing informed consent, ensuring that the participants can communicate their experiences as well as provide suitable feedback that could be useful for those less able to participate in the study. This study supports related research into providing interventions for young autistic adults to manage stress. Espinosa and Escobedo [86] are currently developing a support tool that could be used via smart devices, or via a tactile device, to aid in controlling breathing and reducing anxiety. The authors created low fidelity prototypes designs to include the use of a smartwatch to detect heart rate and stress levels to trigger a smartphone application that notifies the user of the increase in stress. A physical anxiety breathing ball that inflates and deflates in conjunction with the app, allows users to follow breathing exercises and reduce stress levels. The SMART tool could follow a similar path and use entrained audio-visual augmentation related to familiar subjects and objects, that would act as a positive distraction for users.

We are in the process of conducting the next phase of research, which aims to further explore preferences and experiences of potential users that could inform the design of the SMART application. Semi-structured interviews facilitate a deeper understanding of how the target group currently identifies and copes with stress, as well as their interest in and use of technology in the past and present. This will lead to a further participatory design process, where the data will be used as a basis to facilitate the initial design of an application to test audio-visual entrainment, with the aim of reducing stress in autistic people.

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