Assistive technology for autism spectrum disorder children that experiences stress and anxiety

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Abstract

With the development of current technology and influences that have been made by the Industry 4.0 utilizing ICTs, IoT, smart systems and products and many others, Assistive Technology (AT) is an important and integral part of the daily life of many people who experience disabilities. Autism Spectrum Disorder (ASD) is a special category of disorder that can greatly benefit from its use. The purpose of this research is to collect data of Assistive Technology aimed at the detection, prevention and improvement of anxiety and stress (a characteristic of which has been proven to exist and is expressed in various ways in people with ASD). In the introduction, basic definitions regarding the neurobiology of stress and ASD are analyzed. In the main part AT, stress and anxiety correlations are made with ASD and AT devices are described and documented regarding their use for anxiety and stress in children and adolescents with ASD. The Assistive equipment and devices are divided into 2 main categories, 1) Low-tech and 2) Mid-High tech. The results of the research reveal a significant research gap in the use of AT to combat stress and anxiety and the difficulty of many promising options (especially in the domain of Mid-High tech) to be an easy and economical solution in integrating them into the daily life of people with ASD.

Keywords: Assistive Technology, ASD, Autism, Anxiety, Stress.

Tecnologia assistiva para crianças com transtorno do espectro autista que vivenciam estresse e ansiedade

Resumo

Com o desenvolvimento da tecnologia atual e as influências que foram feitas pela Indústria 4.0 utilizando TICs, IoT, sistemas e produtos inteligentes e muitos outros, a Tecnologia Assistiva (TA) é uma parte importante e integrante da vida diária de muitas pessoas que sofrem de deficiência. O Transtorno do Espectro do Autismo (TEA) é uma categoria especial de transtorno que pode se beneficiar muito com seu uso. O objetivo desta pesquisa é coletar dados de Tecnologia Assistiva voltados para a detecção, prevenção e melhora da ansiedade e do estresse (característica que comprovadamente existe e se expressa de diversas formas em pessoas com TEA). Na introdução, são analisadas definições básicas sobre a neurobiologia do estresse e do TEA. Na parte principal, são feitas correlações de TA, estresse e ansiedade com ASD e dispositivos de TA são descritos e documentados em relação ao seu uso para ansiedade e estresse em crianças e adolescentes com TEA. Os equipamentos e dispositivos assistivos são divididos em 2 categorias principais, 1) Low-tech e 2) Mid-High tech. Os resultados da pesquisa revelam uma lacuna significativa de pesquisa no uso de TA para combater o estresse e a ansiedade e a dificuldade de muitas opções promissoras (especialmente no domínio da tecnologia média-alta) serem uma solução fácil e econômica em integrá-las ao cotidiano de pessoas com TEA.

Palavras-chave: Tecnologia Assistiva, TEA, Autismo, Ansiedade, Estresse.

1. Introduction

The biggest contributor to health issues in the twenty-first century is anxiety. Anxiety can be beneficial for our physical and mental health when it is under control, but when it persists it can cause many problems in a person's functioning and general health (Hostinar et al, 2015). Anxiety indicates a potential or actual threat that requires rapid changes in behavior patterns. Coping, recovery and stress response processes are significantly influenced by the brain and its neuronal circuits. Our nervous system more specifically, determines what constitutes a threat and controls how the body reacts to a given stressor in terms of behavior and changes that occur in the body's physiology (Drigas & Mitsea, 2021).

The developing brain is remarkably capable of exhibiting structural and functional plasticity in response to stressful and other experiences, including neuronal replacement, dendritic remodeling, and synaptic renewal. An imbalance in the neural circuitry that supports cognition, judgment, anxiety, and mood during times of stress can lead to changes in how these behavioral states are expressed. Through neuroendocrine, autonomic, immune, and metabolic mediators, this imbalance then affects systemic physiology as well (Bravou et al, 2022). The stress response activates a number of defense mechanisms, including the hormone messenger system, to reduce the threat (McEwen, 2017).

More specifically, glucocorticoids (GCs) regulated by the hypothalamic-pituitary-adrenal (HPA) axis and the catecholamines norepinephrine and epinephrine are the two main peripheral stressors. The autonomic nervous system (ANS), which consists of the sympathetic nervous system, the sympathetic-adrenocortical system, and the parasympathetic nervous system, regulates these two systems. Both the ANS axis and the HPA axis are components of an internal neural control system that is closely linked to the centers of the autonomic nucleus. Following exposure to a stressor, the central ANS is rapidly activated and this is quickly followed by an increase in peripheral catecholamine secretion. A short time later, the HPA axis is activated. After the initial release of corticotropin-releasing hormone (CRH) in the pituitary portal vessels, the anterior pituitary produces and releases adrenocorticotropin hormone into the systemic circulation, which in turn triggers the release of GCs, such as cortisol in humans, from the adrenal cortex. Circulating GCs bound to GC receptors (GR) exert a predominantly negative feedback on the stress response. In addition, several sympathetically mediated effects are enhanced by circulating GCs. Importantly, the ANS directly innervates the adrenal cortex, which may facilitate GC release (Makris et al, 2022).

The term autism spectrum disorder is used to describe individuals who exhibit a specific set of repetitive behaviors, severely restricted interests and/or sensory behaviors from an early age, along with social communication problems. According to the CDC's most recent estimate, approximately 1 in 36 children are diagnosed with ASD, with the data converging toward a 4-fold higher incidence in boys. The prevalence rate in Greece in 10-11 years old children is reported to be 1,15% (Thomaidis et al, 2020). ASD is characterized by core characteristics, despite the fact that each individual with the disorder is very unique. Early abnormal brain development and neural reorganization cause ASD. There are also a lot of researchers investigating the correlations between nutrition of the pregnant mother and the environmental factors that may contribute as well. However, because there are no trustworthy biomarkers, the diagnosis must be based solely on behavior (Lord et al, 2020).

ASD is a highly comorbid disorder including anxiety, ADHD, obsessive-compulsive disorder, mood disorders, and other disruptive behavior disorders. There is a significant amount of heterogeneity in the recent literature. According to a recent meta-analysis of Hollocks et al. (2019) of 30 studies that measured anxiety rates and 29 studies that measured depression rates, it was reported for comorbid oppositional defiant disorder in 46 percent and mood disorders in 8 percent, with 66 percent of more than 600 patients having more than one co-occurring condition. The prevalence of any anxiety disorder was found to be similar, at 42 percent, in children with ASD who were seeking treatment. Other common medical conditions include obesity, sleep problems, seizures, gastrointestinal disorders, dietary restrictions, and food pickiness (Hodges et al, 2020).

2. Materials and Methods

For the methodology of this review the most articles that are gathered and presented are from international scientific journals and the research was performed through the following databases which includes: Google scholar, PubMed, PsycINFO and ResearchGate. The keywords that were used were related to "ASD", "autism", "Assistive technology", "AT", "Stress", "Anxiety" and the combination of them. This literature review is a synthesis based on the past and the present articles of AT, ASD and Stress and Anxiety. In order to create chapters, articles were grouped according to their content, and within each group, the articles were further divided into subgroups, from which the subchapters were derived. Writing the paper and analyzing the results comprised the final act.

3. Stress and anxiety activation in children with ASD

ASD, as has been reported in several studies, is a neurodevelopmental disorder, which presents an increased range, heterogeneity and comorbidity with many and various conditions (Fóthi & Lőrincz, 2020; Vilela et al, 2022; Pergantis & Drigas, 2023). One of its characteristics that is listed and examined in many studies is the fact that people with ASD seem to present increased levels of neurophysiological stress and anxiety disorders compared to the neurotypical population.

More specifically, the study by Spratt et al. (2012) measured cortisol levels in children with and without ASD at rest, in a foreign environment and in response to a stressor (blood draw). The methodology followed by this research included 20 children aged between 3 and 10 years (11 boys and 9 girls) who fully met the DSM-IV-TR criteria for autism as well as 28 participants (15 boys and 13 girls) with no previous history of developmental problems that were included into the study by treatment providers, who were based in community organizations and medical facilities. Children with an IQ below 55 or those who also had other medical conditions (such as endocrine disorders) that may have an impact on the HPA axis were excluded, as were children who had a history of abuse or neglect. In the group of children with ASD, a significantly higher serum cortisol response was observed. In children with ASD, the analysis revealed significantly higher cortisol levels, as well as prolonged duration and recovery of the post-stressor cortisol increase. This study suggests that children with autism have an increased sensitivity of the HPA axis to stress and novel stimuli. The assessment tools used to detect and measure ASD were the ADOS and the CARS, while the Child Behavior Check List was also used as a supplementary questionnaire to the parents. Finally, all demographic information for each participant was collected for analysis. Statistical analysis involved using SPSS or SAS to record and interpret results.

In another study by Kushki et al. (2013) the purpose of the study was first to determine whether or not anxiety affects measurable changes in ANS indices in a population of individuals with ASD and subsequently to describe the pattern of these changes that are presented in ASD. More specifically for the methodology of the present research, heart rate, electrodermal activity and skin temperature were measured in a sample of typically developing children (n = 17) and children with ASD (n = 12) during baseline (monitoring tape) and anxiety state (Stroop task). SAS Institute, Cary, NC, SAS version 9.3 was used to perform the statistical analyses. Demographic variables (age, IQ, and gender) that significantly influenced generalized anxiety scores and Stroop task performance were determined using stepwise regression, which combined forward selection and backward elimination. Although both groups showed significant changes in heart rate and electrodermal activity as a result of the stress condition, there was a difference in the response patterns of the two groups. In particular, relative to the ASD group, both baseline and stress conditions were accompanied by increased heart rates. During baseline and stress conditions, the ASD group showed increased and blunted phasic electrodermal activity, respectively. Finally, findings showed that the ASD group did not show the typical stress-induced drop in skin temperature. The findings suggested that autonomic nervous system signals may serve as stress markers in children with ASD and that ASD may be associated with an abnormal autonomic response to stress that is more consistent with sympathetic overstimulation and parasympathetic understimulation.

The study by Hollocks et al. (2014) investigated physiological correlates of ASD anxiety, focusing on measures of heart rate and cortisol response to psychosocial stress that differentiate ASD participants with and without co-occurring anxiety disorders. The sample consisted of 75 boys between the ages of 10 and 16 with typical intellectual abilities who completed a psychosocial stress test. Participants consisted of neurotypical subjects (n = 23), ASD only (ASD; n = 20), and comorbid lesions and ASD (asdanx; n = 32). Salivary control, Heart rate and heart rate variability were compared with some adjustments of the regression model, according to the rest of the main level and the stress test, the indoor period and the recovery period. For the research methodology, the Child and Adolescent Psychiatric Assessment tools and the Spense children's Anxiety scale were used to measure anxiety. The social communication questionnaire was used for measuring social communication and an adapted scale of the social stress test. Results were analyzed via Stata 11. The response patterns of both the ASD and control groups were different from those of the ASDanx group. Heart rate and cortisol response to psychosocial stress prevailed in the ASDanx group. Additionally, in the ASDanx group, increased anxiety symptoms were significantly associated with decreased heart rate and cortisol response.

The systematic review by Van der Linden et al. (2022) was undertaken to assess and explore data supporting higher levels of emotional stress and different biological response or rhythm to stress, diurnal rhythm or cortisol awakening response (CAR) in individuals with ASD compared to samples control. This research reviewed the literature up to December 2020 where MEDLINE, Cochrane Library and SAGE journals were searched. There were no age, gender, or IQ restrictions in this review. Only studies that compared their findings with control samples without developmental disorders were reviewed. As an indicator of biological stress, only salivary cortisol was considered. Of the 31 studies reviewed, individuals with ASD reported significantly higher levels of emotional distress than controls, according to both self- and parent-reported data. Regarding biological stress, the few studies in adults found that both groups' cortisol stress rates and responses were similar, while CAR did not differ in most studies and the diurnal rhythm was described as blunted or similar. Children and adolescents with ASD were found to have an elevated, blunted or similar cortisol stress response. In most studies, there was no discernible link between biological stress in ASD and parent-reported emotional stress. The findings concluded that ASD can be clinically affected by increased emotional stress.

Further findings were revealed by researchers Chiu et al. (2023) to investigate the association between emotion dysregulation and resting heart rate variability (HRV), a measure of the autonomic nervous system, in adolescents with ASD. Research methodology included a short-term electrocardiogram that was used to collect resting HRV data from adolescents with ASD (n = 23) and typically developing adolescents (n = 32). The Emotion Dysregulation Inventory (EDI) was used by parents and caregivers to assess participants' emotional dysregulation. The analysis revealed moderate group effects after adjusting for age and gender effects, suggesting that lower resting HRV was more strongly associated with greater emotion dysregulation in ASD than typically developing adolescents. The results are consistent with the idea that problems with autonomic functioning may be a factor in emotion dysregulation in ASD.

Makris et al. (2022) adds findings that raise concerns about the interpretation, consistency, and generalizability of the results of other studies. The aim of the present research was to gather and update data and evidence regarding the activation of the stress system of children and adolescents with ASD. The researchers focused on cortisol and alpha-amylase and on changes in the reactivity of the stress system to various stressors factors. In addition, an imaging presentation was made and immunological data were given that have been linked to dysregulation of the stress system. Finally, the function of the HPA-ANS axis coordination, the developmental trajectory of the stress system in ASD and the possible contribution of early stress to the dysregulation of the stress system observed in individuals with these characteristics were examined.

The findings presented inconsistent observations regarding the dysregulation of the stress system in children and adolescents with ASD. The putative specific role of ASD in the pathophysiology and clinical manifestation of the disorder is also called into question by the fact that the majority of the data lead to inconclusive findings. More specifically, the researchers summarize that while there is evidence that children and adolescents with ASD have altered systemic stress response and exhibit circadian cortisol rhythm abnormalities, the extent and relationships of these changes, as well as their underlying mechanisms, are still unknown and require more research.

Despite the physiological and structural occurrences that arise in the activation of the stress mechanism in people with ASD, there are several stressful situations that are combined with the predominant features of the condition and are expressed by activation of the sympathetic nervous system. Some of these include the sensory processing disorders (meltdown in states of sensory overload), phobia towards the unexpected and what comes next (due to lack of cognitive flexibility) and in some cases lack of predictability and understanding in social interactions (Mazefsky et al, 2014; Rodgers et al, 2016; Albein-Urios, 2018).

4. Assistive Technologies for Stress and anxiety for children with ASD

The International Classification of Functioning, Disability, and Health defines assistive products and technology as any product, instrument, equipment, or technology adapted or specially designed to improve the functioning of a person with a disability. So far Assistive Technology is a valuable tool for enhancing the life of any person with a disability. People with disabilities can participate in education, the job market, and civic life with the help of assistive technology, leading healthy, successful, independent lives. Without assistive technology, people frequently experience exclusion, isolation, and poverty, which worsens the effects of illness and disability on an individual, their family, and society as a whole. Assistive technology tools have a significant impact on the well-being of children with ASD, providing new opportunities for therapy methods that are meant to improve different skills that contribute to the integration of these children into society. Assistive technology can be categorized in Low-tech which includes traditional tools and methods that use non-interactive products or do not use energy, Mid-tech which includes simple electronic elements, such as recorders, e-books, headphones, and visual timers and High-tech which includes electronic and computerized elements that improve efficiency, speed, and accessibility. Low-tech devices although presenting several benefits such as cost of manufacture and ease of use, often may present issues of flexibility and adaptability as user needs evolve. Mid-tech and high-tech products combine interactive and intelligent features with multi-sensory enhancements improving the user experience by making it more natural, flexible and dynamic (Cañete & Peralta, 2022).

For the purpose of this literature review, assistive technology will be categorized into 2 categories. The first will include low-technology devices and aids (conventional equipment and procedures that use non-energy-consuming materials or products) and the second will include medium and high-technology devices and aids including basic electronic components that detect or improve stress and anxiety response and enhance functionality.

4.1. Low-tech Assistive Technology for stress and anxiety.

4.1.1. Visual Programs

Children and adults with ASD often face challenges in their daily lives that cause them stress and anxiety. Visual programs are a form of low technology that have been found to be effective when applied to any environment that the individual typically faces a challenge. A visual program consists of a set of images or words that motivate someone to engage in a series of activities. They give concrete form to the abstract ideas of activities and time by describing what will happen, when it will happen, and where it will happen using words, pictures, and other visual elements. They have been used successfully in a variety of settings (classrooms, homes and private practices) to reduce anxiety as well as address problems with sequential memory, time management and language comprehension (Hirano et al, 2010).

Knight et al. (2015) examined the quality of the literature of visual activity schedules (VAS). They assessed their utility by reviewing the literature for articles published between 1993 and 2013. Based on the results of previous reviews, the authors sought to determine whether VAS can be considered evidence-based practice. Of the 16 included studies the findings suggested that VAS can be considered an evidence-based practice for individuals with ASD, particularly when combined with methodical teaching techniques. Individuals with ASD from preschool through adulthood can use the VAS to develop, maintain, and generalize a variety of skills in a variety of contexts.

The study by Macdonald et al. (2018) evaluated how four students with ASD were helped to stay on task and work independently in a general setting using visual programs and work systems. Teachers used these techniques that included visual programs as a core form of inclusive intervention and evaluated them through classroom observations to determine whether they would work in more traditional settings. Regarding behavior at work, all participants showed improvement. Other secondary dependent variables yielded mixed results, with some students showing decreased off-task behaviors and increased productivity.

Another study that supports the use of visual schedules in different settings is the pilot study by Mah & Tsang (2016) which sought to determine if a picture communication system used in a visual schedule system can help children with ASD complete with pass regular dental exams. The sample consisted of 14 children aged 3 to 8 years who were divided into 2 control samples, those who received the method (till-show-do) and those who received the method combined with the use of a visual program. The results showed that compared to the control group, patients in the test group completed their steps an average of 1.38 faster (35.52 seconds per step) and with an 18.7 percent lower level of behavioral distress. Compared to the conventional method, the use of a visual timetable system and frequent weekly visits showed promise in helping autistic children successfully complete more steps, progress more quickly and show lower levels of behavioral distress.

4.1.2. Assistive Technology and wearables for sensory processing disorders.

Sensory processing and modulation problems are a common phenomenon seen in children and adults with ASD. This hyper-response (touch, hearing, smell etc.) to several of the inputs that a person with ASD receives from the environment can cause activation of the ANS and more specifically the sympathetic system causing increased stress and anxiety in the person. Listed below are low-tech items that may help prevent and alleviate this condition (Schoen, 2009; Fernández-Andrés et al, 2015; Kjovic et al, 2019)

4.1.3. Sound protection devices (Noise cancelling Headphones-Earplugs).

Ikuta et al. (2016) in their pilot study investigated the effectiveness of earplugs and noise canceling (NC) headphones in relation to the behavioral control of problems resulting from excessive response to auditory inputs in children with ASD. The results showed that the T-score on the Goal Achievement Scale (G.A.S) was significantly higher during the earmuff use period than it was during the reference period. Five children with ASD showed improved behavior during the headphones period (NC) compared to the reference period. However, there were no differences in Goal Achievement Scale T scores between the headphone (NC) period and the baseline period or between the earplug and NC headphone periods. The sample consisted of 21 children aged 4 to 16 years who, after a two-week period where they did not use any acoustic isolation equipment, they were given NC headphones to wear randomly for two weeks and conventional earplugs as a baseline. Participants responses to the auditory stimuli were assessed by their parents or teachers.

In a related study by Pfeiffer et al. (2019) 6 children with ASD aged 8 to 16 years were treated using a single-subject multiple treatment approach. Participants were randomly assigned to use in-ear and over-the-ear headphones during two treatment phases. Each child underwent four stages of research. The first included a week of baseline data collection, the second an intervention week, the third a non-intervention week, and the fourth the alternative intervention. Electro Dermal Activity (EDA) data were collected using an Empatica E4 wristband. Participants underwent a series of 16 to 20 data collection phases, with five measurements per phase. The purpose of this research was to evaluate the evidence supporting an intervention aimed at reducing sympathetic activity in children with autism and hypersensitivity. This study examined these findings using skin conductance measurements. The results showed that the use of noise-isolating headphones resulted in a statistically significant difference in both skin conductance levels and frequency of non-specific conductance responses between baseline and subsequent phases, as determined from separate analyzes for paired study phases. The results of this study suggested that the use of noise-cancelling headphones could potentially reduce sympathetic activation in individuals with ASD and hyper-reactivity to hearing.

4.1.4. Weighted Vests and Blankets

Several researchers have argued that through the application of deep pressure, students calm down physically, which includes increasing dopamine and serotonin levels, affecting deeper brain structures and reducing involuntary movement and stress levels. Many occupational therapists used Weighted Vests (WV) as a tool in their practice. Olson & Moulton (2004) found that 349 members of the American Occupational Therapy Association responded to Olson's 43-item survey. The survey found that 82 percent of respondents have experience using WV to meet the sensory demands of children with ASD. In addition, anecdotal evidence revealed that the use of WV had effects that favored calmness, concentration of students on tasks, and reduced stereotypic behavior. On the other hand, there are very limited studies that prove and find a positive correlation for their effectiveness.

Regarding weighted blankets, Eron et al. (2020) wanted to examine the effectiveness of Weighted Blankets in reducing anxiety and insomnia through their systematic review. The purpose of this research was to compile the existing literature and provide guidance for the initiation of future study. The results showed that weighted blankets can be effective in reducing anxiety. For the research methodology, a literature search was conducted from January 23 to March 1, 2018. Cochrane Libraries, PubMed, PsycINFO, CINAHL, OTseeker, Web of Science, and Nursing Reference Center Plus were some of the databases and websites used. The total number of studies was limited to 8 (four level I, two level III and two level IV). Research showed that the use of weighted blankets can be beneficial in some cases and among certain populations.

In a related and more recent research in non-ASD population, their effectiveness in combating anxiety and specifically in a psychiatric population and context was tested. The research of Beklund et al. (2021) evaluated the psychiatric patients who used weighted blankets (n=61) before and after compared to control samples who did not use (n=61) to control anxiety symptoms. During a 20-minute intervention, participants could use either weighted or non-weighted blankets. Treatment participants included those who chose to use a pad with weights of 5 pounds, 20 pounds, or 14 pounds. A wider range of activities was observed among the comparison group. Anxiety and pulse were assessed using a pulse oximeter and the Spielberger State-Trait Anxiety Inventory short form (STAI: Y-6) before the blankets were used. Both procedures were repeated after the intervention. Effects of time (pre/post) and group (comparison group/weighted blanket) on the interaction were investigated using a two-way mixed analysis of variance (ANOVA). A repeated-measures ANOVA was used to examine simple main effects of comparison and weighted blanket groups. Another two-way mixed ANOVA was conducted to determine if there was a statistically significant difference between the blanket weight group and those of gender or overall weight. The results of the research revealed that the use of weighted blankets can be a safe and practical solution for patients with anxiety in psychiatric settings. Patients receiving weighted blanket inpatient care had lower heart rates and higher STAI: Y-6 scores, which were statistically significant indicators of anxiety reduction.

4.2 Mid and High-Tech devices for stress and anxiety of children with ASD

4.2.1. Wearables

Several literature reviews have focused on technologies that enable remote physiological and emotional monitoring through various detection methods. For people with ASD there are relevant studies that have been carried out with the aim of detecting the changes in the physiology of stress and anxiety. Wearable devices can have a variety of benefits for their users and can provide a wealth of information in databases and data interpretation and analysis software that can be beneficial. Through them, many functions that are related to neurophysiological changes such as heart rate, variability and response, breathing rate, skin and body temperature, electrodermal activity, cortisol levels, blood pressure and oxygen in the blood. In addition, protocols and interventions can be prepared that will target individual’s secondary difficulties related to ASD that cause stress such as social interaction and communication. Wearable devices can be activity trackers, smart watches, smart glasses, smart t-shirts or vests. These types of technology can fall into three broad categories including commercial, prototype and emerging (Taj-Eldin et al, 2018).

Many researchers have emphasized the importance and value of manufacturing mobile devices that meet specific criteria and specifications that makes them user-friendly and likeable.

The research by Koo et al. (2018) was done to produce and evaluate a prototype based on the defined preferred functions, design elements and features. In this research, 12 design elements that are beneficial for users with ASD were recorded and categorized in order to create a glove design prototype. These included the following: safety, data accuracy, comfort, elasticity of materials, portability, durability, price, ease of use, weight, size, design discretion and uniqueness.

The more recent research by Canete and Peralta (2022) was also referred to it with the aim of developing a method that will support the autonomy of children with ASD in their everyday life through the design of appropriate smart device products and assistive technology. Their findings summarized that devices must meet the following characteristics which were about adaptability, design, sensitivity and learning through play. They also argued that these 4 principles can be applied to any type of medium and high technology that is manufactured for implementation and use by populations with ASD.

Taj-eldin et al. (2018) mentions a broad category of wearables in their research to review available wearables on the market and analyze them in relation to their clinical reliability, utility and perspective regarding their use by people with ASD and how they measure physiological changes. The research methodology included a list of current market devices, new technologies and prototypes that collect and document all or part of physiological parameters. The research was conducted between 2015 and 2018. Internet searches were conducted to identify the devices included in the review (Google Search Engine) to find commercial gadgets. In addition, internet database and scientific literature searches were used. The research results summarized that there were only a few products that offer accurate monitoring of the physiological internal state and could be suitable for people ASD. These findings were also confirmed in the most recent research by Koumpouros & Kafazis (2019). Based on the above studies, some of the wearable devices that aim to detect, treat and combat primary and secondary symptoms responsible for stress or anxiety in people with ASD are discussed below.

4.2.2. Empatica E4 wristband

The E4 wristband is a wearable research tool that provides real-time physiology data and analysis and visualization software. Four sensors are mounted on the E4 to monitor and collect pulses of blood volume, skin temperature, sympathetic nervous system activity, heart rate and its variability.

The E4 has been used in several studies to measure anxiety and stress in special populations such as ASD and has been shown to be reliable and valid in several studies concerning the IBI and mean HR (Pfeiffer et al, 2019; Airij et al, 2020; Benedicto et al, 2022; Takir et al, 2022).

The research by Milstein & Gordon (2020) was done to examine the validity of this particular device as a purely research tool compared to the MIndwave mobile impendence cardiographic device. Its action was studied during naturalistic observation involving live interaction which also included hand gestures. The sample collection involved 30 participants who were connected to both devices and split into pairs while they were at rest and talking to each other. Inter-device correlations of various HRV instruments showed moderate to high values, with higher values during rest than conversation. However, E4 was unable to provide accurate EDA data.

4.2.3. Hexoskin Shirt

Hexoskin (SWS) is a smart T-shirt that has sensors that measure the changes that occur in the body's physiology such as heart rate, breathing, oxygen in the blood and is accompanied and connected to a health platform to record and analyze the data.

Regarding the validity of the results of Hexoskin, its use has been evaluated mainly in populations that do not include people with ASD and in most it is reported as valid and reliable but with difficulties recorded during physical exercise related to connectivity issues.

As a research tool regarding the ASD population it was used in the recent research by Zwilling et al. (2022) to measure differences in physiology. The study was carried out in 3 phases. In the first phase, differences in the physiology of high-functioning adults with ASD and neurotypical participants were measured using the SWS. The second phase involved the development of an ad hoc ML algorithm to predict challenging behaviors (CB) in real-time to be used in conjunction with a smartphone application that will send an alert when CB is likely to occur. In the last phase, acceptance and effectiveness of the system was tested among people with ASD and their caregivers. The first protocol phase involved 20 high-functioning ASD individuals between 20- and 40-years old living at home and in the observation group and another 20 neurotypical peers as a control group, according to the sample size calculation. The second phase involved the recruitment of 10 adults (aged 20-40) with ASD who exhibit severe aggressive or disruptive behaviors, along with their caregivers. The final phase involved a participant with ASD, aged 20 to 40, who had disruptive or aggressive features. Regarding the use of SWS the participants with ASD accepted its use and it did not upset them.

4.2.4. Empower Me, Brain Power glasses

Users can learn fundamental social and emotional skills with the help of Empower Me Brain Power (EMBP), which is available for Google Glass Explorer Edition and other smart glasses. BPS smart glasses are a device that trains social communication and uses augmented reality. BPS has undergone feasibility, acceptability, safety and clinical impact studies.

More specifically, in the research by Keshav et al. (2018) with the aim of creating an intervention that targets attention difficulties and social learning elements that can cause stress in children with ASD in the educational environment of the school, EMBP glasses were used. During a two-week study of a 13-year-old high school student with ASD in Massachusetts, the intervention was given twice a day. The student's general education teacher, special education teacher and health professional participated in the implementation of the intervention. Through the use of a digital journal and a series of face-to-face interviews, teachers documented their attitudes, the usefulness of technology, and its impact on students and their classroom. The use of the smart glasses intervention was found to be logistically feasible, simple for teacher and student use, and not time-consuming to learn or implement. The teachers also noted that the student enjoyed the experience and that she had made progress in both verbal and non-verbal skills. In addition, the technology is reported to have not caused a distraction or had a negative impact on other students or the classroom. These results suggested that social skills interventions delivered through smart glasses may be useful, practical, and may enhance social communication and stress reduction abilities.

Another study using EMBP by Cavallo et al. (2021) was conducted on one subject to investigate the specific device regarding its effectiveness. A technician delivered 15 sessions of the Brain Power intervention over four weeks in a private office. Each session lasted 15 minutes, during which the subject worked with a technician wearing AI-enhanced Google Glasses. Selected neuropsychological tests, qEEG analysis, and behavioral rating scales using a pre-test design were used as measures to demonstrate efficacy. Results and neuropsychological testing showed significant improvements of at least one standard deviation in social perception and facial memory skills. Z-Builder analysis showed changes in specific regions of interest that may be associated with brain regions associated with the specific neuropsychological functions measured. On the contrary teacher reported that he did not notice any significant changes in the students' behavior.

The findings of the above studies for the ASD population, although showing encouraging evidence, show reduced levels of high levels evidence and results that needs further investigation in lager populations.

4.2.5. Social robots to reduce stress and anxiety in children with ASD

A social robot is a machine designed to interact and communicate with humans in any compatible way. Social robots usually have a relatively simple appearance and offer specialized capabilities for verbal and non-verbal communication and are the most commonly used in various application areas. Robots can use speech, eye contact, body language, gestures, head positioning, and social media to communicate with humans in situations where they exhibit predictable and unacceptable behavior, providing them with empowerment, positive feedback and emotional release from stress and anxiety. In the literature there are many social robots that have been used with people with ASD. Some of those found in the literature that have been used in children with ASD to reduce stress are KASPAR, Kiliro and Paro (Guemghar et al, 2022; Rasouli et al, 2022).

4.2.5.1. KILIRO

KILIRO is a robotic parrot that consists of 2 AI ball wireless cameras and a usb to be able to perceive 270 degrees of visibility. It can recognize letters and numbers using QR codes and has 7 tactile sensors to recognize tactile contacts with children. Kiliro can also browse understand and respond to sounds.

Regarding its use in children with ASD and anxiety, it has been used in the research by Krägeloh et al. (2017) to present evidence regarding the reduction of stress symptoms in a population with ASD. In this research, 7 children aged 6 to 16 participated and were studied for 49 days. The measurement tools for stress were taking a urine and saliva sample to measure biological changes in physiology. The results showed efficacy and validity after interacting with the KILIRO robot. More specifically, the stress levels of the study participants appeared to have decreased, according to the saliva and urine test results.

4.2.5.2. KASPAR

Blow and his colleagues first created the KASPAR robot in 2005 (Dautenhahn et al, 2009) as a research platform for human-robot interaction. KASPAR was used to examine how it could be used as a therapeutic tool for children with ASD due to his simplified human appearance. It acts as a social mediator, helping children develop and communicate with adults and other children and has also been used to develop basic emotional skills in children. Uses simple facial expressions, body language and gestures. In addition, sensors on the face, hands, body, and feet are used to respond to touch without external stimulation, helping children gain knowledge about socially acceptable tactile contacts.

The pilot study by Huijnen et al. (2021) was carried out in a special school to investigate how well the KASPAR robot interacted with children with ASD. A mixed methods study with an ABAB design was conducted involving 9 children aged between 8 and 12 years. Four sessions were completed by the children: two with KASPAR and two with their teacher (usual care), for a total of 36 (recorded) sessions. Children's in-session microbehaviors and teachers' responses as seen on videotapes were the primary outcomes. The results showed that the children touched the robot more often than the teacher (p value = 0.028) and that they non-verbally imitated more often for a "cool" (p value = 0.012), remained focused longer (p value = 0.011) and were less frequently distracted (p value = 0.021) in the KASPAR sessions compared to the teacher sessions. Compared to KASPAR, the teacher elicited more positive verbal responses from the children (p value = 0.028). Both the amount of nonverbal behaviors that occurred and the child's spontaneous use of self-initiated verbal utterances showed a clinically significant difference in favor of the KASPAR condition. The conclusions summarized that compared to the teachers, Kaspar was able to connect better with the children, hold their interest for a longer period of time and direct it in a more focused way. The children also appeared comfortable and enjoyed their interactions with the robot and showed reduced anxiety which are critical conditions for further learning and application.

In the research of Coşkun et al. (2022) KASPAR was used and stress response was studied while interacting with him. The aim of this research was to develop an anxiety detection system using blood volume pulse signals (BVP) in children with ASD. In this study, researchers describe a heart rate variability analysis method for stress detection that extracts HRV features from raw BVP signals collected from an E4 wristband during interaction studies with the social robot Kaspar. Analysis of low-frequency and high-frequency power characteristics and findings are confirmed by facial emotion analysis of children with ASD. 21 children from 3 different countries participated in the study. Findings from the children's interaction with the KASPAR robot appeared to be reduced anxiety responses.

4.2.5.3. PARO

PARO is a robotic seal pup developed by AIST in Japan. Autonomous mechanisms, similar to reinforcement, can use user feedback to learn new behaviors. PARO has touch, sound, vision, movement and temperature sensors and can recognize what we hold in our hand and express emotions from the movements of the head, fins and eyes. Regarding the ASD population it was used by Nakadoi (2017) to evaluate the effectiveness of SAR-assisted ASD treatment. 9 psychiatric inpatients, ages 8 to 19, were observed to determine their mood, anxiety, and impulsivity. Over the course of two months, inpatients were free to interact with the robot. The results showed mixed results. It was thought to be helpful for ASD patients themselves in developing good communication or reducing impulsive behaviors or anxiety. However, some aspects such as the large eyes and high frequency navigation noise made it unfavorable for some. Regarding populations without ASD, it has been shown to be effective in combating stress and anxiety symptoms (Aminuddin et al, 2016; Law et al, 2022).

4.2.6. Virtual Reality as an Assistive Technology tool to reduce anxiety in children with ASD

Using tracking software and a video camera in virtual reality allows users with ASD to track movement at different levels without the need for pointers or sensors. Simultaneous interaction with animations and graphics is facilitated by including the user's image in a simulated environment. This technology has been around for 25 years, but only recently has it been used in ASD patients.

In the study of Maskey et al. (2014) the researchers selected 9 boys aged 7 to 13 who were verbally proficient and diagnosed with ASD, but had no known learning disability, to create and evaluate a new treatment using cognitive behavior therapy (CBT) and graduated exposure in a virtual reality environment (VRE). Every individual had concerns about a particular matter. Participants in the VRE received cognitive and behavioral coaching from a psychologist (e.g., breathing exercises) while escalating the child's exposure to the phobia or fear stimulus as needed. Four sessions of 20 to 30 minutes each were given to each kid. Eight of the nine kids who took part in the study were able to deal with their phobias afterward. Four of the participants overcame their fears entirely. After a year, the therapeutic effects remained. These findings demonstrate that for some young people with ASD, CBT combined with VRE can be a very successful treatment for phobias, stress or fears of a particular type.

The objective of Suresh & George (2019) in their research was to evaluate the effectiveness of VR distraction in reducing anxiety and behavior in children with ASD at dental clinic. In this study, 68 children aged 8 to 15 who were diagnosed with ASD and required regular, non-invasive dental treatment were included. These children were scheduled to receive regular, painless dental treatment in two visits held three months apart. To evaluate their behavior and dental anxiety after treatment, the children were given the Venham Picture Test and Frankel's Behavior Rating scales during both visits. 40 children underwent dental work, with data collection and analysis of the results completed. When VR distraction was used, there was a significant decrease in patient reported anxiety scores and a significant improvement in their dental behavior (p=0.042 and p=0.0001, respectively). While receiving routine dental care, ASD children can benefit from being distracted using virtual reality.

An interactive virtual reality game called SoundFields is introduced in this paper by Johnston et al. (2020), which utilizes exposure-based therapy techniques and aims to target auditory stimuli through binaural-focused spatial audio. A trial was conducted on 6 individuals with ASD who were hypersensitive to specific sounds in order to determine the efficacy of SoundFields in reducing anxiety associated with identified troublesome sounds. Each participant was actively engaged in VR gameplay for 4 weeks per week during the investigation. A comparison of pre- and post-study measurements after this time period revealed a significant decline in anxiety related to target auditory stimuli. The study's results suggested that SoundFields could be a useful aid for individuals with ASD to manage their auditory hypersensitivity.

According to the results of the literature review by Sideraki & Stathopoulou (2023) which gathers research and analyzes their results on the effectiveness of VR in reducing stress in people with ASD, VR seems a promising method as an intervention showing effectiveness in some studies. The findings agree with the aforementioned studies and summarize that a person with ASD who is in a virtual reality environment that is appropriately created to promote calmness, can reduce anxiety levels.

5. Discussion

New technologies like AI has been incoorporated significantly in people’s daily living, leading to social changes that have an impact on the ability we have to communicate, diffuse informations, absorb and apply the newly produced knowledge (Pappas & Drigas 2015, 2016; Drigas & Koukiannakis, 2004, 2006, 2009; Drigas & Kontopoulou, 2016; Theodorou & Drigas, 2017; Drigas & Kostas, 2014, Bakola, L., et al., 2019, 2022; Drigas & Politi-Georgousi, 2019; Karyotaki, et al, 2022). ASD is a special neurodevlopmental disorder that can be greatly benefited by these new digital technologies that are also incorporated by specialists, health professionals and educators in evaluation, intervention, decision making and educational procedures. These new technologies including mobiles (Stathopoulou et al., 2018, 2019, 2020; Kokkalia, et al, 2016, Drigas et al., 2015, 2020, 2022, 2022; Vlachou et al., 2017; Papoutsi et al., 2017, 2018; Karabatzaki et al., 2018; Alexopoulou et al, 2020; Stavridis et al, 2020), various ICTs applications (Drigas et al., 2004, 2005, 2006, 2009, 2010, 2011, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Pappas et al., 2015, 2016, 2017, 2018, 2019; Papanastasiou et al., 2014, 2017, 2018, 2020; Alexopoulou et al., 2019; Kontostavlou et al., 2019; Charami et al., 2014; Bakola et al., 2019; Kontostavlou et al., 2019; Papoutsi et al., 2016, 2017, 2018, 2019, 2020, 2021, 2022; Kokkalia, et al., 2014, 2015, 2016, 2017, 2018, 2019; Karyotaki. et al., 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021; Bravou et al., 2019, 2022; Lytra et al, 2021), robotics & Stem (Drigas et al, 2004, 2005, 2009, 2013, 2014, Vrettaros et al, 2009, Anagnostopoulou et al., 2020, Lytra et al, 2021; Pappas et al, 2016; Mitsea et al, 2020; Chaidi et al,2021), as well as games (Chaidi et al, 2022; Kokkalia et al, 2017; Drigas et al., 2021) can greatly benefit the person with ASD within the context of special and general education and also be higly preferable and motivational (Drigas et al., 2014, 2015, Papanastasiou et al, 2017, Kokkalia et al, 2016, 2017, Doulou et al,2022, Chaidi et al,2022, Kefalis et al, 2020, Papoutsi et al, 2016). At also integrates a lot of parts of these technologies in order to facilitate and support the person in their daily living.

Anxiety and stress are important factors that can greatly affect a person's daily life. Although they are necessary for our survival at the level of autonomous action of our nervous system, when they persist and are found to an excessive degree, they can affect the overall homeostasis of the individual as well as the way in which the information received from the environment is transmitted and interpreted. Many researchers have made connections related to increased levels of anxiety and stress in children with ASD and their families.

Assistive technology, whether it is low or medium and high-tech, is a useful tool that can be used and integrated as a detection mechanism for factors that increase stress levels in children with ASD, identifying fluctuations that deviate from the standard, regarding the changes that occur in physiology (heart rate, pressure, oxygen in the blood, body and skin temperature, etc.). It can also be used as a preventive agent with the use of visual programs, noise isolation and weighted vests and blankets, i.e., wearables of low-tech options that improve the person's sensory processing (something that has been identified and officially recognized in the latest DSMV) as well as his psychoemotional organization. Finally, they can be used as devices for intervention such as social robots and wearables with augmented reality to combat elements of anxiety and stress in children with ASD, which are also accompanied by benefits in their social imitation and communication.

Regarding the analysis of the literature, the findings that were gathered on the use of AT as a means to address stress and anxiety in children with ASD and their caregivers, seemed to be encouraging in terms of the prospects for their uses in the daily living. However, future research is suggested to focus on the need for further investigation and also for the creation of personalized options that meet criteria relating to design and encompass vital elements to support the user just like portability, ease of use, sensory needs and production costs that can be better researched and integrated in their lives.

6. Conclusions

Concluding, along with use of AT in ASD for stress and anxiety, it is necessary to refer that the combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation accelerates and improves more over the educational, productive, and decision- making practices and results (Drigas et al,2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Kokkalia, et al, 2014, 2015, 2016, 2017, 2018, 2019; Pappas et al., 2015, 2016, 2017, 2018, 2019; Papoutsi et al, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Karyotaki et al, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021 ,2022; Chaidi, et al, 2020, 2021, 2022; Mitsea et al, 2019, 2020, 2021, 2022, Angelopoulou, et al, 2021; Tourimpampa et al, 2018, Kapsi,et al, 2020; Galitskaya et al, 2021; Bakola et al, 2020; Bamicha et al, 2022).

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8. Authors' Contributions

Pantelis Pergantis: experimental design, writing, grammatical and scientific corrections in the manuscript and publication. *Athanasios Drigas*: experimental design, writing, grammatical and scientific corrections in the manuscript.

9. Conflicts of Interest

No conflicts of interest.

10. Ethics Approval

Not applicable.

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