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Metacognition in Autism Spectrum Disorder: Digital Technologies in Metacognitive Skills Training

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Abstract. Extensive research has been conducted regarding socio-emotional skills training in autism spectrum disorder (ASD). The latest autism research is now beginning to recognize the role of metacognitive deficits in ASD as well as the importance of metacognitive skills training in autism intervention. The purpose of the current review study is to shed light on the role of metacognition in ASD and identify assistive technologies that may compensate for metacognitive deficits. Specifically, we examine autism through the lens of the models of metacognition developed by (Drigas and Mitsea, 2020; 2021). Following these metacognitive models, we identified digital technologies that have the significant potential to train metacognitive skills in people with ASD. These technologies include, among others, robotics, virtual reality, mobile applications, digital serious games, coding digital games and robots. This review provides evidence that people with autism face important difficulties in almost all metacognitive domains. It also highlights that digital technologies are effective tools for training metacognitive skills within the educational settings to facilitate students' inclusion. This study is one of the few studies that deal with autism as a disorder of metacognition and gives pointers for future experimental research regarding metacognitive intervention strategies with the assistance of technologies.

Keywords. Autism Spectrum Disorder, metacognitive skills, robotics, virtual reality, mobile applications, serious games, coding, K-12 education, self-regulation, self-observation, self-awareness, inclusive education

1. Introduction

Autism

Autism spectrum disorders (ASDs) are complex, pervasive, and multifactorial neurodevelopmental conditions. Diagnostic criteria include impairments in social communication and interaction, and restricted, repetitive patterns of behavior, interests, or activities. Comorbid mental and medical morbidities are commonly described, resulting in heterogeneity (Masi et al., 2017). Comorbid psychopathologies significantly over-represented in ASD include anxiety, depression and mood disorders, oppositional defiant disorder, attention-deficit/ hyperactivity disorder, and intellectual impairments (White et al., 2009; Magnuson & Constantino, 2011; Masi et al., 2017).

Metacognition

Flavell who introduced the term and led the studies regarding Metacognition investigated whether children are aware of understanding some components that govern their memories and cognitions. Indeed, the research provided significant evidence that children possessed the ability to reflect on their own cognitive processes. After this research, Flavell defined metacognition as the learners' awareness of their own cognition and cognitive processes (Flavell, 1979). Metacognition comprises both the ability to be aware of one's cognitive processes and to manage them effectively (Fleur et al., 2021). According to Nelson and Narens (1994) two fundamental components are required: metacognitive monitoring and meta-control. Meta-control includes a set of top-down self-regulatory mechanisms responsible for the smooth operation of cognitive functions such as recognition and discrimination of objects, decision-making, semantic encoding, and spatial representation. Metacognition also includes a set of meta-processes individuals can apply in monitoring ongoing cognition to effectively control their behavior (Rhodes, 2019). Observable behaviors are the outcome of all those mental meta-processes that occur before an individual engages in action (Amram et al., 2021). According to Brown (1978) metacognition requires also appropriate evaluation and organization of the thinking processes that people employ to plan their actions and behaviors, make decisions, and solve problems of daily life. Metacognition enables people to create meta-presentations of their internal mental states, monitor and regulate them aiming to achieve effective daily behavioral functioning (Nelson & Leonesio, 1988). Metacognition is the reason for the manifestation of conscious behaviors as well as the development of emotional intelligence (Drigas & Pappas, 2017; Drigas & Papoutsi, 2018).

The 8 Pillars model of Metacognition

Definition

Drigas and Mitsea (2020) define *Metacognition as the set of regulatory meta-abilities and meta-skills that are consciously applied aiming at the smooth operation of the cognitive & psychophysiological mechanism as a means of achieving functional capability, self-efficacy, independent living & life satisfaction. Metacognition involves individuals' ability to observe, regulate and adapt their own internal cognitive processes, recognize the difference between functional and dysfunctional states of mind and consciously choose those states that awaken the full range of their own abilities and identity* (fig. 1,2). Metacognition refers also to the consciousness people have about their abilities, skills, and strategies as well as the flexibility to utilize their mental powers strategically to achieve higher goals. Metacognition includes higher mental abilities such as those described as executive functions. However, the concept of metacognition goes beyond these self-management abilities. It provides people the unique ability to have supervision and awareness of their existence, to seek the reasons for their behaviors, to wonder about themselves, to search for self-explanations, and self-understanding (Drigas & Mitsea 2020, 2021; Mitsea & Drigas, 2019; Mitsea, Drigas & Mantas, 2021).

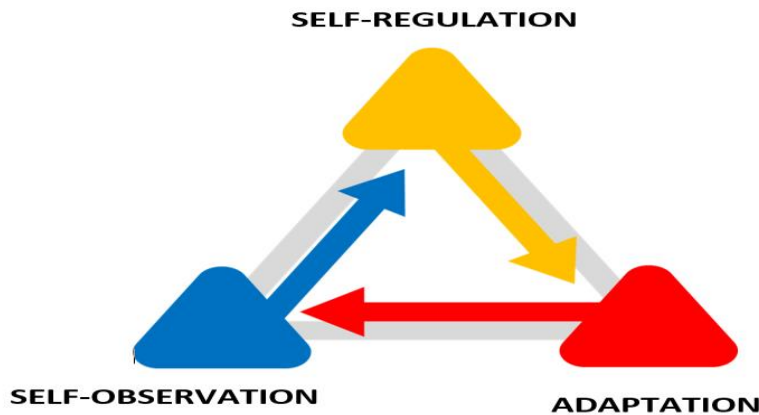


Fig. 1: The fundamental components of metacognition: self-observation, self-regulation & adaptation

Metacognition is structured upon the following 8 fundamental components (fig.2) (Drigas & Mitsea 2020, 2021):

1. **Meta-thinking/meta-learning:** The individuals' ability to acquire knowledge including that concerning their cognitive mechanisms, to make meta-representations of the knowledge. It includes the ability to “learn how to learn”, to understand how cognition works as well as its hierarchical relationships. In other words, to be aware of the phenomenon of self-conscious learning itself.

2. **(Self)-assessment & Context-appropriateness of use of knowledge:** The awareness that the individuals develop through experience regarding the degrees of freedom that define a specific situation along with the awareness of their strengths, weaknesses, opportunities and threats to initiate or cease behaviors that maximize performance in a given task.

3. **(Self)-observation:** Real-time conscious monitoring of the external (exteroception) and internal environment (introspection) including the functions of the cognitive and psychophysiological mechanism. Self-observation requires internal attention to shed light on patterns of thoughts and feelings. However, this process takes feedback from the external environment such as our social environment. Therefore, self-observation stands at the crossroad between intrapersonal and interpersonal routes. Although most people recognize this ability in themselves, it is a metacognitive, self-conscious ability that develops gradually and after systematic training.

4. **Self-regulation:** The ability to modulate any dysfunction that is observed and disrupts the normal functioning of the cognitive and psychophysiological mechanism (i.e anxiety, impulses, over-reactivity)

5. **Adaptation:** The individuals' ability to adjust their mental functions and behavior according to the demands of specific situations, existing needs and goals.

6. **Recognition:** The power of perception that enables individuals to recognize any change in their mental and emotional state (for example, to perceive the wandering of thought, the distractions of their attention, their anxiety) as well as the possible reasons. According to the pillar of Recognition, people are able also to perceive others' mental states, intentions and beliefs.

7. **Discrimination:** refers to the ability of filtering, determining and strategically choosing what is essential and what is not in a given situation, in terms of actions and behaviors.

8. **Mnemosyne**: The ability to remain in a state of positive alertness, and relaxed awareness. It also represents the internalized knowledge that awakens and drives humans towards independence and self-fulfillment.



Fig. 2 **The 8 Pillars Model of metacognition** (Drigas & Mitsea, 2020).

People with autism face important difficulties in almost all metacognitive domains. According to this point of view, Autism could also be characterized as a disorder of metacognition.

The Layered Model of Metacognition

Drigas and Mitsea (2021) proposed a new layered model of metacognition (fig.3). This model integrates the 8 pillars model of metacognition (Drigas and Mitsea, 2020) to the layered model of Knowledge, Intelligence and Consciousness developed by Drigas and Pappas (2017). According to this approach, the 8 pillars of metacognition offer the pathway to ascend the eight-layer architecture of self-consciousness. Ascending from lower to higher levels of self-consciousness entails moving to advanced forms of metacognition. The 8 pillars of metacognition constitute the core elements of the control systems under the rule of which distinct consciousness abilities take place. According to the knowledge pyramid (Drigas & Pappas, 2017) people receive stimuli and transform them into data, data into information, and information into knowledge. However, these processes are considered unfeasible without the pillars of metacognition. This means that impairments in metacognition result in self-consciousness deficits. In addition, metacognitive pillars operate differently at various stages of consciousness. For instance, metacognition in the sensory awareness stage operates differently than the stage of social awareness (Drigas and Mitsea, 2021).

According to Gardner, there are eight distinct intelligences: linguistic, logical-mathematical, musical, bodily kinaesthetic, visual-spatial, interpersonal, intrapersonal and naturalistic intelligence (Gardner, 2011). According to the layered model of metacognition, metacognition creates the conditions for the emergence of Intelligence. Gardner's intelligences

are not one-dimensional, but each one is structured on 8 layers of metacognition and consciousness (Drigas & Pappas, 2017; Drigas & Mitsea, 2020, 2021; Mitsea, Drigas & Mantas, 2021, Gardner, 2011).

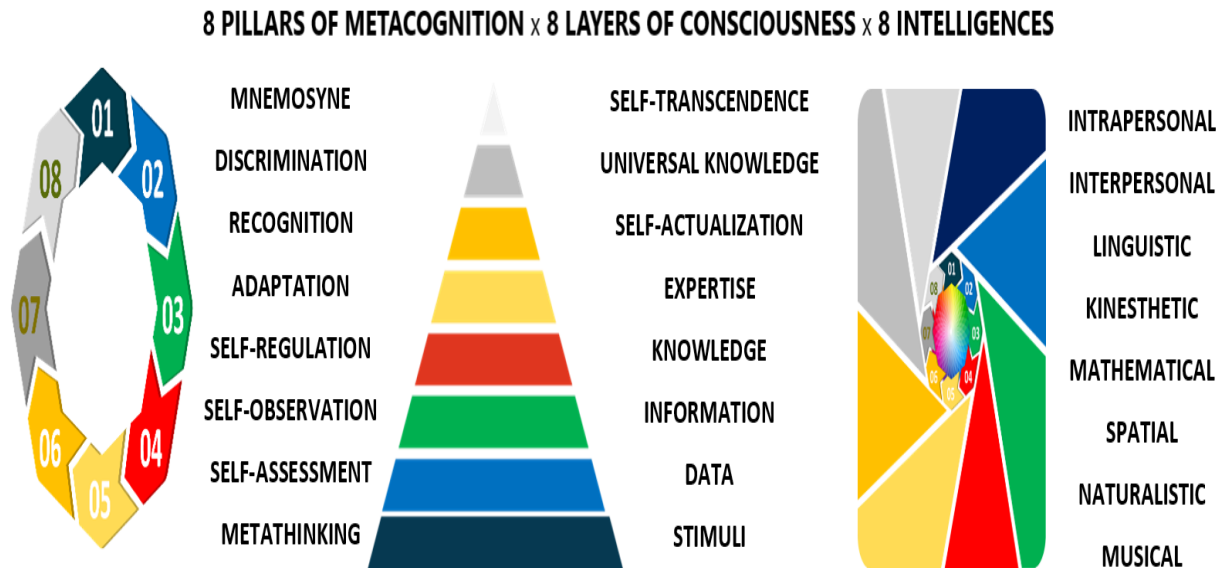


Fig. 3 Autism in the layered approach of Metacognition.

As stated in the 8X8 layered model, metacognitive processes affect the different states of human consciousness as well as the different forms of human intelligence. According to the aforementioned approach, deficits in the autism spectrum may not be linear but hierarchical. People with autism have limited metacognitive skills resulting in self-consciousness impairments and variations in intelligence (Drigas & Mitsea, 2021; Drigas & Pappas, 2017).

The 8 Pillars Model of Metacognition in Autism Spectrum Disorder

Autism is a disorder with a specific impairment in the neurocognitive mechanisms underlying self-consciousness. People with autism face difficulties in engaging in self-observation. They are less able to reflect on their mental states, their intentions or to anticipate their own actions (Frith & Happé, 1999; Lombardo, Barnes, Wheelwright & Baron-Cohen, 2007). As a consequence, individuals with ASD have a diminished awareness not only of their own intentions but also of others' intentions, beliefs, and desires. Therefore, it is extremely difficult for people with ASD to interpret and predict others' behavior (Williams and Happé, 2010; Lombardo et al., 2007). It is obvious that apart from the interpersonal domain, there are significant impairments in the intrapersonal self-referential domain.

One common characteristic of ASD is poorly developed self-management skills, such as difficulty presenting, controlling, and maintaining behaviors required by the class routine (Xin, Sheppard & Brown, 2017). According to Gomez and Baird (2005), people with autism exhibit significantly self-regulatory difficulties. In fact, self-regulation difficulties constitute the early indicators that distinguish infants with autism from neurotypical infants. The aforementioned impairment of metacognition is obvious in many different ways. Self-regulation disorder takes the form of the inability to interact with the stimulating environment, maintain an equilibrium state, remain attuned to interpersonal relationships, delay gratification,

and inhibit impulsivity. Over-reaction, under-reaction, poor self-awareness, state of disorganization and dyscontrol are rooted in self-regulation impairments.

Individuals with autism demonstrate significant impairments in adaptation. For instance, they have difficulties in switching between multiple mental representations of a single object in response to changing contextual factors (Wang & Reed, 2013). According to Mostert-Kerckhoffs et al. (2015), repetitive behaviors, apart from inhibition control deficits, are also linked to the lack of adaptation skills such as attentional flexibility.

People with autism fail to apply essential self-management and discrimination skills. They are less able to discriminate and record the occurrence and nonoccurrence of target behaviors, administer consequences for their performance, evaluate performance against a predetermined goal or target (self-evaluation), and set personal goals (Aljadeff-Abergel et al., 2015).

The autonomic nervous system of people with autism dysfunctions leading to elevated anxiety due to sympathetic over-arousal and parasympathetic under-arousal. This means that people with ASD have severe difficulties in remaining in a state of positive alertness, and helpful relaxation (Kushki et al., 2013).

The role of ICTs in Inclusion

Information and Communication Technologies are now a priority in almost all of the modern world. European Union has already recognized the importance of technologies in bridging the digital gap to promote equal opportunities in the Knowledge Society. ICTs are considered essential to support vulnerable social groups such as those with disabilities and special needs (fig.4). ICTs allow people to have equal access to information, services and communication. They also provide the unique opportunity for active participation in social events. They ensure equal conditions for education and training by creating the appropriate conditions for their subsequent inclusion into the work environment. ICT also aims at uncovering the special abilities and talents of people with disabilities. Therefore, the employment of ICTs in special education seeks to ensure equality, productivity, autonomy, security and life satisfaction (Drigas & Ioannidou, 2013; Drigas, Koukianakis, & Papagerasimou, 2005).

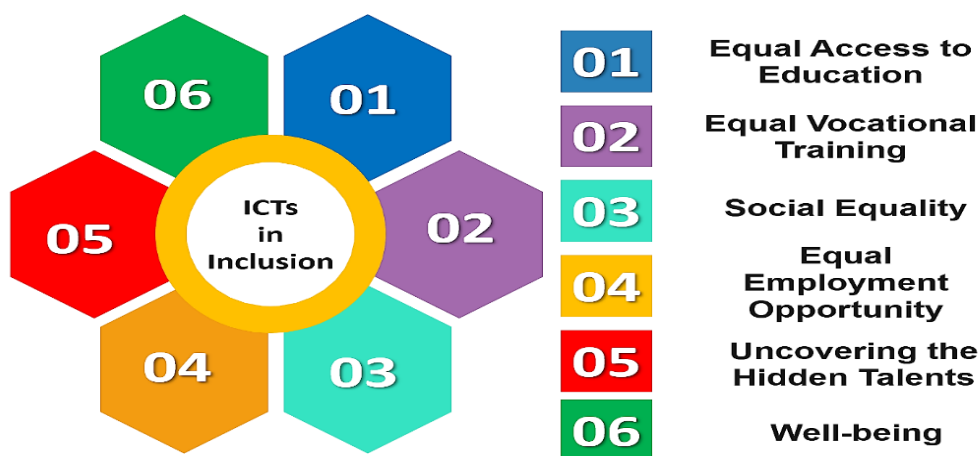


Fig.4 The role of ICTs in the Inclusion of people with special needs (Drigas et al., 2005; 2013).

Use of ICTs in Autism Spectrum Disorder

People with autism show a natural affinity for technology and a good disposition for using technology and learning through the use of ICT. ICTs provide predictable and structured environments, which help people with ASD to maintain their routines without affecting their comfort. ICTs satisfy autistic individuals' needs, enhance self-confidence and other positive emotions, are easy to use and the content is accessible. New technological approaches include the use of sensors, virtual reality, virtual agents, augmented reality, robotics, mobile applications, serious games and e-learning. The use of modern technologies attempts to teach skills to people with ASD such as practical skills, social-emotional and general skills. (Valencia et al., 2019).

However, there is a paucity of studies investigating the effectiveness of high-tech assistive technologies on the development of metacognitive skills. Especially, for people with ASD, the effectiveness of technological tools, such as virtual reality, robotics, mobile apps and serious games in the development of metacognitive skills remain an unexplored option.

2. Method

The purpose of the current review study is to shed light on the role of metacognition in Autism Spectrum Disorder and examine the effectiveness of ICTs in training metacognitive skills. We systematically searched clinical and technical databases including Scholar Google, Pubmed, IEEE Xplore, Scopus, Science Direct following a comprehensive search strategy with main research terms the following: metacognition, self-awareness, self-regulation, adaptation, virtual reality, mobile application, robotics, coding, autism spectrum disorder, asperger. The intervention reported focuses on children aged between 4–18 years with ASD. Priority was given to experimental research studies. Regarding research limitations, we can mention the lack of experimental studies evaluating exclusively metacognitive skills via digital technologies for people with ASD. In addition, there was a limited number of large-scale studies to determine the effectiveness of technologies on metacognitive skills.

3. Results

3.1 Robotics

The term robotics encompasses a variety of research subareas, systems, and applications. Research into applying robots as therapy tools has already shown that improve engagement and elicit novel behaviors from children and teenagers with autism. A more recent trend in robotics focuses on designing and implementing robots that provide social assistance (Scassellati, Admoni & Matarić, 2012). Socially Assistive Robots have special design features and can adopt different roles depending on the content, the trainer, the trainee and the nature of the activity. The interaction of autistic children with robots aims to improve their social skills, emotional awareness and communication through the elicitation of desirable behaviors such as imitation, joint attention, initiation of communication and social interaction (Scassellati et al., 2012 & Matarić, 2012; Mitsea et al., 2020). Recent studies have shown that robotics can foster emotional intelligence skills as well as executive functions and metacognitive abilities (Bakola et al., 2020; Mitsea et al., 2020).

Nikopoulou et al. (2022) examined the case of a 13-year-old girl diagnosed with autism disorder who presented repetitive and compulsive behaviors. Robot-enhanced relaxation training was introduced to support the patient since she declined to undergo any form of talk therapy. The intervention aimed to promote self-regulation skills. The social robot Nao was giving step-by-step instructions according to the relaxation scripts and offered positive

feedback. The intervention protocol involved a breathing scenario, a progressive muscle relaxation scenario, a body scan meditation scenario, and a guided imagery scenario. The robot interacted with the child with both verbal and nonverbal cues using several sensors, such as cameras, microphones, eye color changes, and body movements. The results indicated that the patient acquired relaxation skills, experienced some positive effects on self-regulation, and showed a decrease in the duration of her disruptive behaviors upon completing the relaxation training.

Kumazaki et al. (2021) developed a communication training system using a teleoperated robot intending to test whether this system can maintain motivation and improve metacognitive communication skills. In total, twenty individuals with ASD participated in the study. It was revealed that there were significant improvements in describing their thoughts to others (self-explanation) as well as listening to the thoughts or feelings of others.

Costa et al. (2018) evaluated the usefulness of QTrobot, a socially assistive robot to improve children's attention, imitation, repetitive and stereotyped behaviors. Fifteen children diagnosed with ASD, aged from 4 to 14 years participated in this study. Statistical analyses revealed that children were more able to regulate repetitive and stereotyped behaviors.

Korneder et al. (2021) used a multiple baseline design to investigate the acquisition of the intraverbal skill of answering wh-questions using an ABA-based robot-mediated intervention. Asking and answering wh- questions involves various metacognitive language skills. It requires the ability to understand questions, the information provided as well as the social context. Three 5-years old participants with ASD took part in the study. The results demonstrated that children with a diagnosis of ASD can acquire intraverbal skills such as wh-question answering through instruction from a robot.

The ability to trust and recognize deception is significantly related to metacognitive abilities including recognition and self-regulation. Zhang et al. (2019) used the social robot Nao to teach children how to manipulate their false beliefs through distrust and deception games. Twenty children between the ages of 5 to 8 years participated in the game intending to find out the hidden tokens. In the distrust task, the robot tried to misinform the children about the location of the token, while in the deception task children were asked to hide the token and deceive the robot. Results showed that children with ASD could learn how to adjust their distrust and deception behaviors.

Costescu, Vanderborcht and David (2017) investigated whether a social robot could train children with ASD in adaptive behaviors and strategies, to regulate the intensity of their negative emotions and modify their dysfunctional beliefs. Twenty-seven children aged 6–12 years were randomly assigned to either robot-enhanced therapy (12 children) or treatment as usual (15 children). Through fifteen different situations which may trigger anger or sadness, they were taught to distinguish emotions and use appropriate social answers and strategies. In the last sessions, children were shown some adaptive strategies that could be practiced in different social situations that were associated with negative emotions. They were also introduced to some techniques for anger management and self-control (e.g. breathing exercises). The findings revealed that robot-enhanced therapy could enhance self-regulation skills and behavioral flexibility.

Yun et al. (2017) designed a robot system to assist a behavioral intervention program for 15 children with ASD (between 4 and 7 years old). A randomized controlled trial of eight sessions was conducted with 15 children with ASD randomly assigned to the treatment group (robot-assisted) or control group (human-assisted). The results showed that in the intervention group, the participants could better manage general behavioral and emotional symptoms

including depression, anxiety, social withdrawal, and internalizing problems indicating better self-regulation skills.

3.2 Coding

Programming or coding refers to the application and development process with various sets of commands to solve problems, enable human-computer interaction, and perform specific tasks via computers. Teaching coding at an early age improves children's skills, e.g., analytical thinking, creativity, and problem-solving, and has also benefits for children such as producing problem-based solutions and providing collaboration skills. Basic algorithm knowledge and skills are taught to early-age students through block-based coding platforms. Students can utilize platforms such as Scratch, Code.org, Kodable, The Foos, Tynker. Coding may have an essential place in the education and employment of students with ASD since individuals with ASD are strong in visual processes, focus on details, and have excellent skills in ensuring continuity in a subject (Özgüç and Altin, 2022; Knight et al., 2019).

Knight et al. (2019) evaluated whether teaching digital block-based coding of robots to three high school students with ASD and challenging behavior would improve metacognitive skills as follow: planning, the ability to generalize new skills to novel situations, identifying errors and correct them, to evaluate the progress of strategies implementation. In this study three high school students aged between 16 to 18 years old with ASD took part. The results showed that students improved the aforementioned meta-abilities. They could better analyze problems, retest ideas, and try new ideas. In addition, challenging behaviors were diminished as they were more able to inhibit inappropriate behaviors developing new socially appropriate behaviors. Participants in this study were motivated and excited about being active, learning and manipulating a digital interface to control smart robots.

Knight, Wright and DeFreese (2019) piloted a Model Lead Test intervention to teach coding of robotics to an elementary school-aged student (10 years old) with ASD and severe problem behavior. During Modeling, explicit and systematic instruction was provided allowing students to observe and practice the skill repeatedly before being asked to independently complete the task. The results showed that the student was able not only to code the robot but also generalize his coding skills to untaught codes. He seemed to understand the concept behind coding. The participant also could evaluate the effects of his skills by placing the robot on the tracks and codes he created. Promoting his interests and strengths, the student was more able to regulate challenging behaviors.

Gribble et al. (2017) investigated how engagement in computer science, using a block-based programming environment modified from Scratch, impacts the behavioral flexibility of a student with ASD. It was found that coding intervention helped the participant to be more able to interact with his peers and teacher. He was also open to sharing his work with his peers asking for help.

Özgüç and Altin (2022) conducted a case study to teach coding to a 10-year-old boy with autism spectrum disorder. Researchers used the Code.org platform to teach coding. The results showed that coding improved problem-solving skills as the student gained the ability to develop a solution for a given problem by asking questions on how to get an object to the target in the shortest and fastest way at the end of the application. The student also showed progress in self-management skills identifying mistakes, and trying again when he had incorrect code after dragging and dropping the codes. Also, thinking about a design for a long time and reviewing it again. The student could make plans and express his opinion.

Albo-Canals et al. (2018) used a programmable toy robot (KIBO) to teach coding and sequencing to twelve participants with severe ASD ranging from 6 to 14 years old. Most of the participants were more able to remain motivated, increased their flexibility to interact with adults and they managed to manipulate the KIBO appropriately.

Munoz et al. (2018) developed and evaluated a workshop involving programming digital games using the Scratch environment. Seven adolescents diagnosed with Asperger's syndrome between 11 and 15 years old participated in this study. Participants were found to be more able to organize, systematize and process information. The workshop also permitted the promotion of metacognitive skills such as abstraction and logical thinking.

Kaboski et al. (2015) conducted an intervention in which adolescents with ASD and their typically developing peers learned to program a humanoid robot (Nao) while working collaboratively in pairs. Participants were eight individuals with ASD and eight typically developing peers (ages 12–17 years) recruited in this study. The intervention lasted 3 h/day for five consecutive days. The results of this study provided preliminary support for the effectiveness of robotics in helping self-regulation of social anxiety in highly verbal adolescents with ASD and increasing the ability to gain new knowledge of robotics. Programming the robot to carry out behaviors or conversations made them more aware of the function and effectiveness behind the gestures and words used in natural interactions. For example, to program a robot to tell a joke, participants in this study had to think about the pragmatics of language, eye contact, gestures, when to pause, and when to follow up with a question.

3.3 Virtual Reality

Virtual reality (VR) is a simulation of the real world, or a completely new world based on computer graphics, providing experiences that help people to acquire new skills and transfer them to their everyday life, expand their understanding of concepts and improve their performance in various tasks (Bellani et al., 2011). Virtual reality includes a wide range of technologies such as virtual worlds, massive multiplayer online role-playing games, static VR, and head-mounted displays. VR systems are structured and adjustable environments that create a sense of presence as a consequence of immersion and interaction. Virtual reality is now recognized as a powerful tool for intervention in ASD (Bellani et al., 2011). According to Parsons & Cobb (2011), VR could be particularly helpful for those with ASD for the following reasons: Behaviors and responses can be practiced and built upon in a targeted context that is similar to the real, offering more opportunities for generalization of skills and knowledge. VR environments can be individualized. They are characterized by controllable stimuli, allowing the safe alteration of the environment. Stimuli can be introduced or removed in a regulated way according to the attentional difficulties that the users may face. Interactions can take many forms and do not necessitate face-to-face communication. Users can communicate with their avatars and have active control over their participation. The level and number of non-verbal and verbal features of communication can be controlled (Savickaite, McDonnell & Simmons, 2022; Parsons & Cobb, 2011).

As regards metacognitive skills training, Wang and Reid (2013) examined the efficacy of virtual reality cognitive rehabilitation on contextual processing and cognitive flexibility in a sample of four children with ASD. Contextual processing requires the ability to estimate an object's meaning or significance in a multi-object context. Contextual processing presupposes several meta-abilities such as flexibility to changing contexts, top-down regulation of attention, and the ability to identify qualities and relationships between the objects, to categorize. The

results showed that all children demonstrated significant improvement in contextual processing and cognitive flexibility.

Cox et al. (2017) investigated whether virtual reality driving simulation training could improve metacognitive abilities such as self-monitoring, attentional flexibility, inhibition control, and planning abilities which are essential for safe driving performance. Fifty-one novice ASD drivers (mean age 17.96 years) were randomized to routine training or Virtual Reality Driving Simulation Training (8–12 sessions). The results revealed that virtual reality significantly improved these metacognitive abilities.

Ke, Moon and Sokolikj (2020) explored the effectiveness of a VR-based training environment on metacognitive social skills including flexible thinking and communication, switching between solutions, tasks, or perspectives according to the changing contexts, emergent plans, or rule changes. Participants were also trained in recognition of a conflict between one's and another's perspective, self-identity expression, explaining one's own perspectives and preferences, and identifying commonness with others. Seven 10–14 years old children with ASD participated in this program for 20 hours on average. The 3D desktop VR-based learning environment encompassed a variety of interaction tasks situated in VR-simulated everyday social scenes. The findings as well as parents' and teachers' reports revealed that VR improved the metacognitive social skills of participants with a long-term positive impact.

Maskey et al. (2014) developed and evaluated a novel intervention combining cognitive behavior therapy (CBT) with graduated exposure in a virtual reality environment (VRE). Nine verbally fluent boys with ASD (aged 7 to 13 years) and specific phobias took part in the study. The results showed that CBT with VRE was more effective in developing self-regulation skills. Specifically, eight of nine children were able to cope with their phobia. Four of the subjects completely overcame their phobia. After the intervention, participants were more independent in real life and could manage anxiety effectively by using the techniques they learned in the VR environment.

Didehbani et al. (2016) explored the impact of a 10-session VR training program on several socio-emotional metacognitive skills. Thirty subjects with high functioning autism between the ages of 7–16 diagnosed with ASD completed 10, 1-h sessions across 5 weeks. The program aimed to train participants to recognize behaviors and their causes, make independent social choices, recognize potentially harmful situations, and transfer knowledge from one domain to another. Indeed, the participants showed significant improvement in their metacognitive skills, especially in the ability of analogical reasoning.

Ji et al. (2022) conducted a randomized controlled experiment to evaluate and compare the effects of virtual training (n=34) on inhibition, working memory, and adaptability of children with autism spectrum disorder (ASD). It was chosen a Xbox360 football game, which provided virtual training to practice reaction speed. Children needed to use various tactics and techniques in the game to hit the ball into the opponent's goal. The results showed that virtual reality training improved the ability to control automatic responses, create responses by using attention and judgment, and flexibly inhibit cognitive interference.

Clinical hypnosis can be utilized to develop self-regulation habits and adaptive behaviors for people with ASD (Drigas, Mitsea & Skianis, 2021). Austin, Abbott & Carbis (2008) conducted a feasibility study to uncover the strengths and the weaknesses of virtual reality hypnosis as an intervention tool in two boys 14 and 15 years old with severe autism. The results showed that this technique improves relaxation skills in real life.

3.4. Mobile Technology

Mobile Technology-Based Interventions support new paradigms for rehabilitation, assistance and evaluation. Mobile technologies are easily portable and low-cost and are rapidly advancing in terms of technology, size, functionality, and real-time applications. Mobiles collect data from integrated sensors. Another useful characteristic of mobile technology is the provision of remote control by the parent devices. As communication is a key issue in ASD, mobiles can provide vocal output in different forms (i.e. text to speech). These technologies can be used in a variety of ways. The use of mobile digital technologies to improve health and particularly psychological health and behavioral self-management in neurodevelopmental disorders such as ASD is now becoming a new trend (Koumpouros & Kafazis, 2019; Fage et al., 2018).

Bouck et al. (2014) determined whether an iPad app would be effective for training self-monitoring skills for food preparation in a sample of three secondary students with ASD. The self-monitoring consisted of checkboxes in which students checked via their fingers on the iPad. The results showed that students with ASD could better monitor their behavior. In addition, along with monitoring skills, students expressed positive emotions about their ability to be more independent.

Crutchfield et al. (2015) examined the efficacy of a self-monitoring application to reduce stereotypic behavior in two adolescents with autism. The Android application was designed to provide scheduled prompts for participants to self-evaluate and self-monitor targeted behaviors. It was revealed that both students could better regulate complex stereotypic behaviors.

Fage et al. (2018) evaluated whether the use of mobile applications could help people with autism develop adaptive skills. A total of 50 students aged from 12 to 17 years were recruited. Twenty-nine students with ASD were divided into the experimental (n=14) and the control group (n=15). The experimental group used the assistive application 15 minutes per day for at least 5 days per week for three months. The main results showed that the experimental group improved adaptive behavior and their social response in school settings.

Stathopoulou et al. (2020) evaluated the effectiveness of mobile applications in children with Autism via digital social stories. In the study, thirty high-functioning autistic children were given an Android tablet with interactive social scenarios through which they could enhance their ability to cope with social difficulties. The results revealed that participants improved their ability to self-regulate and adapt to stressful social situations.

Xin, Sheppard and Brown (2017) investigated the effect of utilizing an iPad for students with ASD (10-12 years old) on self-monitoring their behaviors in class. Four students with ASD were taught on-task behaviors by watching a self-modeled video saved in the application "Choiceworks" on their iPads and collected data on their behaviors. This program was developed to help learners to complete daily routines and understand and control their self. Results showed that the participants improved their self-monitoring and self-control skills.

3.5 Digital Games

Digital game-based therapeutic interventions represent a promising area for research in ASD. Digital games are ruled entertainment activities that involve interaction with a user interface to produce visual feedback on a video device. This area includes serious games whose main objective is not just entertainment but the learning or practice of new skills (Valencia et al., 2019; Jiménez-Muñoz et al., 2021). The use of digital games in general and special education has various positive effects improving intrinsic motivation, learning by doing, social

learning through interaction, situated authentic “real” learning, personalized learning and learning from failure. Digital games are also introduced as a promising learning tool for intellectual disabilities and sensory impairments. Research has also shown that digital games can effectively improve new skills for people with ASD (Papanastasiou et al., 2017).

Wijnhoven et al. (2020) conducted a randomized controlled trial investigating the effect of a serious game known as *Mindlight* on helping children with an ASD to develop self-regulation skills to reduce anxiety. In total, 109 children 8–16 years old with an ASD and (sub)clinical anxiety symptoms were randomly assigned to the experimental (N = 53) or the control (N = 56) condition. Children in the experimental condition played *Mindlight*, whereas children in the control condition played a commercial game (*Triple Town*) for 1 h per week, for six consecutive weeks. *Mindlight* is a computer-based intervention that uses visual aids and structured sensory information to train self-regulation skills. *Mindlight* is an experiential game, meaning that it makes children aware of their physical and emotional feelings and teaches them ways to alter these feelings. The experimental group had greater improvements in parent-rated anxiety symptoms than the control group at 3-months follow-up.

Anderson-Hanley, Tureck and Schneiderman (2011) explored the effects of exergaming on repetitive behaviors and cognition in people with ASD. Exergaming combines physical and mental exercise simultaneously by linking physical activity movements to the videogame. Twenty-two young persons with ASD were participants in two pilot studies in which change in behavioral and cognitive performances increased after exergaming. Specifically, participants improved cognitive control as well as their ability to inhibit inappropriate behaviors.

Edwards et al. (2017) conducted a pilot study to investigate whether playing sports active video games can increase the actual and perceived object control skills of 11 children with ASD aged 6–10 years in comparison to 19 typically developed children of a similar age. It was revealed that video games may influence perceptions of skill ability in children with ASD, which could lead to positive active behavior.

Ferguson, Gillis and Sevlever (2013) investigated whether a 10-week group intervention using video games could teach meta-behavioral skills to 8 children with ASD aged between 7 to 11 years old. The intervention targeted sportsmanship skills such as giving compliments, taking turns, and making positive comments. The aforementioned skills have a metacognitive background. For instance, the individual should apply self-regulation strategies to make eye contact with others, regulate the tone of their voice to be friendly, wait patiently for their turn, and to ask nicely for the remote. Following clinicians' modeling of the target behaviors, participants played *Wii* baseball and received feedback if target skills were not observed. There was clear evidence of increased skill acquisition for the target behaviors.

Kirst et al. (2022) examined whether a 6-week serious game intervention could help eighty-two children with ASD (aged 5–10 years) to improve: their awareness and differentiation of their own emotions, awareness of others' emotional states, flexibility to reactions toward other people's emotions, emotional self-regulation abilities. The results showed an improvement in emotional awareness and emotional regulation.

Merena et al. (2019) conducted a feasibility study to compare the amount of social flexibility performed during a full-body interaction videogame versus a free-play activity in children with ASD. A total of 15 children (ages 4–6) took part in four sessions with two sections: playing with the videogame *Pico's Adventure* and free playtime. The videogame is based on the story of *Pico*, a friendly alien. The children had to be friends with *Pico* helping him on different missions. Each mission was designed to address a targeted behavior. The system inserted the image of the children within the game allowing participants' self-

observation aiming to help them understand that their actions have an impact. Results showed that the videogame elicited more flexible and self-regulatory behaviors.

Conclusions

Concluding we underline the role of metacognition in its various forms and applications [69-83] in parallel use and exploitation, with ICTs, Mobiles [84-86], Games, VR, AI [96, 97] and other digital technologies applications [87-95], in all the domains of education, and especially in Autism.

More specifically this review study examined the role of metacognition in Autism as well as the role of assistive technologies in metacognitive skills training. It was revealed that people with ASD face significant metacognitive deficits, especially in domains of self-awareness, self-observation, self-regulation and adaptation. However, digital technologies were found to be promising tools for metacognitive skills training. Evidence-based research revealed that digital technologies can help people with ASD acquire a repertoire of metacognitive skills. Specifically, this review found the following improvements according to the 8 Pillars Model of Metacognition:

Meta-thinking: *better access to knowledge and information, ability to gain new knowledge, to organize, systematize and process information, perception of skills ability, acquisition of higher abilities such as analogical reasoning and logical thinking, develop a solution for a given problem by asking questions, a better understanding of concepts, improved ability to think about knowledge*

Self-awareness: *Better awareness of themselves, of their physical and emotional feelings, self-explanation, evaluation of their performance, evaluation of the implemented strategies, identification of the relationships between objects and their context, more positive self-identity expression*

Self-observation: *better observation of their behavior, monitoring of the occurrence and nonoccurrence of targeted behaviors, monitoring of the implemented strategies during problem-solving tasks*

Self-regulation: *Better self-regulation of repetitive and compulsive behaviors, improved inhibition of inappropriate behaviors developing new socially appropriate behaviors, better ability to cope with social difficulties such as social anxiety and phobias, better ability to regulate even the tone of their voice*

Adaptation: *Improvements in attentional flexibility, flexibility in thinking, switching between solutions, tasks & perspectives, and improved adaptation of their behavioral and affective response to socio-environmental context, better dealing with unexpected difficulties (i.e. social), changing goals based on the context, better generalization of skills, better interaction with peers, flexibly inhibit cognitive interference*

Recognition: *Better awareness of their own as well as others' mental states, better recognition of others' intentions, false beliefs, better perception in multi-object context, identification of commonness with others, identification of mistakes, deceptions, a better understanding of the consequences of their actions*

Discrimination: *better filtering of stimuli and information, improved ability to identify which objects are incongruent according to the established context, better ability to categorize, recognize potentially harmful situations, to judge*

Awareness/Positive alertness: *Improved ability to keep themselves in a state of positive relaxation, to channel their fears into more positive behaviors, better ability to remain*

motivated and patient, to have positive attitudes about their ability to be independent, better ability to use metacognitive strategies to their real life.

We conclude that teachers in special education should make use of metacognitive skills training with the assistance of digital technologies to facilitate the inclusion of students with ASD in all areas of human life. Digital technologies are close to the interests and strengths of people with ASD. Metacognitive skills training via digital technologies in the school years can prepare youth with ASD to develop the skills needed by major tech companies, which have already begun targeted hires of individuals on the spectrum because of their strengths, not only in STEM subjects but also in desirable qualities employers look for, such as careful attention to detail, commitment to high quality and accuracy, out of the box thinking, conscientiousness and diligence, and ability to work independently (Knight et al., 2019). By teaching metacognitive skills to students with ASD during primary and secondary school (or earlier), they have more opportunities to transfer to post-secondary aspects of their lives.

This study is one of the few studies that deal with autism as a disorder of metacognition and gives pointers for future experimental research regarding metacognitive intervention strategies with the assistance of technologies.

References

- [1] Albo-Canals, J., Martelo, A. B., Relkin, E., Hannon, D., Heerink, M., Heinemann, M., ... & Bers, M. U. (2018). A pilot study of the KIBO robot in children with severe ASD. *International Journal of Social Robotics*, 10(3), 371-383.
- [2] Aljadeff-Abergel, E., Schenk, Y., Walmsley, C., Peterson, S. M., Frieder, J. E., & Acker, N. (2015). The effectiveness of self-management interventions for children with autism—A literature review. *Research in Autism Spectrum Disorders*, 18, 34-50.
- [3] Amran, M. S., Zain, S. M., Jamaludin, K. A., & Surat, S. (2021). Thinking About Behavior: Perspective on Meta-Behavior in Education. *Frontiers in psychology*, 12.
- [4] Anderson-Hanley, C., Tureck, K., & Schneiderman, R. L. (2011). Autism and exergaming: effects on repetitive behaviors and cognition. *Psychology research and behavior management*, 4, 129.
- [5] Austin, D. W., Abbott, J. A. M., & Carbis, C. (2008). The use of virtual reality hypnosis with two cases of autism spectrum disorder: a feasibility study. *Contemporary hypnosis*, 25(2), 102-109.
- [6] Bakola, L., & Drigas, A. (2020). Technological Development Process of Emotional Intelligence as a Therapeutic Recovery Implement in Children with ADHD and ASD Comorbidity.
- [7] Bellani, M., Fornasari, L., Chittaro, L., & Brambilla, P. (2011). Virtual reality in autism: state of the art. *Epidemiology and psychiatric sciences*, 20(3), 235-238.
- [8] Brown, A. L. (1978). Knowing when, where, and how to remember; a problem of metacognition. *Advances in instructional psychology*, 1.
- [9] Bouck, E. C., Savage, M., Meyer, N. K., Taber-Doughty, T., & Hunley, M. (2014). High-tech or low-tech? Comparing self-monitoring systems to increase task independence for students with autism. *Focus on Autism and Other Developmental Disabilities*, 29(3), 156-167.
- [10] Cox, D. J., Brown, T., Ross, V., Moncrief, M., Schmitt, R., Gaffney, G., & Reeve, R. (2017). Can youth with autism spectrum disorder use virtual reality driving simulation training to evaluate and improve driving performance? An exploratory study. *Journal of Autism and Developmental Disorders*, 47(8), 2544-2555.
- [11] Costa, A. P., Charpiot, L., Lera, F. R., Ziafati, P., Nazarikhorrām, A., Van Der Torre,

- L., & Steffgen, G. (2018, August). More attention and less repetitive and stereotyped behaviors using a robot with children with autism. In *2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)* (pp. 534-539). IEEE.
- [12] Costescu, C. A., Vanderborcht, B., & David, D. O. (2017). robot-enhanced cbt for dysfunctional emotions in social situations for children with asd. *Journal of Evidence-Based Psychotherapies*, 17(2).
- [13] Crutchfield, S. A., Mason, R. A., Chambers, A., Wills, H. P., & Mason, B. A. (2015). Use of a self-monitoring application to reduce stereotypic behavior in adolescents with autism: A preliminary investigation of I-Connect. *Journal of Autism and Developmental Disorders*, 45(5), 1146-1155.
- [14] Didehbani, N., Allen, T., Kandalaf, M., Krawczyk, D., & Chapman, S. (2016). Virtual reality social cognition training for children with high functioning autism. *Computers in human behavior*, 62, 703-711.
- [15] Drigas, A., Mitsea, E., & Skianis, C. (2021). The Role of Clinical Hypnosis and VR in Special Education. *International Journal of Recent Contributions from Engineering Science & IT (iJES)*, 9(4), 4-17.
- [16] Drigas, A., & Mitsea, E. (2021). 8 Pillars X 8 Layers Model of Metacognition: Educational Strategies, Exercises & Trainings. *International Journal of Online & Biomedical Engineering*, 17(8).
- [17] Drigas, A., & Mitsea, E. (2020). The 8 pillars of metacognition. *International Journal of Emerging Technologies in Learning (iJET)*, 15(21), 162-178.
- [18] Drigas, A. S., & Pappas, M. A. (2017). The consciousness-intelligence-knowledge pyramid: an 8x8 layer model. *International Journal of Recent Contributions from Engineering, Science & IT (iJES)*, 5(3), 14-25.
- [19] Drigas, A. S., & Papoutsis, C. (2018). A new layered model on emotional intelligence. *Behavioral Sciences*, 8(5), 45.
- [20] Drigas, A. S., & Ioannidou, R. E. (2013). Special Education and ICTs. *International Journal of Emerging Technologies in Learning*, 8(2). Doi.org/103991/Ijet.v8i2.2514
- [21] Drigas, A. S., Koukianakis, L. G., & Papagerasimou, Y. V. (2005). A system for e-inclusion for individuals with sight disabilities. *Wseas transactions on circuits and systems*, 4(11), 1776-1780.
- [22] Edwards, J., Jeffrey, S., May, T., Rinehart, N. J., & Barnett, L. M. (2017). Does playing a sports active video game improve object control skills of children with autism spectrum disorder?. *Journal of sport and health science*, 6(1), 17-24.
- [23] Fage, C., Consel, C. Y., Balland, E., Etchegoyhen, K., Amestoy, A., Bouvard, M., & Sauzéon, H. (2018). Tablet apps to support first school inclusion of children with autism spectrum disorders (ASD) in mainstream classrooms: A pilot study. *Frontiers in psychology*, 2020.
- [24] Ferguson, B. R., Gillis, J. M., & Sevlever, M. (2013). A brief group intervention using video games to teach sportsmanship skills to children with autism spectrum disorders. *Child & Family Behavior Therapy*, 35(4), 293-306.
- [25] Fleur, D. S., Bredeweg, B., & van den Bos, W. (2021). Metacognition: ideas and insights from neuro-and educational sciences. *npj Science of Learning*, 6(1), 1-11.
- [26] Frith, U., & Happé, F. (1999). Theory of mind and self-consciousness: What is it like to be autistic?. *Mind & language*, 14(1), 82-89
- [27] Gardner, H. E. (2011). *Frames of mind: The theory of multiple intelligences*. Hachette UK.

- [28] Gomez, C. R., & Baird, S. (2005). Identifying early indicators for autism in self-regulation difficulties. *Focus on autism and other developmental disabilities*, 20(2), 106-116.
- [29] Gribble, J., Hansen, A., Harlow, D., & Franklin, D. (2017, June). Cracking the code: the impact of computer coding on the interactions of a child with autism. In *Proceedings of the 2017 Conference on Interaction Design and Children* (pp. 445-450).
- [30] Ji, C., Yang, J., Lin, L., & Chen, S. (2022). Executive Function Improvement for Children with Autism Spectrum Disorder: A Comparative Study between Virtual Training and Physical Exercise Methods. *Children*, 9(4), 507.
- [31] Jiménez-Muñoz, L., Peñuelas-Calvo, I., Calvo-Rivera, P., Díaz-Oliván, I., Moreno, M., Baca-García, E., & Porras-Segovia, A. (2021). Video Games for the Treatment of Autism Spectrum Disorder: A Systematic Review. *Journal of Autism and Developmental Disorders*, 1-20.
- [32] Kaboski, J. R., Diehl, J. J., Beriont, J., Crowell, C. R., Villano, M., Wier, K., & Tang, K. (2015). Brief report: A pilot summer robotics camp to reduce social anxiety and improve social/vocational skills in adolescents with ASD. *Journal of autism and developmental disorders*, 45(12), 3862-3869.
- [33] Ke, F., Moon, J., & Sokolikj, Z. (2020). Virtual reality-based social skills training for children with autism spectrum disorder. *Journal of Special Education Technology*, 0162643420945603.
- [34] Kirst, S., Diehm, R., Bögl, K., Wilde-Etzold, S., Bach, C., Noterdaeme, M., & Dziobek, I. (2022). Fostering socio-emotional competencies in children on the autism spectrum using a parent-assisted serious game: A multicenter randomized controlled trial. *Behaviour Research and Therapy*, 152, 104068.
- [35] Knight, V. F., Wright, J., Wilson, K., & Hooper, A. (2019). Teaching digital, block-based coding of robots to high school students with autism spectrum disorder and challenging behavior. *Journal of Autism and Developmental Disorders*, 49(8), 3113-3126.
- [36] Knight, V. F., Wright, J., & DeFreese, A. (2019). Teaching robotics coding to a student with ASD and severe problem behavior. *Journal of autism and developmental disorders*, 49(6), 2632-2636.
- [37] Korneder, J., Louie, W. Y. G., Pawluk, C. M., Abbas, I., Brys, M., & Rooney, F. (2021). Robot-mediated interventions for teaching children with ASD: a new intraverbal skill. *Assistive Technology*, 1-10.
- [38] Koumpouros, Y., & Kafazis, T. (2019). Wearables and mobile technologies in Autism Spectrum Disorder interventions: A systematic literature review. *Research in Autism Spectrum Disorders*, 66, 101405.
- [39] Kumazaki, H., Muramatsu, T., Yoshikawa, Y., Haraguchi, H., Sono, T., Matsumoto, Y., ... & Mimura, M. (2021). Enhancing communication skills of individuals with autism spectrum disorders while maintaining social distancing using two tele-operated robots. *Frontiers in psychiatry*, 1641.
- [40] Kushki, A., Drumm, E., Pla Mobarak, M., Tanel, N., Dupuis, A., Chau, T., & Anagnostou, E. (2013). Investigating the autonomic nervous system response to anxiety in children with autism spectrum disorders. *PLoS one*, 8(4), e59730.
- [41] Lombardo, M. V., Barnes, J. L., Wheelwright, S. J., & Baron-Cohen, S. (2007). Self-referential cognition and empathy in autism. *PloS one*, 2(9), e883.
- [42] Magnuson, K. M., & Constantino, J. N. (2011). Characterization of depression in children with autism spectrum disorders. *Journal of developmental and behavioral pediatrics: JDBP*, 32(4), 332.

- [43] Mairena, M. Á., Mora-Guiard, J., Malinverni, L., Padillo, V., Valero, L., Hervás, A., & Pares, N. (2019). A full-body interactive videogame used as a tool to foster social initiation conducts in children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, 67, 101438.
- [44] Masi, A., DeMayo, M. M., Glozier, N., & Guastella, A. J. (2017). An overview of autism spectrum disorder, heterogeneity and treatment options. *Neuroscience bulletin*, 33(2), 183-193.
- [45] Maskey, M., Lowry, J., Rodgers, J., McConachie, H., & Parr, J. R. (2014). Reducing specific phobia/fear in young people with autism spectrum disorders (ASDs) through a virtual reality environment intervention. *PloS one*, 9(7), e100374.
- [46] Mitsea, E., & Drigas, A. (2019). A journey into the metacognitive learning strategies. *International Journal of Online & Biomedical Engineering*, 15(14).
- [47] Mitsea, E., Drigas, A., & Mantas, P. (2021). Soft Skills & Metacognition as Inclusion Amplifiers in the 21 st Century. *International Journal of Online & Biomedical Engineering*, 17(4).
- [48] Mitsea, E., Lytra, N., Akrivopoulou, A., & Drigas, A. (2020). Metacognition, Mindfulness and Robots for Autism Inclusion. *Int. J. Recent Contributions Eng. Sci. IT*, 8(2), 4-20.
- [49] Mostert-Kerckhoffs, M. A., Staal, W. G., Houben, R. H., & de Jonge, M. V. (2015). Stop and change: Inhibition and flexibility skills are related to repetitive behavior in children and young adults with autism spectrum disorders. *Journal of autism and developmental disorders*, 45(10), 3148-3158.
- [50] Munoz, R., Villarroel, R., Barcelos, T. S., Riquelme, F., Quezada, Á., & Bustos-Valenzuela, P. (2018). Developing computational thinking skills in adolescents with autism spectrum disorder through digital game programming. *IEEE Access*, 6, 63880-63889.
- [51] Nelson, T. O., & Narens, L. (1994). Why investigate metacognition. *Metacognition: Knowing about knowing*, 13, 1-25.
- [52] Nelson, T. O., & Leonesio, R. J. (1988). Allocation of self-paced study time and the "labor-in-vain effect.". *Journal of experimental psychology: Learning, Memory, and Cognition*, 14(4), 676.
- [53] Özgüç, c. s., & Altin, d. Teaching Block-Based Coding to a Student with Autism Spectrum Disorder. *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Özel Eğitim Dergisi*, 1-30.
- [54] Parsons, S., & Cobb, S. (2011). State-of-the-art of virtual reality technologies for children on the autism spectrum. *European Journal of Special Needs Education*, 26(3), 355-366.
- [55] Nikopoulou, V. A., Holeva, V., Tatsiopoulou, P., Kaburlasos, V. G., & Evangelidou, A. E. (2022). A Pediatric Patient With Autism Spectrum Disorder and Comorbid Compulsive Behaviors Treated With Robot-Assisted Relaxation: A Case Report. *Cureus*, 14(2).
- [56] Papanastasiou, G., Drigas, A., Skianis, C., & Lytras, M. D. (2017). Serious games in K-12 education: Benefits and impacts on students with attention, memory and developmental disabilities. *Program*.
- [57] Rhodes, M. G. (2019). Metacognition. *Teaching of Psychology*, 46(2), 168-175.
- [58] Scassellati, B., Admoni, H., & Matarić, M. (2012). Robots for use in autism research. *Annual review of biomedical engineering*, 14, 275-294.
- [59] Savickaite, S., McDonnell, N., & Simmons, D. (2022). Defining Virtual Reality (VR). Scoping Literature Review on VR Applications in Autism Research.
- [60] Stathopoulou, A., Loukeris, D., Karabatzaki, Z., Politi, E., Salapata, Y., & Drigas, A.

- (2020). Evaluation of mobile apps effectiveness in children with autism social training via digital social stories.
- [61] Valencia, K., Rusu, C., Quiñones, D., & Jamet, E. (2019). The impact of technology on people with autism spectrum disorder: a systematic literature review. *Sensors*, 19(20), 4485.
- [62] Wang, M., & Reid, D. (2013). Using the virtual reality-cognitive rehabilitation approach to improve contextual processing in children with autism. *The Scientific World Journal*, 2013.
- [63] White, S. W., Oswald, D., Ollendick, T., & Scahill, L. (2009). Anxiety in children and adolescents with autism spectrum disorders. *Clinical psychology review*, 29(3), 216-229.
- [64] Wijnhoven, L. A., Creemers, D. H., Vermulst, A. A., Lindauer, R. J., Otten, R., Engels, R. C., & Granic, I. (2020). Effects of the video game ‘Mindlight’ on anxiety of children with an autism spectrum disorder: A randomized controlled trial. *Journal of Behavior Therapy and Experimental Psychiatry*, 68, 101548.
- [65] Williams, D., & Happé, F. (2010). Representing intentions in self and other: Studies of autism and typical development. *Developmental science*, 13(2), 307-319.
- [66] Xin, J. F., Sheppard, M. E., & Brown, M. (2017). Brief report: Using iPads for self-monitoring of students with autism. *Journal of autism and Developmental Disorders*, 47(5), 1559-1567.
- [67] Yun, S. S., Choi, J., Park, S. K., Bong, G. Y., & Yoo, H. (2017). Social skills training for children with autism spectrum disorder using a robotic behavioral intervention system. *Autism Research*, 10(7), 1306-1323.
- [68] Zhang, Y., Song, W., Tan, Z., Zhu, H., Wang, Y., Lam, C. M., ... & Yi, L. (2019). Could social robots facilitate children with autism spectrum disorders in learning distrust and deception?. *Computers in Human Behavior*, 98, 140-149.
- [69] Drigas, A., & Mitsea, E. (2021). Neuro-Linguistic Programming & VR via the 8 Pillars of Metacognition X 8 Layers of Consciousness X 8 Intelligences. *Technium Social Sciences Journal*, 26, 159-176.
- [70] Mitsea, E., Drigas, A., & Skianis, C. (2022). ICTs and Speed Learning in Special Education: High-Consciousness Training Strategies for High-Capacity Learners through Metacognition Lens. *Technium Social Sciences Journal*, 27, 230-252.
- [71] Drigas, A., Mitsea, E., & Skianis, C. (2022). Neuro-Linguistic Programming, Positive Psychology & VR in Special Education. *Scientific Electronic Archives*, 15(1).
- [72] Drigas, A., Mitsea, E., & Skianis, C. (2022). Clinical Hypnosis & VR, Subconscious Restructuring- Brain Rewiring & the Entanglement with the 8 Pillars of Metacognition X 8 Layers of Consciousness X 8 Intelligences. *International Journal of Online and Biomedical Engineering (iJOE)*, 18(01), pp. 78–95. <https://doi.org/10.3991/ijoe.v18i01.26859>
- [73] Drigas, A., & Mitsea, E. (2022). Conscious Breathing: a Powerful Tool for Physical & Neuropsychological Regulation. The role of Mobile Apps. *Technium Social Sciences Journal*, 28, 135-158.
- [74] Kontostavlou, E. Z., and Drigas, A. (2021). How metacognition supports giftedness in leadership: a review of contemporary literature. *Int. J. Adv. Corp. Learn.* 14, 4–16. doi: 10.3991/ijac.v14i2.23237
- [75] Kontostavlou, E.Z.; Drigas, A. Executive functions training and giftedness. *Retos* 2022, 43, 1005–1014.
- [76] Drigas, A., & L. Bakola: The 8x8 Layer Model Consciousness-Intelligence-Knowledge Pyramid, and the Platonic Perspectives. *International Journal of Recent Contributions from Engineering, Science & IT (iJES)*, 9 (2), pp. 57–72, (2021),

<https://doi.org/10.3991/ijes.v9i2.22497>.

- [77] Drigas, A., & Sideraki, A. (2021). Emotional Intelligence in Autism . *Technium Social Sciences Journal*, 26(1), 80–92. <https://doi.org/10.47577/tssj.v26i1.5178>
- [78] Drigas, A., & Papoutsi, C. (2021). Nine layer pyramid model questionnaire for emotional intelligence. *International Journal of Online & Biomedical Engineering*, 17(7). <https://doi.org/10.3991/ijoe.v17i07.22765>
- [79] Drigas, A., & Papoutsi, C. (2015). Empathy, special education and ICTs. *International Journal of Recent Contributions from Engineering, Science & IT (iJES)*, 3(4), 37-42. doi: 10.3991/ijes.v3i4.5192
- [80] Papoutsi, C., Chaidi, I., Drigas, A., Skianis, C., & Karagiannidis, C. (2022). Emotional Intelligence & ICTs for Women and Equality. *Technium Social Sciences Journal*, 27, 253-268.
- [81] Zavitsanou, A., & Drigas, A. (2021). Attention and working memory. *International Journal of Recent Contributions from Engineering Science & IT (iJES)*, 9(1), 81-91. <https://doi.org/10.3991/ijes.v9i1.19933>
- [82] Angelopoulou, E., Karabatzaki, Z., & Drigas, A. (2021). The role of working memory and attention in older workers' learning. *International Journal of Advanced Corporate Learning (iJAC)*, 14(1), 4-14. <https://10.3991/ijac.v14i1.20355>
- [83] Drigas A, Karyotaki M (2017) Attentional control and other executive functions. *Int J Emerg Technol Learn iJET* 12(03):219–233
- [84] A. Drigas and P. Angelidakis, 'Mobile Applications within Education: An Overview of Application Paradigms in Specific Categories', *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 11, no. 4, p. 17, May 2017. <https://doi.org/10.3991/ijim.v11i4.6589>
- [85] C. Papoutsi, A. S. Drigas, and C. Skianis, "Mobile Applications to Improve Emotional Intelligence in Autism – A Review," *Int. J. Interact. Mob. Technol. (iJIM)*; Vol 12, No 6, 2018
- [86] Alexopoulou, A., Batsou, A., & Drigas, A. (2020). Mobiles and Cognition: The Associations Between Mobile Technology and Cognitive Flexibility. *International Journal of Interactive Mobile Technologies (iJIM)*, 14(03), pp. 146–156. <https://doi.org/10.3991/ijim.v14i03.11233>
- [87] Drigas, A. & Kokkalia, G. 2017. ICTs and Special Education in Kindergarten. *International Journal of Emerging Technologies in Learning* 9 (4), 35–42.
- [88] Drigas A., and Koukianakis L., A Modular Environment for E-learning and E-psychology Applications, *WSEAS Transactions on Information Science and Application*, Vol. 3, 2004, pp. 2062-2067.
- [89] Doulou, A., & Drigas, A. (2022b). Electronic, VR & Augmented Reality Games for Intervention in ADHD. *Technium Social Sciences Journal*, 28(1), 159–169. <https://doi.org/10.47577/tssj.v28i1.5728>
- [90] Kokkalia, G. K., & Drigas, A. S. (2015). Tools and E-tools for Memory and Attention Problems in Pre-school Education. *International Journal of Recent Contributions from Engineering, Science & IT*, 3(3), 13-19. <http://dx.doi.org/10.3991/ijes.v3i3.4729>
- [91] Bakola, N. L. N., Rizos, N. D., & Drigas, A. S. (2018). ICTs Supportive and Therapeutic Contribution in Psychoemotional Disorders in Childhood and Adolescence. *International Journal of Recent Contributions from Engineering, Science & IT (iJES)*, 6(2), 69-78.
- [92] Drigas, A.S., Vrettaros, J. and Kouremenos, D. (2004a) 'Teleeducation and e-learning services for teaching English as a second language to deaf people, whose first language is the sign language', *WSEAS Transactions on Information Science and Applications*, Vol. 1, No. 3, pp.834–842.

- [93] Kefalis C and Drigas A. (2019) Web Based and Online Applications in STEM Education. *International Journal of Engineering Pedagogy (iJEP)* 9, 4 (2019), 76–85. <https://doi.org/10.3991/ijep.v9i4.10691>
- [94] Drigas, A.S., Vrettaros, J., Koukianakis, L.G. and Glentzes, J.G. (2005). A Virtual Lab and e-learning system for renewable energy sources. *Int. Conf. on Educational Tech.*
- [95] Drigas, Athanasios S., and Marios A. Pappas. "On line and other Game-Based Learning for Mathematics." *International Journal of Online Engineering (iJOE)* 11.4, 62-67, 2015 <https://doi.org/10.3991/ijoe.v11i4.4742>
- [96] Gkeka, E.; Agorastou, E.; Drigas, A. Artificial Techniques for Language Disorders. *Int. J. Recent Contrib. Eng. Sci. IT* 2019, 7, 68–76.
- [97] Athanasios S. Drigas, Rodi-Eleni Ioannidou, A Review on Artificial Intelligence in Special Education, Information Systems, Elearning, and Knowledge Management Research Communications in Computer and Information Science Volume 278, pp 385-391, 2013 http://dx.doi.org/10.1007/978-3-642-35879-1_46