

# The role of executive function in autism (2026)

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## Summary

*This paper concerns the role of executive function in autism spectrum disorder. Autism is a neurodevelopmental disorder, characterized by atypicalities in brain development, starting from the embryonic period. As a result of this atypical brain development, the autistic child shows a different behavior, compared to his/her neurotypical peers. Undoubtedly, the executive functions, superior cognitive functions responsible for a person's behavior management, play an important role in the child's behavior. The aim of this literature review is to investigate the role of executive functions in autism. More specifically, it seeks to answer the question of whether executive functions present deficits in the autism spectrum, as this fact would provide an interpretation of the behavioral difficulties often displayed by autistic children. Additionally, some executive function assessment tools are presented, and they are either performance – based or based on parent and teacher reports.*

*Moreover, various types of interventions on executive functions in autistic children are mentioned, as suggested by relative studies. Finally, the practical utility of the present paper is discussed.*

**Key - words:** autism spectrum disorder, executive functions, executive function assessment, interventions on executive functions in autistic children.

## Introduction

The investigation of executive functioning in autism has undoubtedly attracted scientific interest since many decades ago. That is probably because of the fact that executive functions are extremely complex cognitive functions that are still not entirely understood, either in the neurotypical or in the neurodivergent population. If one considers this, along with the complexity that characterizes the autism spectrum disorder, one realizes the reason why the subject of this paper constitutes a matter of scientific interest. Certainly, the investigation of executive functioning in autism, the executive deficits that are present in this disorder and the available interventions, also has important practical utility on an educational and clinical level. At this point lies the significance of this literature review, which aims to provide scientific evidence regarding the executive deficits often displayed by autistic children, the available executive function assessment tools and the currently known types of interventions, implemented by different professionals. Firstly, this paper presents some core elements of the autism spectrum disorder in general, and in the following sections it seeks to provide answers to the aforementioned research questions.

### 1.1 Basic introductory points on autism spectrum disorder

Autism spectrum disorder, or, more briefly, autism, is a neurodevelopmental disorder. This means that the developing brain, even during the embryonic period, shows atypical patterns of development. This could result in substantial differences, in comparison to typical development, in various domains of the neurodivergent child's everyday life, such as speech, cognitive function, social cognition, language and communication, and behavior

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regulation. According to the 5<sup>th</sup> Edition of the Diagnostic and Statistical Manual of the American Psychiatric Association, the diagnostic criteria for the disorder include “persistent deficits in social communication and social interaction across multiple contexts” and “restricted and repetitive patterns of behavior, interests or activities” (Syriopoulou – Delli, 2016, p.23). In order for the diagnostic criteria to be met, symptoms should be present since early childhood and affect the child’s everyday functionality (Kring and Johnson, 2023, p. 532).

## 1.2 A brief history of scientific research on autism

The history of autism research begins in the former Soviet Union, where child psychiatrist Grunya Efimovna Sukhareva (1891 – 1981) published the first clinical descriptions of children, who, according to the current terms, would be considered autistic, (Posar and Visconti, 2017), in a paper titled “Schizoid psychopathy in childhood” in 1925 (Posar and Visconti, 2025). More specifically, Sukhareva described six boys who presented several autistic symptoms, such as a tendency to isolation and avoidance of other children (Manouilenko and Bejerot, 2015), a lack of facial expressions, emotional outbursts, difficulty adapting to change, stereotypic speech, movement abnormalities, and sensory sensitivity (Manouilenko and Bejerot, 2015· Posar and Visconti, 2017). Additionally, those children were of average to high intelligence (Manouilenko and Bejerot, 2015).

Interestingly, two years later, Sukhareva published a paper titled “The particular features of schizoid psychopathies in girls”, essentially investigating how autism can differ between the sexes, and constituting a research rather innovative for its time. The girls mentioned in Sukhareva’s work had average intelligence and language skills, and more advanced social skills, compared to the boys in Sukhareva’s previous paper (Dell’ Osso et al., 2024). Sukhareva was actually the first to mention the nowadays known “social camouflaging” of autistic girls, without using that term at the time (Dell’ Osso et al., 2024). A few years later, Sukhareva replaced the term “schizoid psychopathy” with the term “autistic psychopathy” (Pozzi et al., 2024).

Undoubtedly, Sukhareva’s contribution to our understanding of autism was of great significance and deserves more recognition from the scientific community, as she was the first to provide descriptions of autistic children, despite the fact that Kanner and Asperger are usually considered to be the first scientists to study autism.

Leo Kanner was another significant personality of the field of autism research. He was a Ukrainian psychiatrist who mentioned two important autistic characteristics of the children he studied; their tendency to self – isolation, or “extreme autistic solitude”, and their fear of change, which he named “anxious obsessive need for the maintenance of sameness” (Silberman, 2015, p.183). Kanner’s observations also showed that those children did not respond to their name, and that the presence of others was indifferent to them. Another characteristic behavior of theirs was their habit to place objects in line, as some kind of ritual. Criticism on Kanner’s work concerned his quite strict diagnostic criteria, and the fact that he eventually supported the theory that children with autism grow up to be adults with schizophrenia, as well as the “refrigerator – parents” theory (Silberman, 2015, pp.196, 191).

On the other hand, Hans Asperger’s ideas were closer to the current beliefs on autism. In his PhD thesis, titled “Autistic Psychopathy in Childhood”, he described four boys who, similarly to a lot of his patients, displayed an unexpected delay in social cognition and communication (Silberman, 2015, p.101). Additionally, they tended to talk with a peculiar prosody in their voice and use sophisticated and unnatural vocabulary for their age (Silberman, 2015, pp. 102). Asperger claimed that there is significant heterogeneity between autistic children, so one could assume that, in his mind, autism constituted a spectrum, exactly as it is believed nowadays. He also talked about the genetic basis of autism, suggesting that one specific gene itself cannot interpret the existence of autism (Silberman, 2015, p.106).

British psychiatrist Lorna Wing suggested and used the term “Asperger’s Syndrome” to define the most gifted children that belong in the autism spectrum. Wing believed that “Asperger’s Syndrome” should constitute a separate diagnostic category, and she used the term “autism spectrum” to express the idea of the significant heterogeneity of autism (Silberman, 2015, p.344). Interestingly, “Asperger’s Syndrome” is not used anymore as a diagnostic category, since the revision of the DSM in 2013, and nowadays it is considered a historical term. Therefore, people who would be diagnosed as having “Asperger’s Syndrome” are today provided with a diagnosis of autism.

## 1.3 Characteristics of development in autistic children

The atypical development of the autistic brain results in significant differences in autistic children’s everyday functionality and in various domains of their development. In this literature review, development in children with autism is analyzed, based on the three following domains; social communication, language and motor development.

Firstly, social communication constitutes a crucial developmental domain, which is quite challenging for children with autism and is included in the diagnostic criteria for the disorder. More specifically, children with autism, even from infancy, display reduced social orientation (Elsabbagh and Johnson, 2007). This is also stated in a retrospective study, conducted by Werner and Dawson (2005). The researchers concluded that the two groups of autistic and neurotypical children of their sample did not differ significantly in responding to their name and in turning their gaze to the face of the person who talks to them, during the first year of their life. However, it was noticed that during the second year of their life, the autistic children of the sample looked at their communication partner for much less time and that they responded less to the sound of their name. Similar results were shown in Maestro et al.’s retrospective study (2002), which concluded that infants with autism smiled less at people and did not seek contact with others as often as neurotypical infants.

Research has shown that children –and people, in general- with autism have a different way of processing the human face (Elsabbagh and Johnson, 2007). It is hypothesized that unlike neurotypical children, autistic children, growing up, maintain the ability to recognize reversed faces and identify them to others, as it seems that they process human faces partially, similarly to objects (Sasson, 2006). That does not happen in the typical brain, which, as the person grows up, loses that ability, and processes the human face as a whole, unlike objects, which are perceived partially (Sasson, 2006). Thus, while the

typical brain seems to perceive the human face as a special stimulus, the autistic brain probably tends to process it as an object, which could potentially interpret the difficulties often displayed by autistic children in recognizing emotions by looking at faces.

Additionally, a core deficit of autism, which is also part of the social communication domain, is in joint attention, which means “the coordinated attention between social partners who share interest in objects or events” (Lynch et al., 2013). More specifically, during the second year of life, protodeclarative behaviors are displayed more rarely in autistic children, compared to their neurotypical peers (Palomo et al., 2006). Certainly, responding to joint attention is less challenging than initiating joint attention (Lynch et al., 2013). Interestingly, deficits in joint attention are correlated with social orienting and face processing (Elsabbagh and Johnson, 2007).

As far as language development in autism is concerned, it should be explained, based on the core elements of language. Firstly, autistic children demonstrate deficits in pragmatics, as it can be challenging for them to adapt their speech to different social contexts and to take into account what their social partner already knows (Boucher, 2003). Additionally, echolalia and the use of long sentences, with complex syntax and sophisticated vocabulary, incompatible with the social context has also been observed (Vogindroukas et al., 2022).

Regarding semantics, some studies have shown that autistic children have a limited range of vocabulary, compared to their neurotypical peers, while other studies have found no differences in language development (Vogindroukas et al., 2022). In their review, these authors refer to “idiosyncratic colloquialisms”, used by autistic children, while difficulty in comprehending figurative speech, sarcasm and wordplay has also been observed (Boucher, 2003). Moreover, morphosyntax poses challenges to children with autism, who often make mistakes concerning the use of pronouns (Vogindroukas, 2022). As far as morphosyntax is concerned, a shorter mean length of utterance has also been observed in children with autism. Finally, with regard to phonology, it is considered to be the least affected linguistic domain in autistic children (Boucher, 2003), whereas Vogindroukas et al. (2022) mention that autistic children present deficits in phonology as well, as they display difficulties in phonological processing.

The analysis of development in autism is completed with some interesting data concerning motor behavior. Some motor characteristics that have been observed in children with autism are hypoactivity, difficulty in controlling their balance and posture, stereotypic movements, and a general delay in reaching developmental milestones, such as sitting, walking independently and gaining head control (Paquet, 2016). Fine motor skills are also affected, potentially due to difficulty in imitation, and mixed handedness is also observed (Paquet, 2016).

Thus, atypical neurodevelopment results in significant differences in development as a whole, and in the child's behavior and everyday functionality.

#### 1.4 Genes in autism and the autistic brain

An interesting question, which science has not yet answered, is how autism is inherited. Scientific knowledge has shown that there are some genetic factors that are correlated with autism, but the specific genes that are responsible for the disorder are still unknown. Some studies have shown that

autism and structural abnormalities in chromosomes 15 and 7 could be correlated (Lince et al., 2005). It is also hypothesized that genes related to neurotransmitters, such as serotonin and dopamine and their receptors play a role in autism (Lince et al., 2005), but this hypothesis has to be verified by future studies. Over the last decades, the role of epigenetics, meaning the interaction between genetic and environmental factors, is more and more emphasized. DNA methylation, or the partial modification of the genetic material, with no changes in gene sequence, might be correlated with autism (Yasuda et al., 2023). In the case of autism, advanced parental age, drug use during pregnancy and diabetes are considered to be environmental risk factors that could activate epigenetic processes that contribute to autism (Yasuda et al., 2023).

The first part of this literature review is completed with some interesting data regarding the autistic brain, and how it differs from the typical brain. More specifically, compared to the typical brain, the larger size and periphery of the autistic brain has been verified (Tsiftzi and Vlahos, 2018, p.372). It is also of great importance to mention some brain regions that show atypical patterns of activation in the autistic brain, such as the superior temporal sulcus and the amygdala (Tsiftzi and Vlahos, 2018, p.377, 379-380, Schultz, 2005).

In particular, the superior temporal sulcus has been correlated with the interpretation of non-verbal social cues, so its atrophy and reduced activation could explain some social difficulties that autistic people face (Tsiftzi and Vlahos, 2018, p.377). Some studies have shown that autistic people have difficulty in recognizing negative emotions in faces, indicating atypical function of the amygdala (Ashwin et al., 2006). Reduced activation of the amygdala in tasks that involve recognizing emotions by looking at the person's eyes has also been observed (Baron – Cohen, 1999).

In the case of autism, apart from some brain regions that show atypical activation and function, there is evidence for different connectivity between regions, compared to the typical brain, and more specifically for the hypoconnectivity between anterior and posterior brain regions (Tsiftzi and Vlahos, 2018, p.383-384).

Finally, evidence has shown reduced activity of alpha and gamma waves and increased activity of delta waves in the autistic brain (Strzelecka, 2014). Interestingly, Bernier et al. (2007) showed that  $\mu$  wave activity is maintained and, thus, mirror neuron activity is restricted in the brain of autistic adults, while watching the execution of a movement. This finding could potentially interpret the challenges that autistic people face in imitation and learning through it.

The second part of this paper, that follows, focuses on the role of executive function in autism.

### 2.1 Executive functions

At this point, the present paper focuses on executive function and executive deficits in autism. To begin with, executive functions are defined as “higher – order processes, closely associated with the prefrontal cortex, which are necessary for regulating and controlling behavior” (Pellicano, 2012). In essence, executive functions is a group of superior cognitive processes, which help one to utilize one's cognitive resources to achieve a specific goal, so they contribute to goal – directed behavior (Ganesan and Steinbeis, 2022). These functions are also responsible for implementing new strategies, adjusting to new circumstances, and displaying an adult and socially responsible behavior.

Different executive functions develop in different ages. At 3 – 4 years, inhibition, attentional control and cognitive flexibility seem to start developing (Shanmugan and Satterthwaite, 2016), while, according to the same review, information processing matures later, at 6 – 12 years of age. Goal – directed behavior reaches its peak in puberty, and in later adolescence (18 – 20 years old) inhibitory control, information maintenance in memory, abstract thinking and emotion regulation reach adult levels (Ganesan and Steinbeis, 2022; Tervo-Clemmens et al., 2023).

## 2.2 Theoretical models for the executive functions and their categorization in hot and cold

The executive functions have attracted scientific interest over the past decades, and it has been attempted to organize them in theoretical models, in order to comprehend and study them more effectively.

A recent theoretical model was proposed by Doebel (2020), who presents the executive functions as a cohesive whole of skills that form a single entity, which contributes to the utilization of the individual's cognitive resources, in order to control one's behavior and achieve a desired goal. The individual's cognitive resources include values, norms, beliefs, knowledge and preferences, which are used to attain a goal. On the other hand, Demetriou et al (2024), in their literature review, mention different models of executive function. More specifically, the executive functions can be understood as a group of specific factors, thus clearly separated cognitive functions, each of which is activated in different cognitive tasks, or as a general factor (General Factor of Executive Functions or  $G_{EF}$ ), that is activated in any cognitive task that needs the contribution of executive function, in order to be completed. Additionally, some models suggest that  $G_{EF}$  causally activates the aforementioned specific factors, or that it is these factors that activate  $G_{EF}$ .

However, over the last decades, a rather interesting model of executive function has been suggested. This recent model categorizes the executive functions in cold and hot. Cold executive functions are activated under emotionally neutral circumstances, and concern the cognitive processing of information (Salehinejad et al., 2021). On the contrary, hot executive functions are activated under conditions in which one has to adapt to a situation or solve a problem with personal meaning and emotional salience. Cognitive flexibility, shifting, working memory, inhibitory control, self – monitoring and attentional control are cold executive functions (Salehinejad et al., 2021). On the other hand, emotional decision making, delay of gratification, theory of mind and social cognition in general are included in the category of hot executive functions (Salehinejad et al., 2021). Hot and cold executive functions do not exist separately, but these categories seem to interact in every cognitive task (Sambol et al., 2025).

This categorization becomes even more interesting, if one considers the fact that these two categories of executive function seem to be correlated with different brain regions. Cold executive functions are generally associated with the lateral regions of the prefrontal cortex, and more specifically with the dorsolateral prefrontal cortex, and also with the anterior cingulate cortex and the inferior frontal gyrus in the right hemisphere (Salehinejad et al., 2021). The subcortical areas that are involved in cold executive functioning are the

basal ganglia and the hippocampus (Salehinejad et al., 2021).

On the other hand, the brain network that supports hot executive functioning seems to be more extended, and includes the ventrolateral prefrontal cortex, the medial prefrontal cortex, the orbitofrontal cortex, and the posterior cingulate cortex (Salehinejad et al., 2021). According to the same review, the subcortical areas involved in this network are the amygdala, the striatum and the insula. In this context, it is worth noting that a lot of brain structures that are part of the limbic system, which is correlated with the experience of emotions, are also involved in hot executive function, which is activated when one experiences any kind of emotion.

The fronto – parietal network, the salience network, the dorsal and ventral networks of attention and the cingulo – opercular network are also included in the brain regions involved in executive functioning (Colette and Salmon, 2014). However, these authors clarify that some of the aforementioned brain networks are activated during some cognitive tasks, and some others under different cognitive demands.

## 2.3 Executive deficits in children with autism

Determining the “neuropsychological profile” of autistic children with precision has posed great challenges to the scientific community, as researchers, probably due to methodological differences, do not agree on the executive deficits in children with autism. Some studies conclude that children in the autistic spectrum present extended difficulties in executive functioning, while other studies have found no significant differences between autistic children and their neurotypical peers.

In general, cognitive flexibility and planning are considered to be the most affected executive functions in autistic children (Thommen et al., 2017). In fact, cognitive flexibility, meaning the ability to adapt to change, and planning, which means being able to make a plan and changing one's strategy, can pose significant difficulties for autistic children.

It is worth mentioning, at this point, a study conducted by Kouklari et al. (2017). The authors assessed working memory, inhibitory control and planning, through the Digit Span Test, the Go/No Go Task and Tower of London respectively, in a sample of 56 autistic and 69 neurotypical children. The group of autistic children showed statistically lower performance than the neurotypical participants in all tests, proving that children with autism do present deficits in executive functions, with working memory and inhibitory control, not planning, being the most affected among them.

In the same study the performances of the two groups in hot executive function were compared as well, and more specifically, emotional decision making and delay of gratification were assessed through adapted versions of the Iowa Gambling Task and the Delay Discounting Task respectively. The autistic participants presented deficits in hot executive functioning too, as they did in Kouklari et al.'s (2023) study as well, which actually showed that cold executive functions tend to develop in a linear way, as the autistic child grows up, while hot executive functions develop in a non – linear manner.

Undoubtedly, theory of mind, which means “the knowledge of what other people know” (Thommen, 2017),

and is included in the category of hot executive functions, poses significant difficulties for autistic children, as has been shown through tests of emotion recognition and false belief (Kouklari et al., 2017), and tests of second – order ignorance and second – order belief (Kouklari et al., 2023). These studies actually concluded that there is a correlation between hot executive function and theory of mind, over and above cold executive function (in the former study), and over and above the age of autistic children (in the latter study).

Given these interesting data on executive functioning in autistic children, one could argue that executive deficits in autism could explain the behavioral difficulties often displayed by autistic children. For example, the difficulty in adapting to unexpected change could be interpreted as a deficit in cognitive flexibility. In addition, their difficulty in switching between different activities or following simple written instructions could be explained as a deficit in planning. Emotional outbursts, often observed in autistic children, could be interpreted as a difficulty in inhibitory control and emotion regulation, while social awkwardness, difficulty approaching other people and making friends, could be explained as an important deficit in theory of mind.

To sum up, it seems that executive deficits play an important role in the autistic child's everyday behavior. Thus, the assessment of executive function with validity and reliability is crucial for the early detection of executive deficits. The next part of this paper focuses exactly on this topic.

### 3.1 Batteries and inventories for the evaluation of executive function

The assessment of executive function is undoubtedly a matter of great significance. The batteries, inventories and neuropsychological tests that follow have been used in research, in autistic children, and in other clinical populations as well.

The BRIEF (Behavior Rating Inventory of Executive Function) is probably one the most well – known inventories, that is based on reports from the autistic child's parents and teachers. They evaluate the child's behavior in everyday situations that require executive functioning, by answering relevant questions (Baggetta and Alexander, 2016). The BRIEF consists of the Behavior Regulation Index, that represents the evaluation of hot executive function (inhibitory control, emotion regulation and shifting) (Shakehnia et al., 2021), and the Metacognition Index, representing the evaluation of cold executive function (initiation, inhibitory control, working memory, planning, organizing and self – regulation). Finally, these two indexes together form the Global Executive Composite, which shows the child's overall executive function. Higher scores imply higher executive difficulties.

The most frequently used and ecologically valid assessment tool is the Behavioral Assessment of Executive Dysfunction - Children's Version (Wallace et al., 2016), which includes tasks related to everyday life problems, that require executive function to be completed (e.g. the key search test).

Another very well – known battery is the NEPSY: A Developmental Neuropsychological Assessment, which consists of 32 tests, divided in the six categories of Language, Memory and Learning, Attention and Executive Functioning, Social Perception, Sensorimotor Processing and Visuospatial Processing (Brooks et al., 2010). The Attention and Executive Functioning domain includes tests for the evaluation of cognitive flexibility (Animal Sorting

Subtest, Design Fluency), verbal selective and sustained attention, inhibitory control and shifting (Auditory Attention and Response Set), and planning (Clocks) (Brooks et al., 2010). Inhibitory control is also assessed with the Inhibition and Statue tests, that belong in the same category (Brooks et al., 2010).

The Childhood Executive Functioning Inventory (CHEXI) is based on reports from the child's parents, similarly to the BRIEF. It includes 4 subscales (inhibitory control, working memory, planning and self – regulation). In each of these subscales, the child's parent answers some questions, regarding the frequency of behaviors, each of which is relevant to a different executive function. For example, parents are asked whether their child can follow given instructions step – by – step (planning), or whether he / she can engage in more than one task at the same time (working memory), or inhibit inappropriate behavior (self – regulation) (Golshan et al., 2019). Finally, the D – KEFS battery, which is performance – based and evaluates exclusively executive functioning, includes 9 subscales for the assessment of cognitive flexibility, design fluency, verbal fluency, inhibitory control, problem solving, categorical processing, deductive reasoning, spatial planning and verbal abstraction (Baggetta and Alexander, 2016).

### 3.2 Neuropsychological tests that evaluate cold executive function

Certainly, there are some neuropsychological tests that assess executive function, and have been used extensively in neuropsychological studies in general, and thus, in relevant studies with autistic children. The following tests evaluate cold executive function.

The most well – known test is probably the Stroop Test. In the most complicated condition of this test, children are asked to say the color in which a word is written, while this word means a different color. For example, children see the word "red" written in blue, and have to inhibit their tendency to simply read the word, and utter its color instead, therefore say "blue". Thus, this is a test for inhibitory control (Kouklari et al., 2023). Another well-known test is the Wisconsin Card Sorting Test, which evaluates cognitive flexibility and shifting. Four cards are presented, each of which shows patterns that differ in color, shape and number (Kolb and Whishaw, 2018, p.481). Children are asked to sort the cards according to a given rule, e.g. by color. This rule then changes, and children have to follow the new rule instead, and sort the cards accordingly.

Another neuropsychological test is the Digit Span Forward and Backward Test that assesses verbal working memory. In the first condition (Digit Span Forward Test) children are asked to recall and utter numbers in the same order in which they heard them, while in the second condition (Digit Span Backward Test) they have to recall the numbers in the reverse order (Kouklari et al., 2017).

There are also some noteworthy tests that are considered to measure the executive function of planning. In a relevant test of the WISC, the child is asked to create 10 patterns by using colored pieces that are supposed to be put together in a specific order (Karapetsas, 1988, p. 278). The Trail Making Test also assesses planning –as well as shifting-. In this test, the child is instructed to connect numbers from 1 to 15, and numbers with letters, starting from the numbers, in the next condition (e.g. 1, A, 2, B, etc.) (Karapetsas, 1988, p. 280). Finally, in the Tower of London test, children are asked to reproduce a pattern made of colored blocks in a wooden

construction. The blocks are red, green and blue. The goal is to recreate the construction with a limited number of moves, by taking only one block from each one of the three wooden pegs each time (Kouklari et al., 2023).

### 3.3 Neuropsychological tests that evaluate hot executive function

The following tests assess hot executive function. Their common feature is that children are instructed to tackle a task, which is not purely cognitive, because they themselves are emotionally engaged in it, due to the nature of the test.

To begin with, the Iowa Gambling Task is primarily used to evaluate emotional decision making. Kerr and Zelazo (2004) adapted this test, to render its administration to children possible. This adapted version is called the Children's Gambling Task (Hongwanishkul et al., 2005). Two decks of cards are presented to the children. The cards on one of the decks have more happy than sad faces on them, while the cards from the other deck have more sad than happy faces. The former deck of cards is profitable for the children, as it contains more happy faces, while the latter deck implies loss for the children. They are then instructed to gather as many sweets as possible, by choosing cards from the profitable deck. The candy that children gather is placed in a transparent vase in front of them.

Additionally, delayed gratification is evaluated with the Delay Gratification Task, which is also adapted to be administered to children. Prencipe and Zelazo (2005) used this paradigm in their study, in which the children were asked to choose between an immediate but smaller reward and a delayed but larger reward. Three different types of reward were used; candy, stickers and pens. The children were instructed to choose one reward immediately or two rewards later, one immediately or four later, and one immediately or six later. Thus, there were nine trials. Later, children were asked help the researcher choose ("What do you think I should do?").

At this point, it is important to note that there are some concerns regarding the ecological validity of the neuropsychological tests. It has been observed that some children who achieve high scores in these tests, have difficulty in handling everyday situations that require the same executive functions that are assessed by these tests. Generally, the validity of these neuropsychological tests is doubted, since, when one engages in a cognitive task, it is practically impossible to activate only one executive function, which is thought to be evaluated with this task. It has also been observed that researchers use the same test to assess different executive functions, e.g. the Wisconsin Card Sorting Test has been used to assess shifting, as well as cognitive flexibility and planning.

### 3.4 Tests that evaluate Theory of Mind

The following tests, that assess theory of mind, probably have higher ecological validity, as they present everyday social situations, so they might assess that complex hot executive function more validly.

In their study, Pino et al. (2017) used the Eyes Task Simplified. In this task, children are asked how the child on the demonstrated photograph feels (surprise, happiness, sadness or anger) and what his/her mental state is (excited, thinking, worry and shy), by looking only at the child's eyes. These authors also used the Comic Strip Task, which

includes three pictures that present a short social scenario. Children are given two more pictures, and they are asked to choose the one that more reasonably completes the story. Therefore, children should perceive the mental states of the characters in that story, and predict their next actions.

Happé's (1994) Strange Stories are also quite interesting. Strange Stories are short stories that describe social situations. They are categorized in the following groups, according to the social situation that they present; Joke, Pretend, Lie, White Lie, Figure of Speech, Forget, Appearance / Reality, Double Bluff, Sarcasm, Persuade, Misunderstanding and Contrary Emotions (Happé, 1994). The children listen to the story and are asked two questions, at the end of every story; "Was it true, what X said?", and "Why did X say that?". Strange Stories involve complex social situations, in which people do not usually say exactly what they mean, so children have to comprehend those hidden messages.

The Sally and Ann Task is simpler than Strange Stories. It evaluates the child's ability to attribute false belief to other people (Baron – Cohen et al., 1985) and is based on Wimmer and Perner's work (1983). Essentially, children are supposed to understand that one of the heroes of the story has a belief which is not true (Sally thinks her marble is in the basket), so they will act accordingly (she will look for it in the wrong place). At this point lies the ability to attribute a false belief to a person. Baron – Cohen (1989) used a more complicated test (the story with John and Mary), which assesses the child's ability to perceive a person's beliefs, regarding somebody else's beliefs. This is a second – order false belief test, where the false belief does not concern an object, such as the location of the marble in Sally and Ann Task, but the beliefs of a different person.

Due to the nature of these tests, it actually seems they are more ecologically valid, and they provide a more realistic assessment, compared to the tests that were mentioned in previous segments of this paper. In any case, the valid and reliable assessment of executive function is a matter of great importance, in order to plan suitable interventions. Different types of interventions on executive functioning are mentioned in the next section of this paper.

### 4.1 Educational interventions

Various types of interventions on executive functioning in autistic children have been suggested. Different interventions are implemented by different professionals. At this point, some educational interventions are presented, and they can be implemented by psychologists or by special education teachers at school.

Social Stories are short stories which present social situations and teach children appropriate behavior in a given social context, and also what one is not supposed to do in that context. In these social situations, the child is taught what other people think and how they feel, and in that way he/she realizes that sometimes people have different thoughts and feelings from him/her. At this point lies the contribution of the Social Stories to the development of theory of mind, as they include "perspective sentences", which describe what the characters of the story think, believe, or feel (Attwood, 2012, p.107). Therefore, the child learns what the appropriate behavior is, in a social situation, based on these mental states of others, as they are presented in the Social Story.

Comic Strip Conversations also contribute greatly to the development of the theory of mind, as they depict a social scenario with images and speech and thought bubbles, which the child and the adult complete together. In that way, the child learns what one would say or how one would feel in a given social situation. In these bubbles, colors can also be used, and each color represents a different feeling (e.g. red bubbles for something that one said when one was angry), (Attwood, 2012, p.182), so the child understands how one would feel in that social scenario. In Comic Strip Conversations, it is important to depict incidents and social situations that actually happened, so that the child and the adult (teacher or psychologist) can draw and color bubbles with the thoughts, the words and the feelings of the people involved, if the child had acted differently (e.g. if he/she had held his/her temper, when another child upset him/her).

Finally, one of the most important educational interventions on executive function in children with autism is the TEACCH program, which is considered to improve planning and cognitive flexibility (Thommen et al., 2014). TEACCH essentially concerns the structuring of the child's schedule of everyday activities. This schedule is presented in a visual form, including activities in the specific order in which they need to be completed. The child's visualized schedule can also include different work spaces, so that the child will know where to go after finishing each activity. TEACCH can be effective for the development of cognitive flexibility and planning, executive functions in which autistic children present characteristic difficulties. However, it is important that this schedule is implemented both at school and at home, in order to provide a stable and predictable environment for the autistic child.

#### 4.2 Psychological interventions

Psychological interventions on executive functioning in children with autism also appear to be rather promising. The following psychological interventions can be implemented in a clinical environment, or in research.

A well – known intervention is the Cognitive – Behavioral Therapy (CBT), which was used by Sofronoff et al. (2007), in order to enhance anger management in a sample of children with autism. Undoubtedly, anger management belongs in the category of hot executive functions. During the sessions of CBT, these researchers used the “tool box” technique, and taught the children the use of some “tools” to help them control their anger, such as “physical tools” (e.g. going for a walk), “relaxation tools” (e.g. listening to music), and “thinking tools” (e.g. how probable is it that something that the child fears will actually happen, as a result of his/ her anger?). These authors also mention “social tools”, such as a conversation with a loved one about an incident that caused the child's anger. However, “social tools” may not be as effective for children with autism. Finally, the “Emotion Thermometer” was also used, with which the children of the sample defined the feeling of anger that they experience in given hypothetical situations. After all sessions were completed, the researchers found improved anger management ability. Thus, children had a greater ability to control their anger in various situations, and their parents felt more capable of managing their child's anger as well.

Additionally, it seems that behavioral methods can also improve cold executive function, according to a study conducted by Baltruschat et al. (2011). These researchers used positive reinforcement with different types of reward, which had been previously agreed with the participants. The

aim of this study was to enhance working memory. Indeed, the three autistic children that participated in this research were able to remember the number of circles that they saw in a series of cards. After the phase of positive reinforcement, the children managed to recall the number of circles of even more cards, as the trials progressed. This enhancement in working memory was observed in learned stimuli, and also in new ones (e.g. cards that the children had not been shown before). However, it is not certain whether this improvement in working memory can be transferred in everyday tasks. Nevertheless, this study provided interesting and promising data, regarding the utility of behavioral methods in the reinforcement of executive function.

#### 4.3 Training of executive functions, neuromodulation and the Social Competence Intervention

Research has shown some interventions that focus on the training of the executive functions themselves. One of these interventions is the PIFENA program (Acero – Ferrero et al., 2017), which is computer – based and aims to improve planning, inhibitory control, working memory and self – regulation. The activities that this program includes were proved effective and the authors concluded that after the intervention was completed, the autistic children that participated in this study had better executive functioning, which was measured with the CHEXI.

Additionally, Pasqualotto et al's (2021) review mentions an intervention called “Unstock and on Target”, that includes creating scenarios and solving these hypothetical problems, in order to improve self – regulation. Cognitive remediation therapy has also been suggested, and consists of pen – and – paper cognitive exercises that focus on a different executive function each time. The same review also refers to the Project EVO, which is computer – based and seems to be effective on the improvement of inhibitory control and attention in children with autism and ADHD.

An interesting question, which science has not answered yet, is whether it is possible to increase executive functioning in children with autism with the use of neuromodulation. The data in this field are still scarce, and the existing studies show some improvement in behaviors that are considered characteristic of autism, but not in executive functions themselves.

For example, a study conducted by Sokhanze et al. (2014) in a sample of autistic children, showed that repetitive stereotypic behaviors can be reduced with the use of repetitive transcranial magnetic stimulation (rTMS) combined with neurofeedback. These findings could be interpreted as an improvement in cognitive flexibility. A meta-analysis conducted by Minghui et al. (2025) also found evidence for the effectiveness of rTMS in reducing repetitive behaviors. In addition, these authors mention transcranial direct-current stimulation (tDCS), which seems to be able to improve social communication.

However, there are a lot of questions in this field that research has not yet answered and that will be the subject of future studies. Therefore, the aforementioned data regarding neuromodulation should be interpreted with caution.

Finally, an intervention that provided promising results is the Social Competence Intervention, which was implemented by Stichter et al. (2010) and Stichter et al. (2012) in a sample of autistic teenagers and autistic children respectively. Interestingly, despite the fact that the primary goal of this intervention was to improve social skills, the authors found a statistically significant improvement in

executive function, which was measured with the BRIEF. This enhancement of executive function, as measured with the BRIEF and tests of Theory of Mind, raises the question of whether the development of social skills can contribute to the improvement of executive function, and of how executive function and social cognition are correlated.

#### **4.4 The effectiveness of different interventions; a network meta-analysis**

Given the fact that there are a lot of different types of interventions on executive function in children with autism, and that their effectiveness remains to be verified by future studies, one could raise the question of which of them is the most effective, according to the existing data.

Li et al. (2025) attempted to answer this question and conducted a network meta-analysis for this purpose. They compared different types of interventions based on their effectiveness, as documented in the existing studies. These interventions included cognitive-behavioral therapy, exercise interventions, cognitive training, dietary intervention, social skills intervention and conventional interventions. The authors concluded that, according to the studies included in this network meta-analysis, the most effective intervention on executive function in autistic children is exercise intervention. Interestingly, Li et al. (2025) interpret this finding by claiming that during physical exercise, neurotrophic factors and catecholamines are secreted in the brain, leading to increased cognitive function, and thus enhanced executive function.

Undoubtedly, as mentioned before, the effectiveness of these interventions remains to be studied further. Therefore, it is important that the aforementioned data be interpreted with caution.

### **5. The practical utility of the present paper**

At this point, it is important to mention the practical utility of this literature review, for the scientific community, and for the parents and teachers of autistic children.

Firstly, this paper provides some overall knowledge on autism spectrum disorder. It presents some important data concerning the disorder itself and, more specifically, the characteristics of executive function in children with autism. Thus, this review could be used by anyone interested in autism –scientist or not- as a source of important information and a starting point for further research.

This paper could also interest parents and teachers of autistic children. Executive function deficits in children with autism, which have been proved by the aforementioned scientific data, provide an interpretation of the child's behavioral difficulties. Therefore, considering this, parents and teachers understand the reason why the child behaves a certain way under some circumstances. This comprehension constitutes the starting point for future interventions on the child's executive functioning. Additionally, some of the previously mentioned interventions, especially educational and psychological interventions, could be implemented at school by teachers and at home by parents, creating a stable and predictable environment for the child, through the cooperation between the child's family and teachers, which is crucial for the education of all children.

### **Concluding remarks**

In summary, autism is a neurodevelopmental disorder, which presents executive deficits, starting from childhood. These deficits are evident in the child's everyday behavior, and can be assessed through performance – based tests, or inventories based on parent and teacher reports. Additionally, research has proposed various types of interventions. Certainly, future studies will provide more data on the effectiveness of these interventions and will further investigate not only the research questions of this review, but the complex matter of executive functioning in autism in general.

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