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Learning in Children with Autism Spectrum Disorder: The Role of Attention and Visuospatial Memory

Giovanni Maria Guazzo* and Consiglia Nappo

IRFRI – Gruppo Forte Salerno, Italy.

*Correspondence:
Giovanni Maria Guazzo, IRFRI – Gruppo Forte Salerno, Italy.

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ABSTRACT

Research into deficits in executive functions explains some of the difficulties experienced by people with autism, which lead to their inability to plan, control and monitor their own behaviour and cognitive func-tioning, as well as often manifesting as emotional dysregulation. Among the various components of execu-tive functions that play an essential role in the learning of people with autism spectrum disorder, there are certainly attention and visuospatial memory. Based on the results of this work, albeit preliminary, it can be said that training aimed at acquiring and improving attention and working memory skills should prioritise specific intervention on visuospatial abilities, which are very deficient in subjects with autism but which play a fundamental role in a wide variety of complex cognitive tasks such for example, reasoning, learn-ing, understanding texts, the position of objects, orientation and movement in the real environment.

Keywords

Autism Spectrum Disorder (ASD), Attention, Visuospatial Memory, Learning.

Introduction

Autism spectrum disorder (ASD) is characterised by deficits in social communication and social interaction and restricted/repetitive patterns of behaviour, interests or activities [1]. Other non-social factors, such as stereotypes and sensory problems, also play an essential role in the cognitive profiles of children with ASD, even for those without intellectual disabilities [2].

Autism is a lifelong disability, and despite being the subject of continuous research for over fifty years by psychiatrists, psychologists, neurologists and other scientists, a cure has not yet been found. However, this research has produced encouraging progress (biological origins of the disorder, extraneous maternal behaviour, new assessment tools, cognitive specificity, the validity of specific educational interventions, etc.), even if the role of many environmental and genetic factors in determining the disorder or influencing its course has yet to be clarified. The experimental successes obtained over the last twenty years, as well as allowing us to predict further progress and discoveries shortly reasonably, will also help us to be more critical of statements regarding possible causes (vaccines, food intolerances, metal poisoning, etc.) and/or pseudo cures (diets, facilitated communication, psychotherapy, etc.) which, although recognised by 'common sense', are not supported by adequate empirical evidence, will allow us to overcome the tendency to confirm what we already believe to be true and to neglect contrary evidence (the 'cherry picking' effect) [3,4].

In recent years, biological explanations of the disorder have clarified the relationship between mind and brain and between disorders of brain development and disorders of psychic functions, emphasising the role of genetic inheritance. The data collected mainly through comparisons between monozygotic and dizygotic twins indicate the central role of genetic inheritance in the onset of autism [5]. All this opens up fascinating research paths, but prudence is required. The discovery of which genes are involved in autism, despite the many studies, is still a long way off and certainly involves a large number of genes: perhaps between 500 and 1000. Therefore, in the absence of effective treatment and considering the characteristics of the disorder and its incidence in population[1], the only valid alternative is educational strategies and their ability to improve the person's functional level and decrease dysfunctional behaviour. In this way, subjects with autism will be able to improve their existence in various ways and will be able to lead a meaningful life as adults. From this point of view, we should no longer talk about rehabilitation intervention or treatment but about 'existential planning or life project' [3]. Only with an 'existential programme' is it possible not to fragment the person's existence and to exploit every real-life situation as an educational moment: going to the supermarket to buy a litre of milk to the pizzeria, or the post office or to the cinema should not be a mere instrument of distraction or for ' pass the time', but a way to take advantage of all the spaces and services that the Community makes available to every citizen so that the person with autism can truly feel part of a life that is increasingly slipping through his or her fingers (adults are always the ones who choose what to do and where to go, and adults are always the ones who decide about his or her life). As is easy to understand, the 'Quality of Life' concept best deals with these aspects. The objective of quality of life for each person, and therefore also for those with autism, is achieved by satisfying the following indicators: psychophysical health, personal autonomy, communication, interpersonal relationships, leisure time management, scholastic and professional skills, and self-determination [6,7]. All this is to obtain a high level of inclusion, integration and personal fulfilment (satisfaction) in the various social subsystems (family, school, work environment, community, etc.) in which the individual interacts [6].

Therefore, hypothesising the psychological 'functioning' of particular subjects with a disorder as complex as autism presupposes that the model of person taken into consideration is a highly integrated system between biological repertoire (perception, sense organs, use of drugs, etc.), cognitive repertoire (learning, problem-solving, attributions, etc.), affective sentimental repertoire (how particular experiences are lived, what are the affective disorders linked to sentiment, etc.), behavioural repertoire (deficits and/or excesses of specific actions, etc.) and finally the socio-relational repertoire (how to interact with others). These different repertoires are closely linked so that gaps in any of these 'pieces' of the person are enough to create difficulties in the adaptation process. Therefore, the educator, who is interested in these people for various reasons, must bear in mind all these repertoires when implementing an educational intervention that must necessarily be evolutionary: that is, it is necessary to use the available data on the typical development of the child and the intervention must proceed in successive stages, each stage being possible only if the previous stages have been reached [4].

[1] Recent estimates from internationally accredited sources can vary from one case per 36 children, as in the United States in 2020 (Centres for Disease Control and Prevention - CDC), to one per 77 in Italy (Istituto Superiore di Sanità - ISS) or even with lower or higher incidences in other countries. The apparent discrepancy in epidemiological data is due to the different diagnostic criteria used by researchers.

Knowledge, then, takes on the meaning of 'selection of information from the outside world, orienting one's behaviour according to both past experiences and new situations'. This meaning will be the starting point for answering the questions 'How do people with autism process information?' and 'Which educational intervention is most effective with these people?'.

Information Processing

Modern neuropsychology focuses on the identification and description of cognitive functions and, therefore, for the functional explanation of a behavioural disorder or lack of a skill, it is necessary to precisely define the cortical processes that commonly underlie that skill: malfunctioning of a neuronal network or loss of connection between networks. The neuropsychology of autism, therefore, allows us to understand human cognition and the mechanisms that determine its development and is characterised by the implementation of the following factors: delineation of how the ability is acquired during normal development, an indication of the factors that compromise its development and highlighting of the evolutionary path that leads to the anomalous structuring of some functions.

Analysis of the behaviour of people with autism indicates that, in many respects, it is similar to that observed in patients who have suffered damage to the frontal lobe and the structures directly connected to it, such as the 'basal ganglia' or the 'limbic system' [8,9]. Research into deficits in executive functions explains some of the difficulties experienced by people with autism, which lead to their inability to plan, control and monitor their behaviour and cognitive functioning [10], as well as to emotional dysregulation [11]. Therefore, the main problem in the executive functions of people with autism is the inability to use strategies (ability to plan, to take advantage of negative feedback, to classify and organise information) appropriate to the execution of a task to achieve a specific goal [10]. Using strategies implies a more or less controlled attempt to adapt cognitive processes to the needs of a task given a purpose. Furthermore, strategies can be modified and made more effective. Based on this distinction, the ability to perform a task can be hindered by three types of problems: 1) limited capacity, 2) not knowing how to use the appropriate strategy, and 3) inefficiency of the strategies used [12].

In this context, a distinction has been made between production and mediation deficiencies [13]. Production deficiency is assumed when the subject does not spontaneously use a strategy but does so if trained; mediation deficiency, on the other hand, exists when the subject produces a plan but cannot improve performance. Therefore, teaching aims to lead students to 'manage' his learning through strategies. This function does not exclude rapid automatic processing, which does not require attentive skills and is learnt through repeated exercise [14]. However, attention influences the storage of information in memory and its subsequent retrieval. At this level, three different purposes can be identified: 1) monitoring interactions with the environment, maintaining awareness of the degree of adaptation, 2) synthesising memories and sensations, giving a sense of continuity to the experience, and 3) controlling and planning future actions. Therefore, if we consider attention as the system that regulates the activity of mental processes, filtering and orienting perception towards relevant information to respond adequately to environmental demands, we will have an idea of its connection with the motivational, affective, emotional, and behavioural systems.

Attention is a process of planning and controlling cognitive processes given a conscious elaboration, which is activated and oriented by environmental stimuli or by ideas already present in memory. It is essential for planning action and self-regulation strategies, selecting critical information and not selecting distracting information, creating a situation similar to that of a spotlight that illuminates only one area of the stage, emphasising it.

Experimental data on the attentional processes of ASD subjects indicate that the deficit is not generalised. Some attentional functions seem intact, while others show significant differences compared to control groups [15]. These results suggest the difficulties these children have in focusing their attention on the relevant characteristics of the stimulus situation. In other words, some perceptive clues (shape, colour, etc.) inappropriate for learning would occupy the central space of conscious activity, assuming a dominant character, the *volume of* attention at that precise moment. In other cases, however, it has been noted that the deficit is not so much due to a focus on irrelevant perceptual clues but instead to an attentional behaviour characterised by a very high *oscillation rate*.

Consequently, the time available to the subject to 'process' the information and, therefore, encode it adequately would be highly reduced or completely inadequate [16]. Several studies [7,17,18] conducted on perceptual modalities in ASD subjects have shown that these children do not establish adequate attentive contact with visual stimuli, make few comparisons between the various components of the stimuli themselves, and consequently make inadequate use, for learning purposes, of the data presented to their field of vision. It is easy to see how attention focussed on irrelevant characteristics (distractors) leads to incorrect performance, which the educator usually does not reinforce or reinforce. Given that unreinforced responses tend to die out, we will see a decrease in the subject's attention and the likelihood that he will focus on other correct perceptual clues. In the long run, this mechanism becomes the cause of the typical behaviour of many people with autism, who show a high level of randomness (or the use of particular behavioural modalities: stereotypies, echolalia, various rituals, etc.) in the emission of the required responses. According to some scholars, these problems could be attributed to the *top-down* processing method that, when activated automatically, would produce a 'fixation' of the focus, inhibiting attention and subsequent learning [3].

Over time, various attempts have been made to explain all these perceptual deficits and peculiarities in the light of this or that theory. Some research [20] highlights, for example, the difficulty in integrating the parts into a coherent structure; therefore, the perception of visual and auditory stimuli and action is fragmented precisely because there is insufficient ability to combine the parts into a cohesive whole.

Central Coherence Deficit (CCD) describes a reduced ability to bring together various pieces of information to construct a mental concept caused by an excessive concentration on details that prevents the individual from grasping the whole (shifting) (Figure 1). This deficit would allow subjects with ASD to obtain very high scores in the 'Drawing with Cubes' and 'Perceptual Identification of Hidden Geometric Figures' tests [20,21] (Figure 2). But one aspect needs to be emphasised: global/local processing in HDA does not appear to differ from that of control groups when they are explicitly told what to pay attention to; on the contrary, when they are left free to direct their attention spontaneously, it seems that their attention is directed preferentially to the local level of information. This conclusion also agrees with the results obtained in various non-verbal tasks [22]. Recent research highlights how the DCC theory and other theories are partially falsifiable and cannot explain all the visuo-spatial abilities and problems of subjects with autism [23,24]. Using an analogy, Affolter and Stricker [25] developed an interesting hierarchical theory on attentional development, represented as a building on four levels. On the *first level,* our senses develop and perfect themselves *independently (unimodal level*: auditory, tactile, visual perception, etc.); on the *second level,* they work together to master spatial order (*intermodal level*: orientation response); on the *third level* they learn to work together in temporal order (*serial level*: production of words and phrases through the serialisation of letters and words respectively); finally, at the *fourth level*, the five senses can carry out complex operations and problem-solving that involve events outside the field of perception (past and future events) and without having been previously experienced (*supramodal level*).

Suppose there is a deficit in one of the above levels. In that case, two different situations can occur: 1) the transition to the upper level is delayed (for example, if at the *first level* there is a deficit in one of the sensory modalities, at the *second level* there will be a deficiency and 2) the contiguous levels are, from a performance point of view, deficient (for example, if, at the *first level*, the individual senses have developed typically, but there is a lack of coordination between the individual sensory modalities (*at the second level*), the child, even if he hears the sound, will not orient his gaze towards the sound stimulus and will not try to touch the object. These deficits may explain the difficulties that some children with autism have in developing language, imitation, emotional and social skills, so to evaluate their attentive behaviour correctly, two parameters must be considered [16]:

1. *Duration of behaviour* (spontaneous or on request): measurement of the duration of appearance (in seconds or minutes) of the established attentive behaviour; it is recorded how long the child can perform an attentive behaviour,

spontaneously or on request.

2. *Orientation to the task of the behaviours displayed*: observation and recording of the behaviours displayed when the pupil is asked to perform a specific task (reading, writing, copying a figure, etc.); in this case, it is a question of recording all the behaviours considered relevant to the performance of the task itself.

The limitations and scarcity of tools make it difficult to reliably assess how much attention each ASD student can pay to the numerous environmental stimuli. On the other hand, it is easier to determine the stability and oscillation of the students' attentive behaviour.

This research suggests that in these subjects, visuospatial activity can be represented by a multiform system with both a visual (ventral: occipital) and spatial (dorsal: parietal) dimension or that it can even be divided into two separate systems, one linked to the processing of complex stimuli and the individuation of the ' thing', while the other would be involved in the spatial localisation of stimuli and would involve information about the "where".

Visuospatial Memory

Visuospatial memory (VSM) is responsible for retaining and processing visual and spatial material. It plays a fundamental role in a wide variety of complex cognitive tasks, such as reasoning [25,26], learning [27,28], text comprehension [29-31], object position [32], and orientation and movement in the real environment [33-37].

Logie (1995) considers the visuospatial component to be composed of two short-term stores: the first (Visual Cache) is subject to decay and interference from new information, while the second (Inner Scribe) is a system dedicated to rehearsal of the contents of the visual store and movement planning using the information present in the other store.

Some studies have found effects in VSM that are similar to those present in the Articulatory Loop [38-40]:

– *visual similarity* effect: visually similar stimuli impair recall; this effect would confirm the existence of a temporary memory system based on a visual code. However, this effect seems to be much weaker than the phonological similarity effect, as it is often undermined by the strong tendency in adults to resort to verbal coding, which tends to prevent its onset;
– *effect of 'unexpected information*': visual stimuli to which no attention is paid produce interference, compromising visual memory;
– *effect of path length*: this refers to visual complexity, but experimental data are not yet sufficient due to the difficulty of 'quantitative' manipulation (length, amplitude, etc.) of the material to be memorised;
– *effect due to concurrent destructive activity*: if a spatial task is performed concurrently with an interfering secondary task (for example, 'spatial tapping': the subject is asked to move their hand on a tablet following a simple path, such as a quadrilateral, without looking).

The processing of visual characteristics (*what*: that is, the processing of the characteristics of what the object is like), and spatial characteristics (*where*: that is, the processing of the spatial relationships inherent to the object) use two different neural pathways, the *ventral* and *dorsal* pathways respectively. Within visuospatial processing, the dichotomies between categorical spatial information (to the right of/above, etc.) and co-ordinate/metric (numerical system of measurement) [41] and between sequential (positions of objects presented sequentially) and simultaneous (position of objects presented simultaneously on a matrix) processes. That is to say, the characteristics of an object are processed separately from the spatial relationships relative to the object itself, and the separation of the processing processes occurs at a peripheral level: the two pathways start independently from the retina, pass through the geniculate nuclei until they reach the associative areas of the cortex [42]. Therefore, the distinction between 'what' and 'where' is maintained even at a higher level of processing and even if at an experimental level, it is complicated to isolate the two processes at an intuitive level; on the other hand, if you remember the object, the visual aspect prevails, if you remember the position, the spatial element, if you place both, we speak of *binding*. In reality, it's not so simple to distinguish between the two aspects; for example, the same stimulus, such as a matrix with a series of blackened squares, can be interpreted as a configuration in which visual elements prevail and as a pattern that describes spatial relationships.

A further differentiation in the study of VSM architecture is between passive recall (previously acquired information that does not need to be modified) and active processing (processes of integration, manipulation, and transformation of previously learnt material retrieved from MLT) of visuospatial information [43].

Educational Implications

The proposed model seems to clearly indicate the 'focus' of a possible educational or re-educational intervention, which, in any case, will have to consider the elements that may be deficient or compromised in the process of analysing information [44]. Children with autism need numerous teaching sessions and, therefore, a very long time before learning takes place, which emphasises the centrality assumed in the last three decades of the programming paradigm. This paradigm of behaviourist inspiration has shown evident limits in its original formulation, such as, for example, in the rigidity of the formulation of objectives and in the pretextually 'objective' use of standardised taxonomies, even if it has had indisputable merit, among other things, of challenging improvisation and a certain idealisation of educational spontaneity. Through planning strategies and the curriculum, the need to give learning a logical and sequential order and ensure that it is effectively acquired and verified has been legitimately reaffirmed. From this point of view, behavioural choice has provided a significant boost to the process of 'flexibility' of educational models that include the following points: 1) multidimensionality of experience, 2) personality repertoires and cognitive styles of the educator and the student, 3) peculiarities of educational intervention and 4) scientifically controlled significant learning.

An educational model, therefore, should facilitate the acquisition by the student of a non-homologating, personalised cognitive style that allows him to interpret his own experience about what he is learning. These points represent a premise to be pursued that also concerns the actions of the educator, who should consciously build reciprocity in the educational relationship, according to the following factors [45]:

- Concrete *situation: rehabilitative treatment of subjects with autism (contextualisation of the problem);*
- *Formulating hypotheses: the why, how, when and where of specific behaviours (situation analysis and assessment);*
- *Traditional questions: tracing similar situations that have been resolved in the past (comparison of theories, models and methodological approaches);*
- *Research of sources: historical-experiential references of the situation (Involvement of all the people who interact with the subject);*
- *Significant elements: educational planning models similar to the one proposed, but more flexible (Interactive assessment);*
- *Current instances of confrontation*: spatiotemporal reprogramming of the educational action about other experiences or other treatments (Structured interventions versus Naturalistic interventions);
- *Elaboration of responses: providing indications on intervention procedures and operational tools (the strategies);*
- *Interpretation of situations*: creating and implementing an educational programme that is continually reinvented and reinterpreted according to the 'starting' behaviours (motivation) that each person with autism can activate at any time.

From this point of view, any treatment should try to realise a non-dogmatic idea of educational research, open to every area of experience and the most vital sectors of education, capable of combining methodological rigour and theoretical consistency, the need for critical reflection and operational concreteness, without losing sight of the person with autism [45].

Methodology

Participants

The study involved 11 participants aged between 7.1 and 10.3 years (eight males and three females; average age: 7.9). All participants, recruited from rehabilitation centres, had no visual or hearing problems and had received an independent clinical diagnosis according to DSM-V criteria (Level 2) [1] and had obtained a score above the cut-off for ASD in the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2) [46] and in the Autism Diagnostic Interview-Revised (ADI-R) [47]. Furthermore, before starting treatment, all subjects were given the Questionnaire for the Identification of the Functioning Profile (IPF) [48], and were subjected to two tests on selective attention (Figure 1 and Figure 2).

Procedure

The selective attention test consisted of: 1) presenting subjects with large capital letters composed of small capital letters (Navon Task) [49] (Figure 1) and identifying stimuli within more complex configurations (Figure 2). In the first test, the subject was asked 'Which letter is it?' without being given any clues as to which of the two letters to look at. In the second test, on the other hand, the subject was asked to identify a series of figures in the column on the left of a page within a more complex configuration of stimuli in which the exact figures were masked or 'hidden'. The image to be found was identical and oriented in the same way. The subject's effort lay in not being distracted by the other configurations (sometimes very similar) or remaining independent from the global perceptive field (Figure 2).

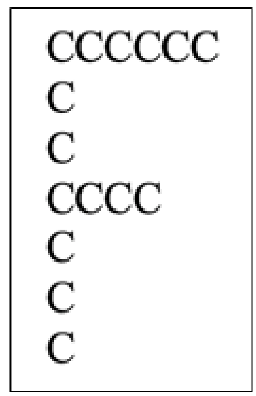

Figure 1: Presentation of a large letter (global level, F) composed of small letters (local level, C) asking the question: 'What letter is it?'.

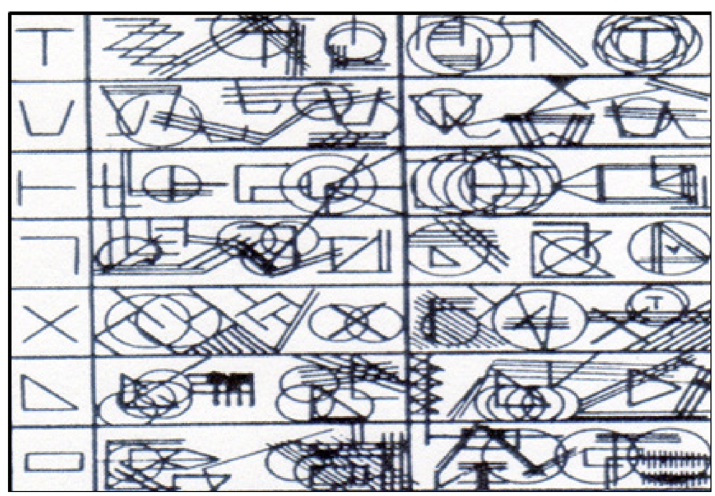

Figure 2: A simple shape (on the left) must be found within a complex design (the central and right-hand columns) in which it is hidden

Table 1 shows the responses of all subjects to the 'Navon Task' and the 'Hidden Figure', from which it can be seen that only one subject perceived the letter 'F' (Global Perception) while all the others perceived the 'C' (Local Perception). In any case, no child has shifted from an initial 'local' perception to a 'global' one or vice versa. Shifting was taught subsequently with verbal and gestural prompts. As for the 'Hidden Figure' test, the averages over five sessions are identical; only the subject who had a 'Global Perception' in the previous test had a much higher average time than the others (132s). This result could be explained by the interference of the 'Global' on the 'Local', which slowed down the scanning of the complex figure to search for the simple figure. The selection method considered their ability to 'match similar figures'. It was divided into three phases [50]: *1. Pre-test* to select the concept and the statement of equivalent identity and prepare the material; 2. *Test* to extract examples and non-examples and to state 'this is ...', 'this is not ...'; 3. Verification: number of correct and incorrect answers, indicating whether or not there was a component that acted as a 'distractor'. this is not ....'; 3. *Verification:* number of correct and incorrect answers, indicating whether or not there was the presence of a component that acted as a "distractor" (due to similarity) more than the other elements.

To test visuospatial memory skills, tasks were used on matrices involving the visuospatial memory store, selective attention and sustained attention; in other words, the subjects were trained to form 'mental images' (the term 'mental image' indicates the activation of the internal representation of an object or a scene in the absence of an external stimulus; Paivio, 1975; Kosslyn, 1080). For example, the children observed a matrix for a few seconds in which there were two figures (targets), and the task was to position the figures in another identical but empty matrix. The task was made progressively more complicated by the exposure time to remember it, the type of target (symbol, drawing, number, etc.), the size of the matrix (2X2, 2x3, 3X4, 4x4, etc.) and the number of targets (2, the simplest, 3, 4, 5, 6, like the one in the example) to remember and position (Figure 3). In this case we used the *shaping* procedure which is essentially based on reinforcing the student's behaviour that progressively gets closer and closer to the goal, in our case six images in a 4x4 matrix, starting from a 2x2 matrix with only two images. With this strategy, the repertoire of skills of the subjects was expanded, facilitating the construction of new skills [51]. In implementing the procedure, the following three points were considered:

- identification of the skill to be mastered (definition of the target behaviour: correctly positioning six images previously seen on a 4x4 matrix and for a few seconds on another identical matrix) and selection of the initial behaviour, i.e. a behaviour already present in the subject's repertoire that was related to the meta-behaviour (doing the same thing as just described but with a 2x2 matrix and only two images);

- delineation of a series of successive approximations, i.e. behaviours that, starting from the initial one, became increasingly similar to the meta one (same previous modalities but with 2x3, 3x2, 3x3 matrices, etc.; Table 1);

Setting up appropriate reinforcement programmes to ensure that the subjects could progressively master the various behaviours until they reached the goal (the reinforcements were differentiated, both from a qualitative and quantitative point of view, based on the complexity of the request: for the 2x2 matrix the reinforcement consisted of a little game with the tablet; for the 3x2 matrix the tablet was used to do a puzzle; for the 3x3 matrix and four figures, it was possible to watch a 30-second YouTube video; and so on up to the meta behaviour, 4x4 matrix with six images, in which the reinforcement consisted of using the tablet for thirty minutes, without restrictions on activities). All the children, except two, who are still working on it, have correctly positioned six images in a 4x4 matrix. The acquisition of this skill has allowed all the children to improve their interaction with the environment spatially correctly, move and relate to others and objects, and improve their autonomy and learning.

SUBJECTS	NAVON TASK		HIDDEN FIGURE	VSM	
	Local	Global	Average Time	Bl	T
Lina	X		52s	2/2x2	5/4x4
Paolo	X		54s	2/3x2	6/4x4
Luca	X		49s	2/3x3	6/4x4
Matteo	X		55s	2/2x3	6/4x4
Enzo		X	132s	2/3x2	6/4x4
Ciro	X		57s	2/2x3	6/4x4
Gianni	X		46s	2/3x2	5/4x4
Paola	X		51s	2/2x2	6/4x4
Clara	X		52s	2/2x2	6/4x4
Davide	X		49s	2/3x3	6/4x4
Carlo	X		53s	2/3x3	6/4x4

Table 1: Responses of each participant to the 'Navon Task' and the 'Hidden Figure', from which it can be seen that only one subject had an 'Overall Perception' of the letter and that the same subject had a much higher average response time than the others in searching for the simple figures in the complex ones. In addition, the results of the visuospatial memory tests are reported at baseline and after the treatment. The task required the subject to reproduce the exact configuration of images he had seen in an identical matrix on a special regular matrix. The task did not evaluate speed but rather the accuracy in reproducing the spatial relationships between the different figures.
VSM = VisuoSpatial Memory, Bl = Baseline, T = Treatment.

This procedure aimed to develop the different components of visuospatial working memory: visual (tasks that require the recall of visual information); spatial (sequential: ability to remember a series of spatial locations performed in temporal sequences; simultaneous: ability to retrieve spatial coordinates presented simultaneously); in turn, these components are distinguished as active processing (variable level of manipulation and processing of stimuli) or passive processing (simple memorisation of information).

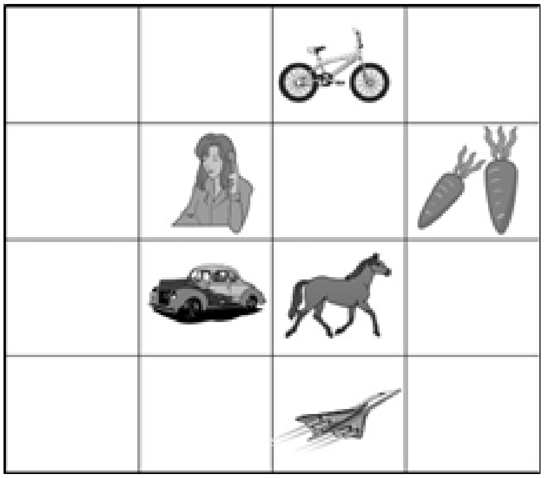

Figure 3: Example of a matrix used to test visuospatial memory, in which children, after observing a matrix containing two or more figures (targets) for a few seconds, had to position them in another identical but empty matrix.

Conclusions

This study shows that the sensory processing of all the subjects considered is of the bottom-up (data-driven processing) type because perception begins with the stimulus itself: the figures in the left-hand column of Figure 2. The process is directed from the retina to the visual cortex. Each subsequent stage in the visual perceptual pathway leads to an increasingly complex analysis of the input. Subsequently, a mental image of the figure is formed. Each stimulus characteristic is processed by an automatic process (without the intervention of attention), which, operating in parallel, leads to segmenting the visual field into perceptually significant objects, which produces an 'anchoring' of the focus (top-down process) and inhibits attention. The results validate the hypothesis that the top-down information from the visual context modulates the salience of the 'image' regions while identifying the figures.

Regarding the visuospatial aspect, it can be said that training aimed at acquiring and improving attention span and working memory should prioritise specific work on the visuospatial abilities that are notably lacking in subjects with autism. The most significant deficiency is the difficulty of integrating visual information with spatial information (binding) while remaining anchored to the same processing modality. For example, in the group of subjects considered by the study, eight were 'visual' and three 'spatial', and the way they constructed a puzzle was very different: the 'spatial' subjects managed to do it without looking at the design but only at the tile and the attachment 'buttons', while the 'visual' subjects always had to check the design and many times, if they were unable to do so, they tried to fit the tiles together even if there was no coincidence in shape for the 'attachment'.

The limitations of the work are due to the small number of participants and the impossibility of controlling all the variables that can affect the processing abilities of people with ASD.

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