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**Developing an assessment protocol to identify the  
characteristics of ASD using eye-tracking for educational  
purpose**

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**Abstract**

The understanding of how written social information is processed by individuals with autism spectrum traits is important for the development and implementation of suitable educational interventions. The use of eye-tracking methodology offers us the possibility to analyze how information is being selected and has a great potential to inform our understanding of cognitive processing in individuals with neurodevelopmental disorders. Our main goal is to develop an assessment protocol, which could identify if there are differences in the way individuals with low autism spectrum traits and high autism spectrum traits process written social information. This information helps to specify the development of educational techniques for individuals with autism spectrum disorder. This study provides the necessary steps for the protocol implementation. We propose an experimental design that can clarify if there are some specific visual patterns when processing social information in the context of autism traits. The findings of our work could document future intervention techniques for social skills.

*Keywords:* social information; eye-tracking; autism spectrum traits; special education

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## **1. Introduction**

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by some degree of impaired social behavior, communication and language, along with restricted patterns of interest and repetitive behaviors (American Psychiatric Association, 2013). Social communication impairments along with the presence of restricted interests and repetitive behaviours represent the central features in ASD (APA, 2013).

Inclusion of students with disabilities has increased over the past 20 years. The inclusive practices have given students with disabilities to gain knowledge in general education curriculum and learn academic skills. While the students with ASD are unique, their strengths and needs will surely differ (Ferraioli & Harris, 2011). In order to best support students with

ASD, it is essential that general teachers, special education teachers, and parents collaborate together to better understand and develop the unique strengths and needs of these students.

The Centers for Disease Control and Prevention's most recent data regarding autism prevalence, released in April 2019, estimated about 1 in 59 children identified with ASD. While research has yielded much on understanding the biology of autism, the mechanisms and ways in which information is processed and is being used by people with ASD remains a challenge.

The most researched diagnostic instruments for ASD, such as Autism Diagnostic Interview-Revised (Rutter, Couteur & Lord, 2003) and Autism Diagnostic Observation Schedule (Lord, et., al., 2012) provide us some clues regarding the behaviours that are being investigated in the assessment phase. Therefore, the clinicians should consider children's social initiations and responses, their joint attention episodes, their social play and their repetitive and stereotypic movements (APA, 2013). Even from the beginnings of research in ASD and also the above mentioned assessment batteries introduce the idea that there are some abnormal gaze patterns in individuals with ASD that clinicians should pay attention to (Kanner, 1943). In the last decade the advances in technology, more exactly the use of the eye-tracker in the research of ASD allowed us to investigate this unusual eye contact pattern and a large number of eye-tracking studies supported the idea of the deficits in attention to social information as a key feature of ASD (Klin, 2013; Sasson & Ellison, 2012; Papagiannopoulou, Chitty, Hermens Hickie & Lagopoulos, 2014).

When analyzing the studies in this domain, different stimuli have been used and diverse regions of interest within these stimuli and the majority of the studies reached the same conclusion of social attention differences, ranging from decreased fixation to others' eyes (Klin, 2013) and social scenes (Chawarska, Macari, & Shic, 2013), to aberrant gaze toward dynamic social stimuli in older cognitively-able individuals (Rice, Moriuchi, Jones & Klin, 2012). However, the increased heterogeneity across eye-tracking studies makes definitive conclusions regarding the exact nature of gaze abnormalities unclear (Frazier et.al., 2017). Findings from two recent meta- analyses show small-to-medium reductions in looking to socially relevant regions, particularly eye and whole face regions, (Papagiannopoulou, et.al., 2017) and increased gaze to less relevant regions of the stimulus (e.g., nonsocial regions) (Chita-Tegmark, 2016).

The results from more than one decade of eye-tracking studies in the domain can be divided in two major approaches. The first approach, referred as social processing theories, highlights abnormal attention to social and affective stimuli, and the main theories that sustain this pathway are theory of mind (Baron-Cohen, Leslie & Frith, 1985), intentional attunement (Gallese, 2006) and social motivation theory (Chevallier, Kohls, Troiani, Brodtkin & Schultz, 2012). The second approach refers to a more general way of cognitive processing, a nonsocial way, which is independent of the social or affective content. Here we mention the theories, which state there are more general executive functions deficits in ASD (Hill, 2004) and the theory developed by Frith and Happe (1994) that refers to hierarchical dimensions within perceptual patterns (eg. global vs. local). However in some cases it is very difficult to make a clear distinction between the two types of approaches, particularly because the direction between cognitive processing and the stimuli that are being analyzed is bidirectional. For example, when analyzing the way executive functioning may explain the social deficits in ASD, the findings may be influenced by the affective nature of stimuli while attention to social information can be influenced by basic sensory processes and stimulus complexity (Frazier et. al., 2017).

Therefore the studies using eye-tracking methodology most likely will not provide direct evidence for confirming or excluding some of the above mentioned theories, but it can inform our understanding of core features that are prominent in a majority of ASD cases. Moreover, when it comes to intervention for social deficits, the most used methods involve social scenarios modeling. For example, Social Stories (SS) are considered among the most promising interventions for children with ASD for improving social skills (Heward, 2006). Although practitioners use multiple visual support for delivering SS, Carol Gray (1995) proposed the technique based on written social rules which are necessary to be respected when interacting with others and which also have the role of self-regulation. As mentioned above several studies have documented the presence of social attention deficits when looking at social scenes or photos, but to our knowledge there are no studies that investigate the way individuals with ASD process written social information in terms of their visual patterns. This aspect could represent an important piece of the puzzle when it comes to understanding how individuals with ASD process the social information especially because an alternative of learning from face to face social interactions is the explicit learning of social rules that govern our behaviors. However, if we want to use these types of techniques in practice, learning explicit social rules for a particular situation, the individuals need to use their reading

abilities. When it comes to reading abilities there is one important aspect that also needs to be considered, which is reading comprehension (Benedek-Molnár, 2013).

### *1.1. Reading comprehension in individuals with ASD*

Reading comprehension is part of the reading ability, which is broadly argued to be an impaired ability in children with ASD. There is evidence that some children with ASD can read accurately, but even amongst these children, levels of reading comprehension are poor (Minsheu et al., 1994; O'Connor & Klein, 2004; Snowling & Frith, 1986). The process of reading comprehension seems to be influenced by language development and decoding skills, and it includes a variety of cognitive skills (Gogh, 2018). When trying to explain the reading comprehension deficits in ASD population there are two possible explanations. The first one may be that the cognitive impairments related to the social communication deficits that characterize ASD overlap with the cognitive demands of reading comprehension (Solari et al., 2017). Meaning that the failure to acquire reading comprehension in the school age years is an important part of the cognitive and social communication phenotype for individuals with ASD (Norbury & Nation, 2011).

On the other hand, Cornoldi, Giofré, Orsini, & Pezzuti, (2014) propose that when it comes to the understanding of written information we should pay less attention to the general intelligence and more to the factor indexes representing intelligence: verbal comprehension (VCI), perceptual reasoning (PRI), working memory (WMI), and processing speed (PSI). Therefore reading comprehension deficits in ASD may be predicted by a specific cognitive profile, including verbal comprehension and perceptual reasoning. One can also define reading comprehension as the ability to decode, to process the information, to operate with the information in the working memory, and then understand the spoken language. Word decoding seems to be more important at a younger age and; linguistic comprehension becomes a more pertinent predictor of reading comprehension in middle elementary years and later (Kendeou, Van den Broek, White, & Lynch, 2009; Vellutino, Tunmer, Jaccard, & Chen, 2007).

In light of this approach and considering the need to have a deeper understanding of how children perceive social information we propose to explore the possibility if the two factors mentioned by Cornoldi et al, (2014) VCI and PSI represent good predictors for information understanding. There is a gap in the present literature considering whether if social information, for example from social scenarios, is perceived in a different way than non-

social information. Information that can be useful for understanding different cognitive profiles of children with ASD and can be applied in the development of interventions for social skills. Therefore we plan to assess reading comprehension and visual attention of children with ASD using a technology-based approach based on eye-gaze methodology.

For identifying visual attention patterns in relation to text reading in a more accurate and objective way we propose to use eye-tracking methodology. Based on prior studies using eye-gaze methodology we hypothesized that, due to their specific abilities children with ASD may focus on those parts of the text that are not relevant for text comprehension, limiting their understanding of the written information. Another possible assumption is that individuals with ASD will use different visual attention patterns when analysing social vs. non-social information. In order to test our assumptions we propose the following theoretical model based on information processing theory (Figure 1), which considers visual attention and reading comprehension as predictors of how social information may be understood by children with ASD.

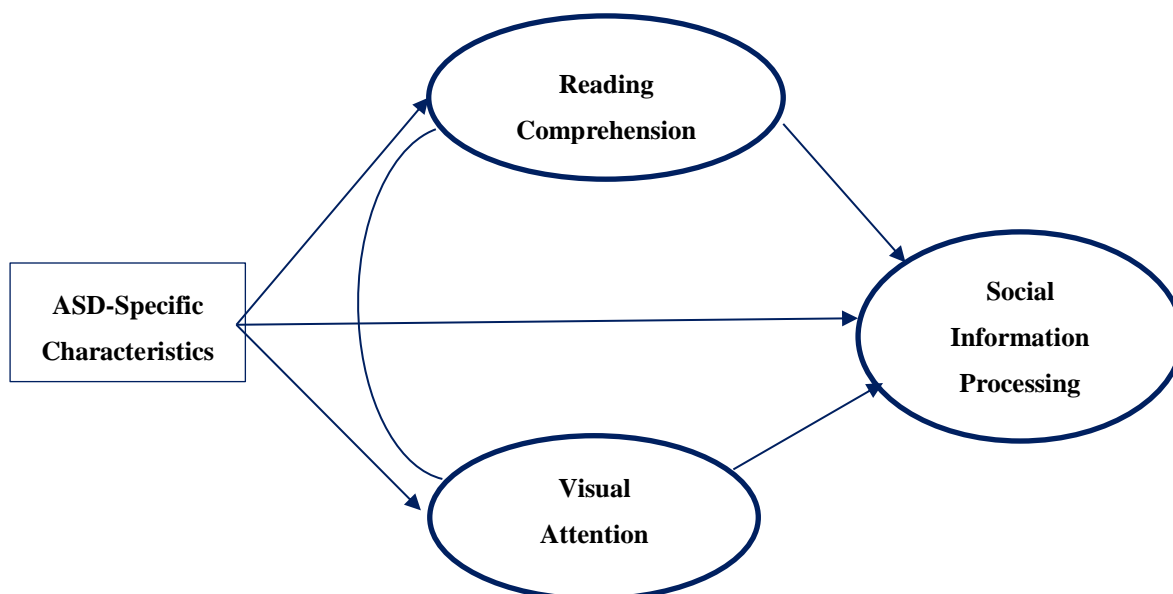


Fig. 1. A theoretical model which may explain the social information processing in children with ASD

Nowadays, eye-tracking measures of social attention are considered to be a potential biomarker for ASD (Murias et al., 2017). These types of measurements can offer us important objective and accurate information regarding the way children process social information. During our study, we plan to observe and record the route of the gaze of the participants, a research-grade device, the Gazepoint GP3 eye-tracker will be applied, which had successfully been applied in some previous research (Edelman, Meng, Gulachek, Cline & He, 2018,

Kovari, Katona & Costescu, in press). The data obtained with the GP3 will be used with OGAMA (OpenGazeAndMouseAnalyzer), which is an open-source code application (Adrian Voßkühler) that tracks eye and mouse movements and record and analyse the received parameters. The use of eye-tracking measures together with the analysis of the visual patterns could provide valuable information regarding the visual attention of children with ASD in reading, which previously has been limited to some standard paper-pencil tests.

Thus, our main goals of the study are based upon the following: a) the demand for better understanding of the way children with ASD perceive social information; b) the need for developing new effective interventions for improving social skills which may impact daily activities of children with ASD; and d) the necessity to increase accessibility of evidence based-interventions for children with ASD. In order to answers the above challenges, firstly we need to test and validate our proposed theoretical model. In this way we could better understand which are the predictors of accurate social information processing in the case of children with ASD.

When it comes to autism spectrum traits it is believed that individuals with high autism spectrum traits are linked to difficulties in understandings others perspective and with reduced empathy (Wheelwright *et. al.*, 2006). Although past research has linked autism spectrum traits to deficits in the perception of others, as noted earlier, it remains unclear whether autism spectrum traits also predict deficits in social cognition. As mentioned above, our main goal is to develop an assessment protocol, which could identify if there are differences in the way individuals with low autism spectrum traits and high autism spectrum traits process written social information. The assessment protocol has three main objectives, as it follows:

Objective 1: to identify if there are differences in the social information processing (considering their visual attention patterns and reading comprehension) between individuals with high and low autism spectrum traits.

Objective 2: to investigate if there are differences in the visual patterns when reading social vs. non-social information in both groups.

Objective 3: to investigate the association between high autism spectrum traits and their social cognition considering also their visual attention patterns.

## 2. Methodology

### 2.1. Participants

In our study we expect to enroll approximately 80 subjects. The participants' age will vary from 18 to 20 years old. The sample will consist from first year university students in Pedagogy and Special Education, Babes-Bolyai University, Cluj Napoca. All of the participants will sign an informed consent form. The exclusion criteria will consist in having a diagnostic of a psychiatric disorder or severe visual impairments.

### 2.2. Instruments

*Autism Spectrum Quotient* (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) is a 50-item scale that measures ASD traits both in clinical and community samples. The questions from AQ are rated on a four-point scale from "Definitely Disagree" to "Definitely Agree" and included items such as "I enjoy meeting new people" and "I would rather go to a library than a party". The instrument has 5 subscales measuring: social skill, attention switching, and attention to detail, communication and imagination. The AQ has good construct validity and internal consistency (Cronbach's alpha 0.83).

*Dewey Story Test* (Dewey, 1991) It is a vignette-based test that measured implicit social cognitions and it requires that participants depict violations of social norms using eight sample situations. The participants are explicitly asked to rate how they thought most people would judge the described behaviour in the stories if they witnessed it, according to a multiple-choice answering format. (See an example in the methodological part).

*Prove MT di Comprensione Elementari e Medie* (Cornoldi & Colpo, 1995). The MT reading tests, prepared at the Institute of Psychology of Padua by the MT research group, allow us to examine the reading comprehension from the first class of primary school to the third class of middle school. These tests are differentiated by age: the syntactic and semantic difficulty, the length and the size of the typographical character of the pieces, vary according to the class they are addressed. The MT reading tests are divided into tests of comprehension and tests of correctness and speed, and allow the assessment of the levels of learning achieved by children at different times of the school year (Molnár 2013) (Ujbanyi, 2017). Although our participants are older than third class of middle school we use this texts in order to analyse the visual patterns of the participants in text readings not the comprehension level.

### 2.3. *The evaluation of the parameters of the eye movement*

During the experimental tasks we plan to analyze the following parameters: the number of fixations, the average fixation duration as well as the average saccade lengths in pixels. We also plan to examine the attention maps generated by the OGAMA software, which will be determined while recording the route of the gaze. In the attention map there are the following colors: red, yellow, green and transparent field. The red color means that the participant focused his/her attention in that region for a longer period of time; yellow color means that the participant focused their attention in a specific area for a medium length of time; green means that the participant focused his/her attention for a short time and transparent field means that the participant focused his/her attention only for a very short time. Considering all the above-mentioned parameters we will try to extract visual attention patterns that may be characteristic for a certain type of participants (low or high autism spectrum traits) or for a certain type of text (social vs. non-social).

### 2.4. *Procedure*

The GazePoint 3 (GP3) eye-tracker hardware unit and the OGAMA software package will be used in the research to observe eye-movement tracking and to record the metrics.

#### 2.4.1. The Gazepoint GP3 eye-tracker hardware unit

The Gazepoint GP3 eye tracking system will be used to collect data from participants. This system is recommended for use with single displays up to 24" and provides data at a 60 Hz sampling rate. Data recorded includes a user's left and right pupil diameter (in pixels, corresponding to a fraction of the camera image size) and left and right point-of-gaze (x and y-coordinates on the screen). The software also enables capture of the location of each eye in 3D space, with respect to the camera, as well as pupil size, all in meters. Fixation data (x and y-coordinates and duration) will be also available. GP3 is an ultra-portable device (320 x 45 x 40 mm, 145g) that can move 25 cm horizontally, 11 cm vertically and 15 cm in depth; it can be fitted on the monitor and uses infra camera observation and image procession to detect and follow eye movement with 60Hz sample rate.

#### 2.4.2. The OGAMA software package

The OGAMA (is an open-source code application that allows recording and analyzing eye-tracking and mouse tracking data from slideshow eye-tracking experiments. The main



features of the application include slideshow design, database-driven preprocessing, attention map creation, filtering and recording of gaze and mouse movement data and the areas of interest definition and saliency calculation (Itti, and Kock,2001) (Sziladi, 2017). Furthermore, data stored in the database can be exported for different statistic software in proper formats, which eases efficient statistic evaluation. The application supports several gaze routes observing and recording hardware units, including the Gazepoint GP3 hardware unit as well.

### 2.4.3. Implementation Steps

Firstly the Gazepoint software package will be installed; the package contains the camera driver. After successful installation, the device will be connected through a USB and it will be placed under the monitor which will be used to run the experimental tasks approximately 65 cm length distance from the eyes. Later the Gazepoint Control application will be started, which supports the configuration and the start of the gaze-date server, ensuring real- time information obtaining. Afterwards we will start the OGAMA software.

The participants will enter in the laboratory one by one. At the beginning they will sign an informed consent and a questionnaire containing their demographical information. They will answer then to the questions from the AQ in order to identify their profile as having low or high autistic traits. All the data gained from each participant will be saved on the server. Data collection will occur during one single session. Right before starting the experimental task the calibration process needs to be done. The calibration will consist in tracking a circle with eye movement from the top left corner of the monitor without moving their heads. After the calibration the participants will see their eye gaze rendered on the screen in real time in order to qualitatively verify the accuracy of their calibration. If the calibration process will fail we will ask the participants to do it one more time. The experimenters will check the distance from the monitor and the calibration process for each participant.

After calibration, participants will be instructed to look at the screen and select with mouse the correct answer. Afterwards we expect the participant to engage in two consecutive tasks: nonsocial written information and social scenarios (see some examples for Task 1 and Task 2 below). Each task will have 8 written texts and each text will have a set of questions. The social scenarios will have two types of questions: which measure social cognition and comprehension. The nonsocial written information text will have only the comprehension questions. Most importantly, each of the two tasks will require the participant to focus his/her

attention in the center of the screen and all input will be provided by mouse clicks on the screen, so participants did not have to divert visual attention away from the screen, to the keyboard. Each task will take a variable length of time to complete, depending on how quickly participants input their responses. All the tasks will have a limited area in which relevant information will be displayed and for purposes of this paper are considered to be low in visual complexity. During the reading process and also while they answer to questions the eye movement parameters will be observed and recorded, and after finishing the test, the data will be saved into a database for further statistic evaluation.

#### Task 1: Social Scenario extracted from Dewey Story Test (Dewey, 1991)

*“6:1 Roger, 22, lived in a rented room alone. He was quite a nervous person, but it seemed to him that he felt better if he ate every two hours and limited his diet to certain foods. One day, a lady called and invited him to dinner, explaining that she was a friend of his parents. Roger gladly accepted. **However, he warned his hostess that he eats no meat and would like his vegetables served unsalted.** 6:2 When Roger arrived at the appointed time, he recalled that he had not eaten for two hours. **Without wasting any time, even before the introductions, he asked his hostess when dinner would be served.** 6:3 She replied that it would be about an hour before the meal would be ready. **Hearing this, Roger opened his briefcase, removed an apple and some nuts, and promptly ate them.** 6:4 After that, he was introduced to the family, and they sat talking for an hour. Just before dinner, the hostess showed him an attractive platter of fruits and vegetables, asking whether it looked like enough. **‘It looks fine, thank you’, Roger said, ‘but if you don’t mind, I will wait another hour to eat. I just had some food an hour ago’.** “*

#### Social cognition questions

Rate how do you think that most people would judge the described behaviour in the stories if they witnessed it:

- 6.1 a. It is strange to take food from strangers yes/no
- b. It is normal/not normal
- c. Because he is a vegetarian it’s like being allergic, then you should also tell people yes/no
- 6.2. a. It will be strange yes/no
- b. One usually does not act like that yes/no
- 6.3. a. If you’re hungry you must eat yes/no

- b. You shouldn't eat anything before dinner yes/no
- c. Fruit is not wrong to just eat, but the nuts? yes/no

**Comprehension question**

Roger needs to eat every two hours because:

- a. he has a medical condition
- b. he has lactose intolerance
- c. he becomes irritable
- d. he needs to have a snack before dinner

Task 2: Non-social information – sample from Prove MT (Cornoldi & Colpo, 1995)

*“The days began to get longer: with his moped, at the end of the work, Mircea was going to explore the river and its fluencies upstream from the city. He was particularly interested in the places where the water flowed further down the paved road.*

*Once he was lost: he was going through steep ravines and you swarmed, and he could no longer find any path, he didn't even know where the river was: suddenly, removing some branches, he saw, at a few palms below him, the silent water - it was a wide area of the river, which had formed a small, calm accumulation - light blue in color, looking like a small mountain lake.....”*

**Comprehension questions:**

Mircea searched, along the river bank, for a place:

- a. in the vicinity of the road.
- b. away from traffic and dust.
- c. where the road goes down.
- d. where it was possible to reach on foot.

**3. Data analysis and expected results**

For the data analysis we will use SPSS 20. We can answer to the research questions by using correlational design and we can test the mentioned predictors from the theoretical model with multiple regression analysis. In order to test some possible mediators we will use the mediation analysis a methodological approach proposed by Preacher and Hayes (2008).

In terms of the possible findings, we expect to identify some differences in the social information processing, considering both their visual attention patterns and their rating the social vignettes (from Dewey Story Test), between individuals with high and low autism spectrum traits. Meaning that we expect that individuals with high autism spectrum traits to focus less on the strange behaviours from the vignettes and therefore rate it as more usual behaviours than individuals with low autism spectrum traits. However, we plan also to test to what extent one or another visual strategy of analysing the texts may also influence the rating of the behaviours or if the comprehension of the text influences in a way the answers of the participants. Considering the fact that the comprehension questions are very easy for their age level we do not expect to find any significant differences neither between groups nor between texts. The only difference that we expect to see in terms of how they understand the texts (reading comprehension) will be incorporated in the composite indicator of the visual patterns. In order to better analyse reading comprehension as a predictor for social information processing a group of individuals with a diagnosis of ASD is needed to be included in the study.

Another interesting questions that our study tries to answer is whether there are differences in the visual patterns, fixation time and area of interest when reading social vs. non-social information. Considering the approaches described in the introduction part for the understanding of social and attention deficits of individuals with ASD, we do expect to find some differences in the way social vs. non-social information is perceived and processed. One of our assumptions it that when social content is being analyzed people tend to focus their attention for a longer period of time. It would be interesting to see if the relation between high autism spectrum traits and the ratings of the vignettes is being mediated by a particular visual attention patterns terms of area of interest or fixations. Also interesting analysis could be developed if we consider the five subscales of the AQ. For example, it would be interesting to see which of the following: social skill, attention switching, and attention to detail, communication or imagination better predicts social cognition in both groups.

#### **4. Conclusion and discussion**

Children with autism may have trouble understanding or communicating their needs, they can have difficulty understanding some classroom instruction, and they have difficulties with imaginative or creative play interactions and mean that many teaching strategies will not be effective. It is necessary to better understand the differences of students with autism to

develop specialized curriculum content, teaching methods, learning environment, support and services for these children.

Our main goal is to develop an assessment protocol, which may test if there are differences in the way individuals with low autism spectrum traits and high autism spectrum traits process written social information. The answers to this question may have important implications not only for the understanding of how individuals with ASD think and process social information but also can guide the development or improvement of the techniques that aim to target social skills and inclusion these students in the general education process.

Although our work is only in an incipient phase, proposing an experimental design for testing an theoretical model, we believe that it has a great potential in the domain of eye-tracking application for special education. Further steps in our work, after implementation of the proposed experimental design, will be to involve first grade relatives of children with ASD. Only after our theoretical model is being validated on several samples we propose to investigate the proposed variables on special population.

In the proposed assessment protocol we can only partially test and validate the proposed theoretical model, especially because the proposed sample of participants consist of individuals that have only autism spectrum traits and not a autism diagnosis. We consider this step to be an intermediate and a necessary one for the validation of the theoretical model, considering the difficulties that may arise when testing individuals with a diagnosis using sophisticated technological tools. Another possible constrain that needs to be considered is the fact that the reading comprehension may not be affected by the autism spectrum traits as it is in the case of a diagnosis of ASD. Accordingly we will consider reading comprehension only from the perspective of visual patterns in reading social vs. non-social information in the absence of deficits in the reading ability (which will be the case for our participants). Future studies are needed to be implemented in order to verify our model that should involve individuals that have a ASD diagnosis.

The understanding of social and attention deficits in individuals with ASD is important not only for the diagnosis process but also can document the development and implementation of suitable interventions. The use of eye-tracking methodology offers us the possibility to look into every moment of the information selection and has a great potential to inform our understanding of cognitive processing in individuals with ASD (Nelson, 2012).

Regarding the practical implications of our work, we consider that the findings from this research could help the practitioners to increase the effectiveness of SS or other techniques that are based on written social scenarios. By analysing the visual patterns of individuals with high autism spectrum traits or with a diagnosis with ASD in reading a social text we may extract relevant features regarding the way they process the information which may lead us to improving or modifying the way we present them the texts.

The use of technological tools in special education appears to bring more light in terms of diagnosis, underlying mechanism and interventions. These findings may impact daily activities of children with special needs and can increase accessibility of evidence based-interventions for them and help to identify the best teaching methodologies for better inclusion these children in the general education.

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