Correlating perceptual load capacity and sensory symptoms in autistic and neurotypical adolescents

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Abstract

Autism Spectrum Condition (ASC) is a lifelong, neurobehavioural condition that affects 1 out of 68 people, which equates to approximately 700,000 people in the UK. Although the condition presents differently in each individual, there are some commonalties relating to social and non-social behaviours. In this study, the aim was to correlate the perceptual capacity, defined as the amount of sensory information you can process at any one time and recently proven to be enhanced in autistic groups, in neurotypical and autistic adolescents aged 11-18 and sensory questionnaires to meet requirements of ecological validity. Psychological laboratory experiments often fail to provide realistic assessment of behaviours and thus representation of abilities; therefore, the development of more ecologically valid experiments may improve the 'representativeness' of a given task, leading to more robust findings. Owing to study limitations, such as small sample size (autistic group n = 6), quantitative data could not be compared for the two groups. Data from the neurotypical groups revealed that the perceptual load capacity was effectively manipulated in the administration of the tasks but failed to provide meaningful correlations between sensory questionnaires and the performance in the auditory processing tasks. Future studies would aim to expand sample size, with the ultimate aim of increasing our understanding of this complex neurodevelopmental condition.

Abbreviations

AASP	Adolescents/Adult Sensory Profile
ASC	Autism Spectrum Condition
CS	Critical Stimulus
EEG	Electroencephalography
FIQS	Full Scale Intelligence Quotient
MEG	Magnetoencephalography
MMN	Mismatch negativities
MRI	Magnetic Resonance Imaging
RRB	Repetitive, Restricted Behaviour
RT	Reaction Time
SCI	Social Communication and Interaction
SPQ	Sensory Perception Questionnaire
SSP	Short Sensory Profile
WASI	Wechsler Abbreviated Scale of Intelligence

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Introduction

Autism Spectrum Condition

Autism is a neurodevelopmental, lifelong condition characterised by differences in two main domains: Social Communication and Interaction (SCI) and Repetitive, Restricted Behaviour (RRB) (Frazier et al., 2012; McPartland, Reichow, & Volkmar, 2012). The word "autism" was first coined by Paul Eugen Bleuler, a Swiss psychiatrist, to refer to aspects of schizophrenia in adults (Bleuler, 1912); the term was later adopted by Leo Kanner (1943) to describe people who had a "need for sameness" or "a resistance to change" (Kanner, 1943, 1949). Originating from the Ancient Greek word "autos", "self" in English, it was originally suggested, autistic people experience a sense of detachment from the real world, whereby they tend to hide in their "self", developing feelings of personal inadequacy (Bleger, 1974; Eisenberg & Kanner, 1955). Since these early definitions, it is now acknowledged autism is a spectrum condition that affects how people perceive and experience the world, and how they interact with others. In recent years, attitudes in the UK are shifting towards autism awareness and acceptance, and an understanding of the difficulties autistic people are presented with in navigating a neurotypical world. The ultimate aim of this research and CRAE's wider research is to improve autistic people's quality of life.

Social Communication and Interaction (SCI)

Social skills are extremely crucial in our lives. They include the ability of interpreting social cues, predicting people's responses and dealing with person-to-person relationships (Bauminger, Shulman, & Agam, 2003; Paul, 2003). For autistic individuals, these actions might be more challenging. For example, in autistic children and adolescents, it has been shown they may struggle to take turns while playing, sharing toys or engaging in conversations with their peers. In adulthood, this may evolve in difficulties in maintaining relationships and in securing employment (Parsons & Mitchell, 2002). In conjunction with social interaction, autistic individuals may experience different communication abilities (Lenroot & Yeung, 2013); including verbal skills, i.e. use of expressive language, intonation and fluency (Bishop & Norbury, 2002), and in non-verbal skills, such as, eye-contact, hand gesturing and understanding facial expressions (Bishop & Norbury, 2002; Kasari, Brady, Lord, & Tager-Flusberg, 2013).

Repetitive, Restricted Behaviour (RRB)

Autistic people may present rigid and/or repetitive patterns of behaviour; this could be represented by adhering inflexibly to routines, performing the same movement or repeating words, however, may change over a person's lifetime (Frazier et al., 2012; McPartland et al., 2012). Rocking or flapping of the hands – also known as stimming (self-stimulation) – is thought to demonstrate pleasure or in times of anxiety, and rather than discouraging these behaviours, they may be used as a way to communicate and for 'sensory seeking' to provide comfort. In addition to this, they tend to develop a very narrow range of special interests, such as, mathematical calculations, train timetables or tractors (Wing, 1997), showing an incredible knowledge and curiosity in items. It has also been shown that there may be differences in sensory processing skills in autistic people (Jambaque, Mottron, Ponsot, & Chiron, 1998; Ornitz, Guthrie, & Farley, 1977; Volkmar, Cohen, & Paul, 1986); a number of studies that the Short Sensory Profile questionnaire (SSP) results of autistic children show a significant difference in tactile sensitivity and auditory filtering compared to neurotypical children (Lane, Dennis, & Geraghty, 2011; Lane, Young, Baker, & Angley, 2010; Tomchek & Dunn, 2007). Additionally, the use of neuroimaging techniques, including electroencephalography (EEG), magnetoencephalography (MEG) and Magnetic Resonance Imaging (MRI), has helped to delve more into this widely spread feature in the autism spectrum: (Marco, Hinkley, Hill, & Nagarajan, 2011). Autism presents itself as a very wide spectrum; autistic people may exhibit different combinations of behaviours and it is imperative that large sample sizes and data sets are analysed in order to ensure research is robust to provide evidence based support to ensure the best quality of life for the autistic population.

Prevalence

Data on epidemiological surveys of the incidence of autism have been circulating since 1960s (Fombonne, 2003). Up-to-date analysis of the prevalence of autism in the UK showed that 1 out of 68 individuals have a diagnosis of autism (The NHS Information Centre, Community and Mental Health Team, Brugha, T. et al, 2012). Whilst data sets failed to correlate ASC with specific ethnic/cultural background, it is evident that the size of data sets appear to differ between high- and low-income countries and screening opportunities within high-income countries are often variable, factors which limit the power of such statistical analysis (Elsabbagh et al., 2012). With regards to sex prevalence, a body of evidence shows a male preponderance of autism in the population; the commonly agreed ratio for it is about 4:1 male/female (Werling & Geschwind, 2013). Why autism appears to be a male-typical conditions still remains unclear; it has previously been shown that X-linked genes mutation may be responsible for autism but at the same time it could be argued that male preponderance is noticeable because diagnostic criteria are developed and standardised with male samples, meaning that many girls may be misdiagnosed (Jamain et al., 2003; Laumonnier et al., 2004). This mixed picture about prevalence in autism clearly underlines that more studies need to be conducted to draw more definite inferences

Aetiology

Many studies attempted to identify the causes of autism but no clear answer has been found yet. Research on autistic twins revealed that the concordance rate, the probability that two individuals exhibit the same biological trait, for monozygotic twins reaches approximately 90%, as opposed to 20% in dizygotic twins (Bailey et al., 1995; Mason-Brothers & Mo, 1985; Steffenburg et al., 1989). This paved the way for more thorough research studies on genetic roots for autism and many publications have successfully identified variations or insertions of genes in coding regions that could potentially be responsible for ASC (Ingram et al., 2000; Risch et al., 1999). It also believed that no single gene is responsible for autism: due to the heterogeneity of autism, it can be asserted that more genes are accounted for the development of autism (Toriello, 2016); studies discovered a number of genes, including *CHD8, DYRK1A, GRIN2B, TBR1, NLGN3* or *NLGN4,* whose mutation may predispose to autism (Jamain et al., 2003; O’Roak et al., 2012).

In contrast, other studies have indicated that neurophysiological differences may be identifiable between neurotypical and autistic individuals: it has been suggested that the size of the amygdala presents differently in autistic people, which has led to speculation around elevated feelings of anxiety and differences in social and communicative skills (Juranek et al., 2006; Munson et al., 2006) and a reduced number of Purkinje fibres has been noticed in a number of studies, which could potentially lead to deceleration in response times (Courchesne, 1997).

Perceptual load capacity

According to the most recent set of diagnostic criteria (American Psychiatric Association, 2013), ASC is associated with differences in sensory processing skills; in other words, the amount of sensorial stimuli autistic individuals can process at any given time is different to that of neurotypical people. Recent research studies show that the perceptual load capacity of autistic individuals is enhanced compared to neurotypical control groups, demonstrating unique strengths and abilities (Remington & Fairnie, 2017a; Remington, Swettenham, Campbell, & Coleman, 2009; Swettenham et al., 2014) . These findings will be further explored in this report.

The Load Theory of Attention and Cognitive Control

The studies regarding perceptual load capacity are built on ‘The Load Theory of Attention and Cognitive Control’. The theory states that the rate of distraction in a task is dependent on the perceptual load, which is defined as the amount of sensory information processed at any one time; the capacity of processing task-relevant stimuli will “spill over” to detect irrelevant stimuli if the perceptual load is low; conversely, if the perceptual load is high, such that it exhausts the total perceptual capacity, distractor processing will not be seen (Lavie, 2005). Two main domains have been taken into analysis while trying to assess perceptual load capacity in autistic and neurotypical groups: visual and auditory domain.

Visual domain

The assessment of perceptual load capacity in the visual domain is conducted by utilising two types of task: a search task (primary) and a detection task (secondary) (Remington, Swettenham, & Lavie, 2012; Swettenham et al., 2014). In the search task, participants were asked to identify whether they were able to see target letters (X or N) in a circle of letters; to increase the perceptual load, more letters were added to the circle. The detection task involved identifying whether, a grey scribble (critical stimulus; CS) was present on the screen or not. Participants were asked if they had seen a target letter and the CS at the end of each trial (Remington et al., 2012). Another study proposed two slightly different tasks, still following the differentiation search and detection task (Swettenham et al., 2014). For the former task, participants were asked to identify which arm was the longest in a cross; for the latter, they were required to detect a shape in one of the four corners of the cross. In case they detected anything on the screen, an additional question asking what they saw exactly was included. The results of both studies match; autistic individuals performed significantly better than non-autistic control groups, demonstrating that their perceptual load capacity is enhanced i.e. they can process more information at any one time. The studies highlight the positive aspects of these unique abilities to what people often refer to as being a disadvantage: capitalising on autistic people's strengths is key in order to improve their overall quality of life.

Auditory domain

As per the visual domain, two types of tasks were used to assess perceptual load capacity in the auditory domain: search task and detection task (Fairnie & Remington, 2016; Remington & Fairnie, 2017b). In the former, participants were asked to identify whether they could hear the dog's bark or the lion's roar in different audio recordings. In the latter, they were asked to press two different key presses, according to whether they could hear a car sound (CS) or not. Participants were asked what animal sound they heard and if the CS was present at the end of each trial (Fairnie et al., 2016). Concordantly with the studies in the visual domain, autistic individuals performed significantly better than neurotypical groups, i.e. they were able to hear the CS as well as perform the animal search task, which provides further confirmation that perceptual load capacity is increased in autistic people (Remington & Fairnie, 2017b). In addition to this, participants were also asked to listen to a conversation about a birthday party; during the dialogue, a voice repeating "I'm a gorilla" appears and, at the end of recording, participants were asked questions about the conversation, as well as, if they heard anything unusual. It has been shown that autistic groups, who performed better at detecting the CS, were more likely to hear the gorilla compared to neurotypical groups (Remington & Fairnie, 2017b). This further corroborated the theory that autistic people possess an increased perceptual load capacity.

Cross-modality domain

Attempts to combine the two domains have been made; more specifically, it has been investigated whether any increase of the visual load would have any significant effect on the auditory load. The results appear to be conflicting: some studies suggest that increasing the visual load would reduce the amount of auditory information processed (Raveh & Lavie, 2015), whereas others revealed that there was no significant effect on the amplitude of electrophysiological response as distractor stimuli were added (Parks, Hilimire, & Corballis, 2010). It is therefore apparent, further research is required to verify whether exists a correlation between the two domains.

Aims of the study

Previous literature has not looked at a correlation between the perceptual load capacity and the sensory symptoms of the groups under analysis. A body of evidence shows that autistic and neurotypical groups can be classified in two different clusters (Jambaque et al., 1998; Ornitz et al., 1977; Volkmar et al., 1986): hypersensitive individuals, which corresponds to an extreme sensitivity perceived in the sensorial spectrum, and hyposensitive individuals, which conversely, indicate individuals whose sensitivity is significantly low. Data retrieved from the auditory task will be combined using two questionnaires: the Sensory Perception Questionnaire (SPQ) and the Adolescent/Adult Sensory Profile (AASP). Successively, statistical analysis was used to verify whether there is a significant correlation between the two groups; hypersensitive and hyposensitive adolescents (12 -18 years old). Previously, perceptual load capacity has been investigated uniquely on an auditory task, which would not necessarily accurately reflect sounds experienced by autistic children in their daily lives; the incorporation of questionnaires data would potentially provide more ecologically valid results. The hypothesis of the study is that hypersensitive adolescents will show better task performance in the search and detection tasks compared to hyposensitive adolescents as, per definition, they are more sensitive to environmental stimuli. Hypersensitive adolescents are expected to exhibit a lower score in the SPQ and values of lower registration and sensory sensitivity subscales in the Sensory Profile.

Methodology

Participants

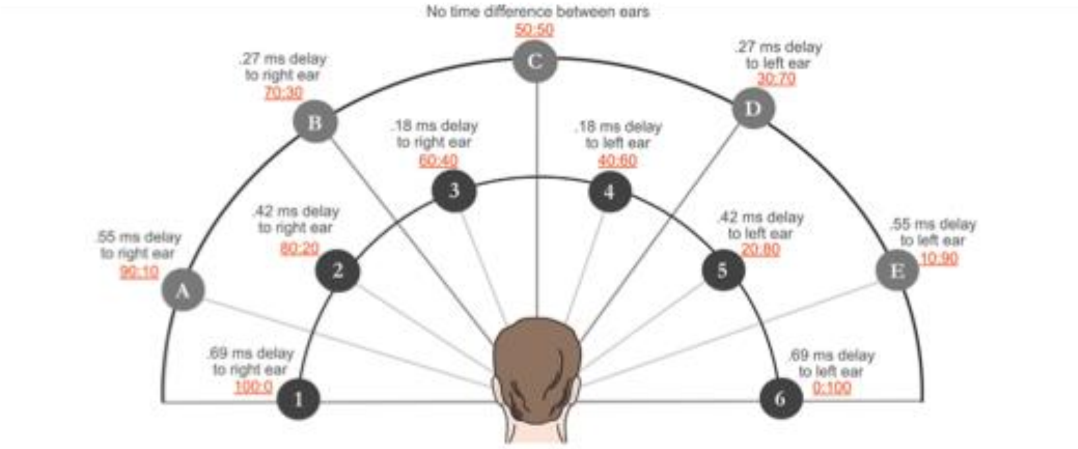
Due to time constraints, data was collected on a small sample size for the group of autistic individuals (n = 6), thus only the data set from the neurotypical group has been analysed (n = 15 females, n = 5 males, with mean age = 16.1 and standard deviation = 1.92). Participants within the neurotypical group were matched for IQ (within 70 and 130 in the Full Scale Intelligence Quotient 2 (FIQS-2) of the Wechsler Abbreviated Scale of Intelligence – Second Edition [WASI-II]) (McCrimmon & Smith, 2013) and gender. Participants, who previously expressed interest in following-up research projects in previous events, were recruited via email through databases. The tasks were carried out during Brain Detectives science workshop at UCL Institute of Education under timetable/time constraints. Audiometric thresholds were measured prior to the administration of the tasks, following the procedure outlined by the British Society of Audiology (2004). Both the left and the right ear were assessed for frequencies that ranged from 250 to 8000Hz using a Kamplex Diagnostic Audiometer AD17 and Telephonics TDH39P head-phones. All participants had audiometric threshold equal to or better than 20 dB for all frequencies tested in both ears, which is deemed to be within the typical hearing range for this age group.

Apparatus and Stimuli

The experiment was composed of two tasks: the primary task was an auditory search task developed by Fairnie, Moore and Remington, 2016.

Participants listened to different audio recordings in which animals' sounds were played simultaneously. The target sounds were the dog's bark and the lion's roar; the non-target sounds included the duck, the crow, the chicken, the rooster and the crow. Audio recording presented different set sizes to vary the perceptual load: set size one (target sound), set size two (target sound + non-target sound), set size four (target sound + three non-target sounds) and set size six (target sound + five non-target sounds). All sounds last for 100ms with 10ms fade in and 10ms fade out. The secondary task was a detection task. In 50% of trials, a car sound, the critical stimulus (CS), was present. The animal audio recordings were spatially located in a semi-imaginary circle around their head (Fig. 1, and the sounds were manipulated by changing the interaural amplitude (IAD) and time differences (ITD), as it has been confirmed that sounds are perceived differently according to where they originate from (Fairnie et al., 2016). The total number of trials was 288, preceded by 16 experimental trials and followed by 64 control blocks (16 for each set size), in which participants were asked to identify the presence of the CS. Control blocks were administered to ensure that, whenever participants couldn't hear the CS, it was attributable to the high perceptual load of the animal search task and not to an inherent ability to hear the CS. After completion of the experiment, two questionnaires were administered to the participants: the Sensory Perception Questionnaire (SPQ) and the Adolescents/Adults Sensory Profile (AASP). The former has been published by Tavassoli and Baron-Cohen at University of Cambridge in 2009. It is composed of 35 items assessing how people perceive the environment from a sensorial perspective. Each question has four possible answers (Strongly agree, Agree, Disagree and Strongly Disagree) and each of them corresponds to a set amount of points i.e., Strongly Agree = 0 points to Strongly Disagree = 3 points. Item 7, 13, 14, 22 and 32 are reverse-scored to eliminate acquiescence bias. People with elevated sensorial symptoms are more likely to score higher than those with low sensorial symptoms. The latter questionnaire has been widely used to investigate sensory processing patterns in adolescents and adults. Published in 2002 by Catana Brown and Winnie Dunn from University of Missouri, it is composed of 60 items divided into six different categories: (i) Taste/Smell Processing, (ii) Movement Processing, (iii) Visual Processing, (iv) Touch Processing, (v) Activity Level and (vi) Auditory Processing. Each item can be answered with one of five possible choices; Almost Never = 1, Seldom = 2, Occasionally = 3, Frequently = 4 and Almost Always =5.

Fig. 1 Interaural amplitude (underlined ratios in red) and time differences (grey text) for sounds in the first experiment. Circles with letters indicate possible positions for the CS; numbered circles indicate possible positions for target and non-target sounds. The sounds in the inner ring were 9dB higher than those in the outer ring.



Task Procedure

Participants were told that they would hear a number of audio recordings in which they had to identify the target sounds (dog or lion) and that in some trials the CS would be present. Participants were required to press two keypresses (Z or X) according to whether they heard the dog's bark or the lion's roar for the auditory search task and another two keypresses (N or M) according to whether they heard the CS or not. Visual prompts were used to guide the participants. Participants were encouraged to work quickly and accurately with as many breaks as needed between the blocks. Questionnaires were given to participants at the end of the auditory processing task.

Results

Primary task

Mean and standard deviation for Reaction Time (RT) and Dog and Lion's accuracy (D&L's accuracy) were calculated (Table 1, 2). Mean values for RT increase as the set sizes increase from 1 to 4. A drop of 157ms can be noticed from set size 4 to set size 6. Trials in which the reaction time was smaller than 150ms have been eliminated, as it is assumed that RT cannot be faster than 150ms. Additionally, a repeated-measures analysis of variance (ANOVA), with load as factor, revealed that there was a statistically significant difference in terms of RT as the set size increased ($F(3,57) = 3.73$, $p < 0.05$, $\eta p^2 = 0.164$) (Table 5). This implies that load was manipulated effectively. Mean values for D&L's accuracy decreases as the set sizes varies, meaning that the increase of set size had the desired effect. A repeated-measures analysis of variance (ANOVA), with load as factor, proved that there was a significant effect on the D&L's accuracy. ($F(3,57) = 16.76$, $p < 0.01$, $\eta p^2 = 0.469$) (Table 5). This signifies that the rate at which participants correctly identified the target sounds decreased in higher perceptual load environments.

Table 1

Mean and Standard deviation RT

Set size	Mean (ms)	Standard deviation
1	809	160
2	917	190
4	936	201
6	779	231

Table 2

Mean and standard deviation D&L's accuracy

Set size	Mean	Standard deviation
1	0.87	0.14
2	0.75	0.14
4	0.72	0.14
6	0.71	0.18

Secondary task

In order to measure the accuracy in the detection task, the parameter A (corrected version of a'), the non-parametric version of d', has been used. This was due to the fact that original and false hits showed to be insignificant in the normality test (Shapiro-Wilk). A can assume values from zero to one, where 0.5 signifies poor detection of CS and one latter perfect detection (Remington & Fairnie, 2017b). Trials in which the primary task was not correctly performed were excluded. Mean values of A decreases as the set size increases, meaning that CS detection was less frequent in higher perceptual load environments (Table 3). Furthermore, a repeated-measures analysis of variance (ANOVA) with load as factor, exhibited a significant difference as the set size increases ($F(3,57) = 9.61$, $p < 0.01$, $\eta p^2 = 0.336$)

(Table 5). This showed a decrease in performance in detecting the car as the perceptual load conditions increased.

Table 3

Mean and Standard deviation A

Set size	Mean	Standard deviation
1	0.85	0.14
2	0.78	0.10
4	0.72	0.18
6	0.71	0.19

Control blocks

Mean and standard deviation values for control blocks in each set size were calculated (Table 4). It is shown that the correct CS detection rate decreased as the set size increased. This suggests that the CS was more difficult to identify when many non-target sounds were present. This is further proven by a repeated-measures analysis of variance (ANOVA) with load as factor, which exhibited a significant difference in the control blocks at different set sizes ($F(3,57) = 6.81$, $p < 0.01$, $\eta p^2 = 0.264$) (Table 5). This suggests that the correct CS detection rate was not affected by the presence of the primary task.

Table 4. *Mean and Standard deviation: Control block*

Set size	Mean (%)	Standard deviation
1	82	2.2
2	76	3.5
4	69	5.1
6	67	2.9

Table 5. *Repeated-measures analysis of variance ANOVA for RT, D&L's accuracy, A and Control block*

Variable	df	Error	F	Significance	Partial Eta Squared
RT	3	57	3.73	0.016	0.164
D&L's accuracy	3	57	16.8	0.000	0.469
A	3	57	9.61	0.000	0.336
Control Block	3	57	6.81	0.000	0.264

Correlations

Kendall's tau correlation tests were used due to the small sample size (n = 20) and the non-parametric nature of A. No meaningful correlations were shown between A and the two sensory questionnaires administered ($p > 0.183$). These analyses suggest there is a negative correlation between the SPQ and the values of A at different set sizes. However, this difference was not significant ($p > 0.05$).

Discussion

The results reported fail to meet the hypothesis. The lack of meaningful correlations in the neurotypical group between sensory questionnaires and A may indicate that inherent sensory processing abilities are not conditioned by sensory symptoms in neurotypical individuals. Several explanations could be provided to justify the finding: firstly, a large autistic sample could not be reached due to time limitations. The testing time was considerably long (45 minutes) and data could only be collected in a time period of six weeks. It would have been fundamental to see whether meaningful correlations were identifiable in autistic individuals and whether differences could be detected between the two groups. Secondly, the participants recruited depict a portion of adolescents, which may not be fully representative of the real population: adolescents who had a pre-interest in psychology and neuroscience were more likely to participate, which may have led to biased results. Lastly, it can be hypothesised that the perceptual load capacity and sensory symptoms are not fully developed in adolescents aged 12-18 years. This means that individuals may still be in the process of reaching the greatest load perceptual capacity and their final set of sensorial symptoms, thus their performance in the task and their responses in the sensory questionnaires may be dependent on what stage of their development they are currently at. Despite presenting initially conflicting results in terms of auditory processing abilities of autistic groups, it can now be asserted that autistic individuals possess an enhanced perceptual load capacity compared to the neurotypical group (Remington & Fairnie, 2017b). From a neurological perspective, a mixed picture can be obtained in terms of auditory processing abilities in autistic people: while electrophysiological studies have identified shorter N1 and greater mismatch negativities (MMN) latencies, indicative of enhanced auditory processing capacities (Ferri et al., 2003; Oades, Walker, Geffen, & Stern, 1988), other studies have presented complete opposite findings whilst dealing with more complex tones (Gomot, Giard, Adrien, Barthelemy, & Bruneau, 2002). Neuroanatomically, grey matter levels in a region of the auditory cortex called Heschl's gyri were higher in autistic than in neurotypical groups; this area is the primary site for auditory processing and the increase in cortical thickness may explain why autistic individuals possess an enhanced perceptual capacity (Hyde, Samson, Evans, & Mottron, 2009). A single study investigating correlations between sensorial symptoms and identification of auditory intensities has been carried out (Jones et al., 2009). Their findings showed a trend which is opposite to what was hypothesised in this study: hyposensitive autistic individuals performed better compared to neurotypical controls. It is clear that more research needs to be conducted than can be retrieved from current studies before drawing conclusions. Future studies would benefit from, firstly, and most importantly, a wider sample size for both the neurotypical and the autistic group should be gathered. If more time were to be allocated to the conduction of the experiments, this objective could easily be met and the analysis of new and more data could be performed. Secondly, interconnected with the first point, either the creation of another, shorter task, or performing the task outside of Brain Detectives, to facilitate data collection and reduce recruitment bias. At the latest International Meeting for Autism and Research (IMFAR), held in San Francisco, May 10th-13th 2017, Dr. Anna Remington proposed a simple task, very easily administrable and with little training required, that could harness the perceptual load capacity in a classroom environment. In the task, participants were asked to listen to a woman narrating Greek myths and then answer a series of question about the story. The woman was shown in three different background settings: a white screen, a representation of the myths narrated (relevant) and a mixture of out-of-context pictures (irrelevant). Initial results showed that both neurotypical and autistic groups learnt more about the topic discussed during the relevant background than other backgrounds and that autistic participants managed to recall more information about the irrelevant background than neurotypical groups (Remington, 2017) What can be concluded is that increasing the number of essential information may reduce the tendency of autistic individuals to distract, thus improving learning outcomes. This further corroborates the finding so far collected and paves the way to the idealisation of a simpler, quicker and easy-to-administer task that would allow a larger sample to be recruited. The development of a smartphone app, in a cross-modality domain study (examples of similar studies are outlined in the Introduction) may also benefit the accessibility of the task. An audio file including a conversation (e.g. Party Task, (Dalton & Fraenkel, 2012)) could be incorporated in the app and a visual task, similar to the ones performed by (Remington et al., 2012) or (Swettenham et al., 2014). Each participant will have a smartphone and earphones to put on for the duration of the task. During the task, participants will have to answer to some question about what they see on a sheet of paper. At the end of the hearing task, participants will have to answer questions about what they heard on a sheet of paper as well.

The visual questions and the hearing questions will have a specific time in which they will be displayed on the screen to ensure that the time given to answer is consistent. It is expected that as the visual tasks get harder, people will not be able to focus on the conversation, leading to scarcer responses in the questions related to the auditory domain. However, this idea does present some constraints that would need to be faced, should it be taken forward: for instance, the screen in which the visual task is displayed would need to be the same to ensure that different performances are not due to screen size. This would mean using the same type of smartphone for all the participants, which may affect costs. In addition to this, all participants would require to be at the same distance from the screen, which may result challenging, considering that the task would not be performed in a laboratory setting and people naturally position their smartphones at different distances from their eyes. To overcome this difficulty, a photo-application could be built in to ensure the participant is in focus; repeating the photo-application procedure multiple times would provide further consistency. Identifying cognitive strengths is key to improve autistic children's quality of life; in environments of over-arousal, autistic people may experience great feelings of discomfort, which may have a negative impact on learning outcomes and employment opportunities (Remington & Fairnie, 2017b). It is therefore imperative that more research is pursued to guarantee same opportunities and better life conditions to the entire autistic population, capitalising on their strengths and enhanced capacities.

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