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A sound advantage: Increased auditory capacity in autism

Anna Remington *, Jake Fairnie

Centre for Research in Autism and Education, UCL Institute of Education, United Kingdom

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ABSTRACT

Autism Spectrum Disorder (ASD) has an intriguing auditory processing profile. Individuals show enhanced pitch discrimination, yet often find seemingly innocuous sounds distressing. This study used two behavioural experiments to examine whether an increased capacity for processing sounds in ASD could underlie both the difficulties and enhanced abilities found in the auditory domain. Autistic and non-autistic young adults performed a set of auditory detection and identification tasks designed to tax processing capacity and establish the extent of perceptual capacity in each population. Tasks were constructed to highlight both the benefits and disadvantages of increased capacity. Autistic people were better at detecting additional unexpected and expected sounds (increased distraction and superior performance respectively). This suggests that they have increased auditory perceptual capacity relative to non-autistic people. This increased capacity may offer an explanation for the auditory superiorities seen in autism (e.g. heightened pitch detection). Somewhat counter-intuitively, this same 'skill' could result in the sensory overload that is often reported – which subsequently can interfere with social communication. Reframing autistic perceptual processing in terms of increased capacity, rather than a filtering deficit or inability to maintain focus, increases our understanding of this complex condition, and has important practical implications that could be used to develop intervention programs to minimise the distress that is often seen in response to sensory stimuli.

1. Introduction

Autism Spectrum Disorder (ASD) is most often associated with social communication difficulties and the presence of rigid and repetitive behaviors (APA, 2013). Alongside these symptoms, however, are unusual perceptual and attentional processes that are increasingly being considered as central to the condition (Taylor et al., 2013). Indeed, altered sensory processing was included in the most recent set of diagnostic criteria (DSM-5; American Psychiatric Association, 2013), highlighting the timely nature of research in this area. Existing research on attention and perception in autism has revealed an intriguing profile of strengths and difficulties. Autistic individuals show evidence of superior discrimination abilities and yet also cases of increased distractibility (see Ames & Fletcher-Watson, 2010 for a review).

One possible explanation for this diverse set of observations is that autistic individuals have an increased perceptual capacity relative to neurotypical individuals which allows them to process more information at any given time. This hypothesis is based on the Load Theory of Attention and Cognitive Control (Lavie, 2005), which asserts that the extent of distractor processing depends on the level of perceptual load in a given task. When perceptual load is high, such that the task exhausts perceptual capacity, irrelevant distractor processing is eliminated. Conversely, on tasks with low perceptual load, the spare capacity that remains will automatically 'spill over' and result in irrelevant distractor processing. Hence, with respect to autism, an increased capacity could underlie both superiorities and deficits: in some cases the additional capacity would be useful and promote enhanced task performance, and in other cases the same extra capacity would result in task-irrelevant processing, thereby increasing susceptibility to distraction. Our previous work on autistic visual attention has shown evidence for both these hypotheses. First, on selective attention tasks autistic adults and children demonstrated increased processing of irrelevant peripheral information under high levels of perceptual load, compared to neurotypical children and adults, despite having intact performance on the central attention task (Remington, Swettenham, Campbell, & Coleman, 2009; Swettenham et al., 2014). Second, on a dual-task paradigm where participants were asked to perform a central search task and a secondary detection task, autistic adults showed equivalent performance on the central task and superior performance on the detection task,

* Corresponding author at: Centre for Research in Autism and Education, UCL Institute of Education, 55-59 Gordon Square, London WC1H 0NU, United Kingdom.
E-mail address: a.remington@ucl.ac.uk (A. Remington).

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particularly under high levels of load (Remington, Swettenham, & Lavie, 2012) Together, these studies suggest that autistic individuals have a greater perceptual capacity – at least in the visual domain.

There are many reasons to believe that the phenomenon should extend to the auditory domain. There is a great deal of evidence suggesting altered auditory processing in autism (see O'Connor, 2012 for review). For example, autistic individuals appear to show superior pitch perception (Bonnel et al., 2003) and better identification of, and memory for, musical notes (Heaton, Hermelin, & Pring, 1998). Akin to the findings in the visual domain, there also seems to be a local-processing bias with auditory stimuli. Bouvet, Simard-Meilleur, Paignon, Mottron, and Donnadieu (2014) used hierarchical stimuli to demonstrate that autistic individuals showed intact global processing, but superior local processing and reduced global interference when compared to neurotypical adults. Indeed the Enhanced Perceptual Functioning model of autism (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006), which consolidated a number of experimental findings to propose an explanation for the observed superior attentional behavior in the condition, highlighted increased levels of processing both visual and auditory stimuli. The importance of this line of auditory research is further emphasized when considering the difficulties that seem to accompany these areas of ability. Autistic individuals often show hypersensitivity to certain sounds, leading to great distress in noisy environments (Gomes, Pedroso, & Wagner, 2008). Clinical observations and testimonies reveal the high levels of anxiety that can surround auditory processing (Grandin, 1995, 1997). This, in turn, leads to a variety of coping behaviors that range from grimacing and ear shielding to screaming (Attwood, 1998).

We suggest that both the strengths and difficulties seen with respect to auditory processing in autism might be subserved by increased perceptual capacity. For example, being able to process more auditory information at any given time could offer an advantage on auditory detection tasks but also lead to an overwhelming level of arousal. Here, we use two different attention paradigms to test auditory capacity in autism. To our knowledge, this is the first time that auditory capacity has been directly assessed in autistic individuals.

2. General methods

2.1. Participants

Twenty autistic adults and 20 neurotypical adults (aged 17–34 years) were recruited through social networking websites and autism support groups around London. Sample size was determined by previous research using similar paradigms (Remington, Campbell, & Swettenham, 2012). Participants in the ASD group had received a clinical diagnosis of autism from a trained, independent clinician who used the criteria listed in the Diagnostic and Statistical Manual of Mental Disorders, Fourth or Fifth Edition (American Psychiatric Association, 1994, 2013) and reached threshold for an ASD on Module 4 of the Autism Diagnostic Observational Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2002). Three participants with a clinical diagnosis of ASD did not meet the ADOS criteria and were therefore excluded. The remaining group of autistic participants showed a mean ADOS score of 9.8 (SD = 2.0). None of the participants reported having any other mental or neurological disorder.

In order to improve group matching, one neurotypical individual was excluded due to an extremely high IQ (greater than 2 S.D. above the mean) (see Table 1 for resulting participant groups). The resulting 17 ASD (13 males) and 19 neurotypical adults (11 males) did not differ in IQ, as measured by the Wechsler Abbreviated Scale for Intelligence – Second Edition (Wechsler, 2011) (mean ASD IQ: 110, SD = 13.0; mean neurotypical IQ: 114.5, SD = 10.0; $p = 0.26$). The autism group was significantly older than the neurotypical group (mean ASD group age: 30 years, SD = 3.6; mean neurotypical group age: 23.6 years, SD = 5.0; $p < 0.001$). All participants had their audiometric thresholds measured prior to taking part in the study, following the procedure recommended by the British Society of Audiology (2004). Audiometric air-conduction thresholds were measured for the left and right ears for octave-spaced frequencies from 250 to 8000 Hz using a Kamplex Diagnostic Audiometer AD17 and Telephonics TDH39P headphones. All participants had normal hearing, defined as audiometric thresholds equal to or better than 15 dB HL for all frequencies between 250 and 8000 Hz in both ears. Participants took part in both Experiments in the same testing session, and the task order was counterbalanced.

2.2. Ethics

All procedures were carried out in accordance with the British Psychological Society code of ethics, and were approved by the UCL Institute of Education Ethics Committee. All participants gave written informed consent prior to participation.

2.3. Apparatus

The experiments were presented using OpenSesame (version 2.8.3) experimental software (Mathôt, Schreij, & Theeuwes, 2012) on a Dell Latitude 15 5000 series laptop computer using Audio-Technica ATH-M30X Professional Monitor Headphones.

3. Experiment 1

In Experiment 1, we used an auditory dual-task paradigm previously developed by the authors (Fairnie, Moore, & Remington, 2016). The primary task was an auditory search task, and the secondary task was an auditory detection task. Participants were asked to listen to an array of animal sounds, presented simultaneously, that appeared to emanate from different positions located on an imaginary semi-circle around their head. One sound was the target (a dog bark or a lion roar) and the others were non-target animals (duck, cow, chicken, rooster, crow). The perceptual load of the task was altered by varying the number of non-target sounds in the array to create four set sizes: one (target alone), two (target plus one non-target sound), four (target plus three non-target sounds) and six (target plus five non-target sounds). In addition, a non-animal sound (a car, the critical stimulus, CS) was presented on 50% of trials concurrently with the array of animal sounds. The CS was positioned on an imaginary semi-circle around the listener's head, with greater eccentricity than the animal sounds (see Fig. 1). All sounds had a duration of 100 ms (including a 10 ms fade in and a 10 ms fade out). The position of each sound in space was set by manipulating interaural amplitude and time differences, and overall level differences. Previous research has confirmed that participants do indeed perceive the elements to be spatially distinct (Fairnie et al., 2016). For full temporal and spectral properties of the sounds, see Table S1 in supplementary materials. Participants were told that they would hear a number of animal sounds concurrently, and were asked to indicate with a keypress (as quickly as possible) whether the dog or lion sound was present. They were informed that on some trials there would also be a car sound, and that after responding to the main task (dog/lion) they should indicate whether the car sound was present or absent. Visual prompts on the screen reminded participants when, and how, to respond.