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Effects of perceptual load and socially meaningful stimuli on crossmodal selective attention in Autism Spectrum Disorder and neurotypical samples

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ABSTRACT

The present study examined whether increasing visual perceptual load differentially affected both Socially Meaningful and Non-socially Meaningful auditory stimulus awareness in neurotypical (NT, $n = 59$) adults and Autism Spectrum Disorder (ASD, $n = 57$) adults. On a target trial, an unexpected critical auditory stimulus (CAS), either a Non-socially Meaningful ('beep' sound) or Socially Meaningful ('hi') stimulus, was played concurrently with the presentation of the visual task. Under conditions of low visual perceptual load both NT and ASD samples reliably noticed the CAS at similar rates (77–81%), whether the CAS was Socially Meaningful or Non-socially Meaningful. However, during high visual perceptual load NT and ASD participants reliably noticed the meaningful CAS (NT = 71%, ASD = 67%), but NT participants were unlikely to notice the Non-meaningful CAS (20%), whereas ASD participants reliably noticed it (80%), suggesting an inability to engage selective attention to ignore non-salient irrelevant distractor stimuli in ASD.

1. Introduction

1.1. Selective attention

Selective attention is the process of focusing on, and reacting to certain stimuli when several occur simultaneously (Broadbent, 1958; Peterson & Posner, 2012; Treisman & Riley, 1969). The ability to ignore certain stimuli, whilst attending to other aspects of the environment is important to prevent overloading our sensory and perceptual systems. Research on selective attention in Autism Spectrum Disorder (ASD) is a large, complex, and expanding literature (see Fein, 2011; Just & Pelphrey, 2013; Marco, Hinkley, Hill, & Nagarajan, 2011, for example). ASD is a lifelong neurodevelopmental condition, defined in the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-5 American Psychiatric Association, 2013) by impaired communication, impaired social interactions, and repetitive behaviors (see also Landa, Holman, & Garrett-Mayer, 2007). Attentional deficits have been noted in the condition since Kanner's (1943) and Asperger's (cf. Frith, 1991) original definitions. Much literature suggests that people with ASD often have difficulties processing everyday sensory information and in focusing attentional resources which can be detrimental to social functioning (e.g., Baron-Cohen, 2008; Frith & Mira, 1992; Laurie, 2014). There have been a number of recent advances in the field of selective attention in ASD.

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1.2. Selective attention in Autism Spectrum Disorder

Much of the research on selective attention in ASD has provided contradictory findings. On one hand, for example, Burack (1994) suggested that children with ASD have a deficit in their selective attentional lens insofar as ASD participants were more distracted by peripheral visual stimuli, therefore, suggesting an inability to narrow their focus on a target stimulus. Participants in this study were asked to state whether they saw an 'O' or a '+' in the centre of the screen, and their reaction time was recorded. Variables manipulated included the presence/absence of a window only showing the central target stimulus, the amount of non-target distractor stimuli, and the distance between the target and distractor stimuli. The results demonstrated that the presence of distractor stimuli negative impacted performance in the ASD group compared to the control group. These findings led to the conclusion that children with ASD had an overly broad attentional lens that they were unable to narrow efficiently (Burack, 1994; see also Adams & Jarrold, 2012; Christ, Kester, Bodner, & Miles, 2011; Ciesielski, Courchesne, & Elmasian, 1990; Kanakri, Shepley, Varni, & Tassinary, 2017; Smith & Milne, 2009).

O'Riordan (2004) used visual search tasks to show that ASD participants had a superior ability to detect target stimuli compared to neurotypical (NT) participants. Furthermore, when distractor stimuli were more similar to target stimuli NT participants showed significantly reduced detection of target stimuli compared to ASD participants. This suggests that adults with ASD have enhanced selective attention abilities or a superior visual discrimination ability more specifically. While it could be argued that performance on the visual search task may be affected by memory for rejected distractors in search abilities, Joseph, Keehn, Connolly, Wolfe, and Horowitz (2009) accounted for the potential confounding influence of memory by using both a standard static and a dynamic search task, with target and distractor stimuli randomly changing position every 500 ms. Their findings showed that ASD participants had quicker reaction times and their performance accuracy was greater in the dynamic search task than that of NT participants. This suggests ASD participants have an enhanced ability to discriminate between targets and distractors at the locus of attention.

Both O'Riordan (2004) and Joseph et al. (2009) have argued that such performances observed in ASD samples is characterized by a superior selective attention coupled with an overly narrow attentional lens. The findings from these studies are supported by ASD individuals outperforming NT individuals in Stroop tests (Adams & Jarrold, 2009), and the weak central coherence theory of ASD (Frith, 1989; Happé, 1996; Happé & Frith, 2006). The weak central coherence theory suggests that individuals with ASD overly focus on the smaller parts of an overall picture, and are therefore more able to pick out finer detail due to selectivity in attention leading to enhanced focus and fixation on minor details. However, it could feasibly be argued that O'Riordan's (2004) and Joseph et al.'s (2009) data could be accounted for by enhanced awareness of an overall visual scene (e.g., Kanakri et al., 2017).

1.3. Load theory

Thus, it is apparent that there exists ambiguity in the literature on how selective attention functions in ASD. The discrepancies noted in previous selective attention research in ASD (e.g., for an impaired selective attention and an overly broad attentional lens; Burack, 1994; Smith & Milne, 2009; versus an overly narrow lens and superior selective attention; Joseph et al., 2009; O'Riordan, 2004) has recently been addressed by one particularly intriguing line of research that incorporates Lavie's (1995) *Load theory* of attention and cognitive control (e.g., Remington, Swettenham, Campbell, & Coleman, 2009; Remington, Swettenham, & Lavie, 2012; Swettenham et al., 2014; Tillmann, Olguin, Tuomainen, & Swettenham, 2015; Tillmann & Swettenham, 2017). Load theory suggests that task-irrelevant distractor stimuli will only be processed if there are enough cognitive resources left over after the primary target stimuli have been processed. In other words, the bigger the perceptual load of the main task, the less the ability to process additional stimuli. If the perceptual load is low, a 'spill-over' of attentional resources will occur and additional stimuli will be processed automatically. For example, perceptual load can be manipulated by altering the number of task-relevant stimuli in a display (e.g., number of items in a search task; Tillmann & Swettenham, 2017), or the perceptual processing requirement of a task (e.g., the subtlety of a line discrimination; Lavie, 2005; Tillmann et al., 2015).

Remington et al. (2009) hypothesized that individuals with ASD would have an enhanced visual perceptual load capacity as past research had shown that they performed better than control groups in visual search tasks when there were a large number of visual stimuli (e.g., O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001). They explored perceptual load capacity in an ASD and a NT control group, by using a mix of both a visual search task (Treisman & Gelade, 1980) and a flanker task (Eriksen & Eriksen, 1974). Wherein both NT and ASD groups showed they were still processing distractor (flanker) stimuli at a low perceptual load search task (i.e., finding two target items amongst distractor stimuli) the NT group showed signs of distractor stimuli interference at a higher perceptual load (four target items), whereas the ASD group did not. At the highest perceptual load (i.e., six target items) both groups showed distractor stimuli interference. This suggests that there might be a higher perceptual load capacity in ASD individuals as it took six target items to exhaust their perceptual capacity, whereas NT individual's perceptual capacity was exhausted after just four target items. These findings were further supported in a study of visual detection sensitivity (Remington, Campbell, et al., 2012; Remington, Swettenham, et al., 2012) and the detection of an unexpected task-irrelevant visual stimulus in an inattentional blindness task (Swettenham et al., 2014).

1.4. Crossmodal attention

Such studies reviewed above, however, only tested the effects of perceptual load on selective attention in ASD in the visual domain. Therefore, it was not possible to generalise these findings across sensory modalities. Cross-modality research needs to be further explored as sensory input is not usually limited to one sense (e.g., vision; see Stein, 2012), and ASD individuals often present