Changes in the Focus of Attention across Time in Individuals with Autism:

The Effect of a Dual-Stream Paradigm

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Abstract

The Attentional Blink (AB) refers to the impaired identification of a second target that appears after a first target in a stream of rapidly presented stimuli (Raymond et al., 1992). Lag-1 sparing is the intact ability to correctly identify a second rapidly appearing target if it is presented directly following the first target (Potter et al., 1998). Individuals with autism spectrum disorder (ASD) have characteristically presented with atypical spatial attention profiles (Ames & Fletcher-Watson, 2010) and the purpose of the current study was thus aimed at exploring the AB and Lag-1 sparing in autism by employing a rapid dual-stream presentation of stimuli at two different stimulus-onset asynchronies (SOA) where targets could appear in either of the streams. Eleven adolescents with ASD and 18 typically developing (TD) individuals were compared and it was found that while the TD group generally displayed Lag-1 sparing across nearly all conditions, the group with ASD never did. This is in contrast to previous researchers who reported the presence of Lag-1 sparing in individuals with ASD (Amirault et al., 2009). We hypothesize that the combination of dynamic changes in focused attention together with task difficulty inherent in the dual-stream paradigm, prevented Lag-1 sparing from occurring in individuals with autism, but not in TD individuals. Implications of these findings and future research directions are discussed.

Keywords: autism, attentional blink, lag-1 sparing, dual-stream, spatial attention

Résumé

Le clignement attentionnel (CA) fait référence à la réduction de l'identification d'une seconde cible qui apparaît après une première cible dans un flux de stimuli présentés rapidement (Raymond et al., 1992). Le « lag-1 sparing » est la capacité intacte d'identifier correctement une deuxième cible apparaissant rapidement immédiatement après une première cible (Potter et al., 1998). Les personnes atteintes de troubles du spectre autistique (TSA) ont typiquement présenté des profils atypiques d'attention spatiale (Ames & Fletcher-Watson, 2010) et le but de la présente étude visait donc à explorer le CA et le « lag-1 sparing » en autisme par l'utilisation d'une présentation rapide à double source à deux différents asynchronismes d'apparition des stimuli, où les cibles peuvent apparaître dans l'une des deux sources. Onze adolescents atteints de TSA et 18 ayant un développement typique (DT) ont été comparés et il a été constaté que, bien que le groupe DT ait généralement affiché un « lag-1 sparing » dans presque toutes les conditions, le groupe atteint de TSA ne l'a jamais fait. Ceci va à l'encontre de précédents résultats, qui ont révélé la présence de « lag-1 sparing » chez les individus atteints de TSA (Amirault et al., 2009). Nous émettons l'hypothèse que la combinaison des changements dynamiques de l'attention ciblée, ainsi que la difficulté des tâches uniques au paradigme de double source, a empêché le « lag-1 sparing » de se produire chez les personnes atteintes d'autisme mais pas chez les personnes de DT. Les implications de ces conclusions et des orientations futures de recherche sont discutées.

Mots-clés : autisme, clignement attentionnel, lag-1 sparing, double source, attention spatiale

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Autism has been described as a set of neurodevelopmental conditions that is typically characterized by particular early-onset problems (Lai, Lombardo, & Baron-Cohen, 2014) associated with deficits in social communication and interactions, and restricted repetitive behaviours, interests, or activities (American Psychiatric Association [APA], 2013). The symptoms fall on a continuum, with some individuals displaying mild symptoms while others experience symptoms that are more severe (APA, 2013; Mayes et al., 2014). Although attention atypicalities are not a diagnostic characteristic of ASD, nevertheless they are reportedly the most common neurocognitive type of problem in ASD (Ronconi, Gori, Ruffino, Molteni, & Facoetti, 2013) and are therefore considered essential to understanding ASD (Allen & Courchesne, 2001; Ames & Fletcher-Watson, 2010) and its development (see Dakin & Frith, 2005; Happé, 1999; Mottron, Dawson, Soulières, Hubert, & Burack, 2006 for reviews). Attention could be regarded as a complex assembly of interrelated, yet distinctively discernible processes, which are governed by both endogenous cues (top-down / situation-dependent influences) and exogenous cues (bottom-up/image-based saliency influences), which represent the degree to which an individual's interest is captured by the environment (Corbetta & Shulman, 2002).

In this paper the narrowing and broadening of attention in individuals with autism will be addressed. Specifically, some of the inconsistent findings in this domain will be considered as well as the potential application of a research paradigm that could provide greater clarity into the processes underlying the narrowing and broadening of attention in autism. For example, Burack (1994) found that individuals with autism have an inefficient attentional lens meaning that their ability to narrow their attention and to zoom-in on a target is somewhat compromised. In a later study, Mann and Walker (2003) suggested that individuals with ASD have a limited ability when it comes to zooming-out or broadening the spread of attention, but not in terms of narrowing attention. Ronconi et al. (2013) recently revisited these conflicting findings by using an attention task that necessitated individuals with autism to zoom their attention both in and out. They found, as did Mann and Walker (2003), an attentional atypicality among individuals with ASD that involved the broadening (zooming-out) but not narrowing of attention (zooming-in). In this paper, these findings will be reconsidered and elucidated by means of an attentional blink (AB) paradigm. AB paradigms are used primarily to study the temporal dynamics of attention, although, through a number of adaptations of the original AB tasks, it has become possible to investigate both the spatial and the temporal dynamics of attention. This provides a new option for examining the spatiotemporal dynamics of attention in autism, including the narrowing and broadening of attention, and is the purpose of the current study. Thus, in this paper, the narrowing and broadening of attention in ASD together with associated features will be considered, followed by applicable aspects of the AB, thereby shedding light on spatial attention in ASD and the dissimilar findings in the research.

Perception and Attention in Autism

Atypicalities in basic aspects of perception and attention are potentially able to cause deviations in typical development, leading to impairments in the more complex domains of cognitive development (Elsabbagh et al., 2012; Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012). Additionally, such atypicalities are often considered an early sign of a later ASD diagnosis (Elsabbagh & Johnson, 2007, Maestro et al., 2002; Mundy & Newell, 2007; Sodian & Thoermer, 2008; Sasson, Dichter, & Bodfish 2012; Sasson & Touchstone, 2014) and even for the development of communication and language problems (Adamson, Bakeman, Deckner, &

Romski., 2009; Leekam, Libby, Wing, Gould, & Gillberg., 2000). For example, Elasabbagh et al. (2013) measured how effectively infants can disengage attention from a designated stimulus in order to orient their focus to a peripheral one. They found that infants in their first year of life who were later diagnosed with autism as compared to infants who were not eventually diagnosed with autism, were slower to disengage from a designated stimulus in order to orient their focus to a peripheral one and did not show the same steady developmental increases in the flexibility and speed of attending. Similarly, Sasson, Elison, Turner-Brown, Dichter, and Bodfish (2011) showed that when typically rigid or restrictive stimuli, such as computer equipment and road signs, which are characteristically of high interest in individuals with autism, were presented to toddlers with ASD and typically developing (TD) comparison groups, the children with ASD displayed significantly heightened evidence of visual attention to those stimuli. Thus, even the simplest ways in which a toddler will interact with his or her immediate surroundings are likely to be impacted from very early in age. Attention has also been implicated as a mediating factor in terms of the impact of general intelligence on school performance (Steinmayr, Zeigler, & Träuble, 2010), and is inextricably bound up with learning across various domains (Dosher, Han, & Lu, 2010; Swanson, 2011; Zeithamova & Maddox, 2007).

Visual Attention

Visual attention is vital for the development of normal social interaction skills and functional behaviour as it is required to orient to targeted features in one's environment and to search for specific desired elements. It is also essential for overall cognitive development as well as in emotional regulation (Casey, Gordon, Mannheim, & Rumsey, 1993; Enns & Cameron, 1987; Johnson, 1990; Rothbart, Posner, & Rosicky, 1994). Finally, attention permits the filtering out of irrelevant or unimportant information, thereby allowing for the efficient processing and utilisation of appropriate information, be it social or non-social in nature (Enns & Cameron, 1987).

Atypical visual processing in particular, has been singled out as an exceptionally intriguing aspect in the field of autism research (Mazer, 2011; Vlamings, Jonkman, van Daalen, van der Gaag, & Kemner, 2010), and understanding the characteristics and mechanisms underlying visual attention has been seen as being central in both the neuro and cognitive sciences (Miller, 2003). This implies that deficits in the development of visual attention might be at the core of the restricted behaviours and the temperamental emotional profiles that contribute to the compromised communicative and social developmental elements that are characteristic of autism (Landry & Bryson, 2004). Accordingly, the focus of the current study is to better understand the cognitive and attentional underpinnings of autism by further exploring the dynamic and spatial changes in visual attention with a research paradigm that has been employed in the TD population but never, to our knowledge, in autism research.

Local and Global Attention in Autism

Selective attention involves the ability to maintain a cognitive or behavioural focus despite the presence of competing or distracting stimuli (Fletcher-Watson, Leekam, Turner, & Moxon, 2006), including the processing of local/global stimuli. Local processing has been defined as the focusing of attention to a small section of a stimulus whereas the stimulus as a whole is ignored, while global processing is the opposite: namely, attention is broadly directed to the overall representation, often at the expense of the details (Johnson, Blaha, Houpt, & Townsend, 2010). Put differently, local processing involves the zooming-in of attention to specific aspects or areas of the stimuli, while global processing involves the zooming-out of attention.

Assessing Local and Global Attention

In order to assess the local/global processing in selective attention, researchers use many different methodologies, including the Navon task (Navon, 1977, 1981; Ozonoff et al., 1994). The Navon task consists of large numbers or letters, which are made up of small numbers or letters. By comparing how accurately observers are able to report the global letter as compared to the local elements, conclusions can be drawn regarding how various dimensions and elements are processed. Although researchers have reported that participants with autism tend to be slower than TD comparison groups with regard overall processing (e.g., Behrmann et al., 2006; Mottron, Burack, Stauder, & Robaey, 1999), findings as to whether a difference exists between global and local processing have proven somewhat contradictory. For example, Ozonoff et al. (1994) asked adolescents with and without autism to classify various stimuli as being either Hs or Ss. The Stimuli conditions included compatible conditions where the large letter was made up of the same small letters as the large one, or of different small letters (the incompatible condition). They found that relative to the TD comparison group, the group with autism exhibited no particular difficulty processing the global elements of the stimuli, nor did they demonstrate any superiority in their processing of local features.

Other researchers report significant differences between how TD individuals and those with ASD process local and global stimuli. For example, Wang, Mottron, Peng, Berthiaume, and Dawson (2007) used free-choice and forced-choice paradigms to assess the reading of numbers from local and global points of view. They found that when participants were given the choice as to which level they preferred, then the individuals with high functioning (HF) autism displayed a local advantage in terms of naming-time, regardless of the angle of presentation, while the TD comparison group exhibited a global advantage in naming-time that interacted with the visual angle of presentation. When they used a forced choice paradigm, whereby the participants had to name either local or global targets, those with HF autism displayed a more accentuated local-to-global interference than global-to-local interference than the TD group. Behrmann et al. (2006) studied these effects on adults particularly, using a traditional Navon task with large and small letters, and found that adults with ASD exhibited a local bias specifically. Conversely, Mottron et al. (1999) found that when a group of TD children and adolescents and a group with autism were assessed on their experience of whole versus parts of objects, the individuals with autism actually demonstrated a global advantage. In a later study, the findings of Mottron et al. (1999) were replicated with small visual angles; however, when larger visual angles were employed, the individuals with autism responded faster to local targets (Mottron et al., 2003). When the researchers manipulated various features of typical global/local tasks and then created an expectancy bias toward attending to either the local or global level, it emerged that children with high functioning autism had intact global and local processing abilities, however, they were more sensitive to the implicit biases based on the task and less to structured global biases (Iarocci, Burack, Shore, Mottron, & Enns, 2006). Consequently, they posited, that rather than being associated with local/global processing problems per se, autism is more about an ineffective executive control process that is associated with zooming-in and zooming-out attention, and is used to direct attention to global or local stimuli. Thus, comparisons among findings involving different age groups and mixed age samples might be behind many of the discrepant findings due to inconsistent developmental stages and abilities being grouped and compared (see for example Burack, Iarocci, Flanagan, & Bowler, 2004; Burack, Russo, Flores, Iarocci, & Zigler, 2012). Furthermore, many of the differences between the findings may be due more to the task and methodologies employed, than to the actual deficit, or advantage, that was being studied. Indeed, Ramdoss et al. (2011) report that any observed difference between the processing of local and global stimuli in TD individuals and those with autism, could be eliminated with training, highlighting the importance of training in discovering the real potential of all participants (see also Pennington, 2010).

Shifting Attention in Autism

Attention is highly flexible and dynamic, and the attentional focus can be rapidly shifted from one object or group of stimuli to another (a process known as attentional orienting; Driver et al., 1999). In his visual orienting task, Posner (1978) employed visual cues to direct attention to a specific location. A target subsequently appeared either at the cued location (a valid trial) or at an uncued location (invalid trial), and participants made a speeded response to the onset of the target. Based on the pattern of RTs in the cueing paradigm, Posner proposed three independent components of an attentional shift: disengaging from the initially attended location, shifting attention to the cue, and engaging attention at the cued location. Applying these findings to research in ASD, Landry and Bryson (2004) conducted a study where individuals with autism were seated in front of a computer screen and dynamic patterns of geometric shapes were presented at the centre and periphery of the screen. Reaction times for initiating an eye movement toward the stimuli, for shifting the focus of attention from an existing stimulus to a new one that appeared following the fading of the old one, and for overlap trials where the old and new stimuli remained on the screen, were analyzed. Landry and Bryson found that relative to a TD comparison group, individuals with autism were somewhat impaired in disengaging their visual attention. Similarly, Wainwright-Sharp and Bryson (1993) tested attention shifting in adolescents and young adults with autism with Posner's cueing paradigm. They found that while the TD comparison group was faster to respond to the target when the cue was valid, the group of individuals with ASD did not show an improved reaction time or percentage of correct identification of the target, when cues were valid. Put succinctly, they did not benefit from the valid cue and is suggestive of a problem with disengaging and shifting their attention. It thus appears from these, and other studies (see also Bryson, Landry, & Wainwright, 1997; Casey et al., 1993; Courchesne, Akshoomoff, & Townsend, 1990; Sergeant, Geurts, & Oosterlaan, 2002) that individuals with autism, across various developmental stages, experience atypicalities in terms of disengaging and shifting their attention.

The impact of these findings is mitigated by the failure of other researchers to find these atypicalities in shifting and disengaging attention among persons with autism. For example, Todd, Mills, Wilson, Plumb, and Mon-Williams (2009), used a gap-overlap paradigm, similar to that of Landry and Bryson (2004) but they report that the gap effect in participants with autism was not significantly different from a TD comparison group. Similarly, in another effort to assess the shifting of attention in individuals with ASD, Goldberg et al. (2005) employed the Cambridge Automated Neuropsychological Test and Battery (CANTAB) to research, among other attentional attributes, attentional shift. The CANTAB shifting test involves a series of contingency-specific stages, with a maximum of nine stages, beginning with the simple discrimination of basic patterns in stage one, and gradually becoming more complex. They found that no atypical shifting on the CANTAB tasks occurred for the participants with ASD, as compared to TD comparison groups. However, findings on these types of tasks will often vary depending on the nature of the task itself and the participants being studied (see for example Grubb et al., 2013; Russo et al., 2007. See also Brian, Tipper, Weaver, and Bryson (2003), who discuss the feasibility of variable findings on these types of tasks.)

Narrowing and Broadening of Attention in Autism

The focus of attention can be not only shifted from one object to another, but it can also be broadened or narrowed in size or spatial extent to encompass smaller or larger objects. According to Ames and Fletcher-Watson (2010), these processes involve an increase or decrease in the physical domain of interest, or in the number of targets. To explain this phenomenon, researchers explicate that the orienting of attention in general could be compared to a spotlight that can be directed to a particular region of the visual field. The focus of attention (i.e., the region to which one is attending) can be shifted from one object or location to another (a process known as attentional orienting) or expanded or contracted in spatial extent (a process known as attentional focusing; Eriksen & St. James 1986; Eriksen & Yeh, 1985; Castiello & Umiltà, 1990; LaBerge, 1983; Posner, 1980; Posner, Snyder, & Davidson, 1980). Tasks such as these involve the ability to both narrow (zoom-in) and broaden (zoom-out) the visual spread. Being as this model allows for the continuous adjustment of attention, it is often discussed within the framework of an attentional spotlight (Eriksen & St. James, 1986). It thus follows that when attention is zoomed-in, one could anticipate an increased proficiency for processing stimuli that fall in the spotlight (Ronconi et al., 2013) and this was demonstrated by Castiello and Umiltà, (1990) who showed that due to the limited capacity of attentional resources, when the attentional area increases, processing efficiency decreases, whereas when the area decreases, efficiency increases. Similarly, evidence from fMRI studies indicates that the extent of visual cortex activation is more spatially restricted but stronger in magnitude, when the focus of attention is narrow, while activation is more spatially spread and weaker in magnitude, when the focus of attention is broad (Müller, Bartelt, Donner, Villringer, & Brandt, 2003).

Theories of Autism and the Broadening and Narrowing of Attention

Both the zooming-in and zooming-out of attention in autism as well as the related global versus local processing discussed earlier, are seen as prominent characteristics in the attentional profile of individuals with autism, as was elucidated above. These attributes are better understood in terms of two of the prominent theories of perception in autism. Frith (1989) noted that TD children and adults tend to make sense of the information in the world around them by cognitively constructing it in a global gestalt fashion and this often comes at the expense of attention to detail. In contrast to this drive for a general meaning referred to as central coherence, individuals with autism tend to display a detail-focused, or weak central coherence style of processing, which involves a preference for attention to details as opposed to the global picture (Frith & Happé, 1994; Happé & Frith, 2006). According to weak central coherence theory, individuals with ASD would apply their attentional resources in a narrow or zoomed-in area of the visual field (Ronconi et al., 2013).

In the second model called the enhanced perceptual functioning (EPF) model, the emphasis is on the perceptual low-order superiority in individuals with autism, over their higher-order cognitive operations (Mottron & Burack, 2001; Mottron, et al., 2006). According to this theory, the enhanced perceptual ability of individuals with autism translates into an attentional style that is more oriented to local or zoomed-in stimuli, rather than the global or general picture. This is in contrast to typical processing of hierarchical information (Robertson & Lamb, 1991) that involves a combination of superior global target detection as well as a healthy propensity for the detection of local elements of stimuli (Mottron et al., 2006). This preference for zooming-in and focusing on details has led researchers to assess how the preference for detail in individuals with autism would impact their visual search ability (meaning how they would identify or locate visual stimuli among a group of distractors) as compared to their TD peers. For example, O'Riordan, Plaisted, Driver, and Baron-Cohen (2001) conducted two visual search experiments with children with autism and compared them to TD children matched on chronological age (CA) and general non-verbal ability. Regardless of whether the task included a uniquely defined feature target that differed maximally from other stimuli and was similar in terms of a single property (such as colour of shape), or a conjunction target that was only minimally dissimilar, and differed in terms of only one property (such as in size or texture), the children with autism outperformed their TD peers despite the difficult nature of the tasks (see also Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009; Kemner, Ewijk, Engeland, & Hooge, 2007). O'Riordan and Plaisted (2001) explained that the reason for the enhanced visual search ability was due to a superior ability for zooming in and discriminating between the displayed items.

Focusing Attention and Enhanced Perceptual Load

In order to better appreciate why individuals with ASD displayed an enhanced ability for zooming-in and discriminating information, Hessels, Hooge, Snijders, and Kemner (2014) studied reaction times (RTs) across a series of different types of zooming-in visual discrimination tasks. They noted that the participants with ASD significantly outperformed TD individuals when the task was designed to be easy, but not when the task was more difficult. Hessels et al. hypothesized that these findings were linked to the amount of perceptual processing resources available for each task, as more difficult tasks impose a greater perceptual load (Lavie, 1995). This hypothesis is actually at the root of load theory, according to which an individual has a limited perceptual capacity (Lavie, Hirst, Fockert, & Viding, 2004). According to load theory if a task is demanding enough it will exhaust one’s perceptual capacity leaving no available resources for the processing of other stimuli. Conversely, if the maximum perceptual load capacity is not reached, then the available resources are available for the processing of other extraneous stimuli including those that might be irrelevant or distracting (Remington, Swettenham, & Lavie, 2012). Based on load theory one could predict that an easy task requiring minimal attentional zooming-in, would result in available resources for attending to non-related stimuli, however when the task is more difficult and the perceptual load is heavy, no attentional resources remain for the processing of other information (Hessels et al., 2014). Thus, the participants with ASD outperformed the TD participants as long as the task was not difficult because the perceptual processing capacity of the individuals with ASD had not been reached. However, this advantage was no longer present when the task was more challenging, thereby requiring increased perceptual processing resources. In this case the findings mirrored their performance on the identification of a single stimulus in which the individuals with ASD and TD were similar.

Hyper-focused Attention, Narrowing of Attention, and Cognitive Load

Individuals with autism commonly experience abnormal levels of arousal which could result in hyper-focused attention in relation to certain stimuli (e.g., Dawson & Lewy, 1989; Gold & Gold, 1975; Keehn et al., 2013) and this over-arousal subsequently leads to the narrowing of the spotlight of attention around a stimulus (Tracy et al., 2000). This very ability might lie at the core of the multiple findings that individuals with autism display superior visual search performance over TD individuals (e.g., Hessels et al., 2013; Joseph et al., 2009; Kemner et al., 2007; O'Riordan 2004; O'Riordan et al., 2001; Plaisted et al., 1998). It stands to reason that the more challenging the task, the greater the perceptual arousal involved, and the result will be an increased amount of attentional resources being expended in order to complete the task. Researchers in the domain of perceptual load have found that while a higher perceptual load can impair visual detection in TD adults, this is not the case for adults with autism (Remington et al., 2012). For example, Remington, Swettenham, Campbell, and Coleman (2009) examined perceptual load in TD adults and in adults with autism by applying a response-competition paradigm in which the participants were told to respond to an appropriate target while ignoring those that were irrelevant and were merely distractors. They found that the group with ASD only ignored distractors once higher perceptual load levels had been reached and did not display a reduction in speed or accuracy. Remington et al. (2009) suggest that the reason the individuals with ASD ignored the distractors later than the TD adults was due to their enhanced perceptual capacity which allowed them to catch the distractors as well as the targets; in contrast, TD adults were not able to identify the distractors due to a more limited perceptual capacity. These findings indicate that the superior visual search capabilities are not only present in the zoom-in type tasks, as noted above, but also for zooming-out broadening of attention tasks where distractors were on the periphery of the search field.

In a follow-up study, Remington et al. (2012) confirmed the findings of enhanced perceptual ability among persons with autism using a specialized dual-task that first required of the participants to detect a target letter (X or N) and to then indicate whether a meaningless gray character was present or absent outside the ring of letters. They found that adults with autism, as compared to matched TD adults, did not show an impaired detection of the grey character even when there was a higher perceptual load due to a greater number of letters being presented. These findings support the clinically relevant observation by Dawson and Lewy (1989) that individuals with ASD often experience a bombardment of perceptual information due to an inefficient filtering-out capacity. Indeed, this is likely due to the higher than normal attentional perceptual load capacity among individuals with ASD (Remington et al., 2009, 2012) as that zooming-in and discriminating stimuli is an area of attentional strength in individuals with autism.

Deficit in Narrowing or Broadening of Attention in Autism

To further explore the narrowing of attention in ASD Burack (1994) administered a forced-choice RT filtering attention paradigm to low functioning individuals with autism who were matched on mental age (MA) with TD children, and two groups of children with intellectual disability. The nature of the task allowed for the study of the number and location of specific distractors, and the impact that the absence or presence of an imposed attentional window, which would narrow the spotlight of focus, would have on filtering. Although the RTs of the persons with autism improved in the absence of distractors relative to the other comparison groups, the introduction of distractors to the attentional window negated this improvement. Burack concluded that individuals with autism have an inefficient attentional lens resulting in a deficient ability to zoom-in on a target and filter out distractors. In a subsequent study in this area, Mann and Walker (2003) applied a task whereby participants were required to decide which of two pairs of cross-hairs was longer. Mann and Walker concluded that the group with autism displayed a problematic capacity for zooming out or broadening the spread of attention when it came for them to engage the attentional spotlight. The result of such a deficit, according to Mann and Walker, would be a difficulty in shifting attention to peripheral targets in the attentional spotlight. While these findings initially seem to be inconsistent with those of Remington et al. (2009, 2012) in which individuals with ASD effectively broadened their attention to include peripheral distractors and stimuli, Remington et al. note that this only occurred as long the perceptual load processing capacity was not reached. Thus, the nature of the task used by Mann and Walker that included visual measuring and comparing was complex enough to negate the zooming-out perceptual strength noted by Remington et al. in their studies.

Ronconi et al. (2013) revisited the findings of the studies by Burack (1994) and Mann and Walker (2003). They used a paradigm that allowed for the presentation of both small and large spatial cues and for the measurement of the attentional gradient by asking participants to respond as quickly as possible to the targets that were presented at varying eccentricities. The attentional gradient refers to a specific pattern of RTs that is generally evoked when a small cue is presented, causing the attentional spotlight to be focused. When targets are subsequently flashed on the periphery, RTs should be slower than when they appear at a nearer eccentricity resulting in a steeper attentional gradient. They suggested that a small focusing cue should evoke a zoom-in attentional mechanism, whereas a large cue would result in a zoom-out effect. Thus, the zoom-in task would result in a steeper attentional gradient and RT, depending on the degree of the eccentricity of the target in terms of the initial fixation point, whereas the zoom-out task should not have these effects due to the greater attentional reserve dedicated to the whole cue-delimited area. Ronconi et al.'s attention gradient hypothesis was supported for both the small and large cues among children with ASD whereas only the small cue hypothesis was supported among matched TD children. Ronconi et al. (2013) suggest that this is evidence of a specific impairment in the zoom-out aspect of the spotlight, but not in zooming-in. These findings can be seen as consistent with those of Mann and Walker (2003) as the attention atypicality in terms of narrowing or broadening attention in ASD, was relevant specifically in terms of the broadening of attention (zooming-out) but not when narrowing attention (zooming-in).

Similarly, in a neuropsychological study Ronconi et al. (2012) found that symptom severity in individuals with autism is related to an impairment in zooming-out their attention.

These findings seem to contradict those of Remington et al. (2009, 2012) that individuals with autism have a higher capacity for processing stimuli on the periphery when zooming out attention. Inconsistent findings such as these might be explained by the nature of task difficulty in which a difficult task would result in the perceptual benefits noted in individuals with ASD being negated due to the level of one's perceptual capacity required for completing the task. However, such an explanation would not be appropriate here as, based on the description of the tasks used by Ronconi et al. (2013), the complexity and difficulty of the tasks appear to be similar to those used by Remington et al. (2009, 2013). Hence, a difficulty or complexity effect is unlikely. Yet, the explanation conceivably lies in the different populations used in the two studies. The participants in Remington et al.'s studies were adults whereas Ronconi et al. (2013) studied children. Perhaps the zooming-out capacity is compromised in children with ASD but not in adults. Indeed this seems tenable in light of the finding by Elasabbagh et al. (2013) discussed earlier where younger children with ASD displayed a compromised ability for disengaging their attention from a specific stimulus in order to orient to a peripheral one. Further studies might explore this developmental difference and its ramifications for the development of autism. These discrepant findings underscore the importance of comparing findings from a developmental approach with a consideration of both chronological and mental ages (see Burack et al., 2004; Burack et al., 2012). Indeed this is well understood in context of the assertion that a significant challenge when studying individuals with autism is the unique pattern of strengths and weaknesses that they display (Burack, Iarocci, Bowler, & Mottron, 2002). The frequently noted discrepancies between various age groups and populations are often inextricably bound up with fundamental attributes and core diagnostic criteria that are unique to a specific developmental stage (Burack et al., 2001; Zelazo, Burack, Benedetto, & Frye, 1996).

Attention, the Attentional Blink, and Lag-1 Sparing

In order to further explore the narrowing and broadening of the attentional spotlight in ASD, the attentional blink (AB) paradigm, which is typically used to explore the temporal dynamics of visual attention, could be applied. The attentional blink paradigm was first described by Raymond, Shapiro, and Arnell (1992), who used a rapid serial visual presentation (RSVP) technique to display a rapid stream of distractor stimuli at fixation. Embedded within that stream were two letter targets; the observers' task was to report the identities of the two targets (see Figure 1). Raymond et al. found that although observers could accurately report the identity of the first target (also known as T1), their accuracy in reporting the identity of the second target (T2) depended critically on the amount of time between the presentations of the two targets. If the stimulus onset asynchrony (SOA) between the two targets was between approximately 200 and 500 ms, then T2-identification accuracy was impaired. (SOA refers to the time that elapses between sequential items in the stream thereby determining the speed or rate of the stream.) If, on the other hand, the SOA was longer than about 500 ms, then T2 could be identified very accurately. In other words, the observers' ability to report the two targets varied as a function of the temporal lag between the two targets.

Raymond et al. (1992) based their work on early studies by Broadbent and Broadbent (1987) and Weichselgartner and Sperling (1987). Broadbent and Broadbent (1987) asked participants to identify two uppercase words that were embedded between lowercase words and they varied the lag, or delay, between the targets to times between 80 ms and 120 ms. They found that when there was an accurate detection of the first target (Tl), then identification of a second target (T2) which appeared within 500 ms of T1, was compromised. Broadbent and Broadbent (1987) explained that these findings were consistent with some of the pioneering work done by Duncan (1980) in this area who noted that the targets in RSVP style presentations would cause identification interference with each other. Researchers highlight a recovery period where identification accuracy of T2 improves as the lag between stimuli presentation is increased (Duncan, Martens, & Ward, 1997; Joseph, Chun, & Nakayama, 1997; Visser, Zuvic, Bischof, & Di Lollo, 1999).

Raymond et al. (1992) further found that if T2 was presented directly after T1 in the ordinal position known as Lag 1, then the AB did not necessarily occur (see also Weichselgartner & Sperling, 1987). This spared T2-identification accuracy is known as Lag-1 sparing; the converse--an inability to identify T2 at Lag 1--is referred to as Lag-1 deficit (Potter, Chun, Banks, and Muckenhoupt, 1998). Furthermore, if T2 appeared at Lag 2 and there was one distractor intervening between T1 and T2, correct T2 identification is negatively impacted and only improves some 300-400 ms later and the AB phenomenon could thus be depicted as U-shaped curve that is a function of lag (Chun & Potter, 1995).

Models of the Attentional Blink

Numerous theoretical explanations have been forwarded to explain the deficient identification of T2 (for reviews see Dux & Marois, 2009; Martens & Wyble, 2010). Raymond et al. (1992) proposed that when T2 is presented before the processing of T1 is completed, an attentional interference occurs and processing of the second target is suppressed. Given that attention is episodic in nature (Sperling & Weichselgartner, 1990, 1995) this attentional suppression could be depicted as an attentional gate that closes for a few hundred milliseconds, resulting in the missing of T2 if it presented during that period of time (Chun & Potter, 1995; Shapiro & Raymond, 1994). Raymond et al. (1992) termed this phenomenon the attentional blink due to its being so analogous to the visual processing suppression that briefly occurs when a person blinks his or her eyes after taking in a visual scene.

Chun and Potter (1995) proposed a 2-stage model to explain the AB and Lag-1 sparing. In the first stage, features that are relevant for identifying T1 are analyzed. The representations that were captured during stage 1, however, require additional processing, and they must then be transformed into a more robust form of representation. This transformation, they propose, requires a second stage of processing to complete target consolidation and to allow accurate target identification. However, when interference occurs during stage 1, which may arise from the presentation of additional stimuli in the RSVP stream, some of the representations are then subject to being lost. Stage 2 is probably capacity-limited and commences after stage 1 target detection is complete. Thus, when T2 is presented at Lag 1, both targets will be processed together in stage 1 and will result in a delay of stage 2 processing. The longer the delay of stage 2 processing, the more probable it is that T2 will be lost, resulting in the AB phenomenon. It stands to reason that a shorter delay will result in Lag-1 sparing. This slower, resource-limited processing system is often referred to as a bottleneck model, because of out how it limits perceptual processing (Jolicoeur, Dell'Acqua, & Crebolder, 2001).

Di Lollo, Kawahara, Ghorashi, and Enns (2005) proposed that the AB deficit is not the result of having a limited amount of processing resources, as in Chun and Potter's 2-stage model, but is rather the result of a temporary loss of control (TLC). Thus the stimuli are processed based on a form of filter that is set to accept appropriate targets while excluding non-target items. Based on the TLC hypothesis, only one function can be performed at a time. Accordingly, as soon as a target is identified the cognitive system discontinues direct monitoring for different categorical targets. If the next stimulus that appears is part of the same category, that stimulus is processed accurately along with the first, and Lag-1 sparing will occur. However, if the next stimulus belongs to a different category, processing will take longer, making it, and subsequent stimuli, liable to inefficient processing because the attentional system can process only one specific configuration type at a given time.

One final theoretical approach that has been forwarded to explain AB and the resulting Lag-1 sparing is called the boost and bounce theory (Olivers & Meeter, 2008). According to this approach, an attentional gate controls the perception of targets by providing an excitatory feedback boosting of attention mechanisms when an appropriate target is detected, and inhibiting processing by bouncing attention when a non-target appears. Based on this theory, Lag-1 sparing should be attributed to T2 arriving at the crest of the T1 induced attentional boost. Consequently, this would not only allow T2 to be spared at Lag-1, but even for a better processing of T2, being as it is being processed at the attentional peak of T1.

Spatial Attention and AB

In a meta-analysis by Visser, Bischof, and Di Lollo (1999) of over 100 studies in which the AB had been studied, the cases where Lag-1 sparing occurred were often when there was a single RSVP stream and were always when the targets appeared in the same spatial location. However of the 41 studies that dealt with two targets being presented in different special locations, Lag-1 sparing was never found (Visser et al., 1999). Moreover, Kristjánsson and Nakayama (2002) demonstrated that when the two targets were spatially distant from each other, the recovery from the AB was faster than when they are nearby. Visser et al. (1999) tested the spatial AB phenomenon specifically and ran a series of experiments including where TI and T2 were not presented in the same spatial location, but one of them was presented in one of four positions. They found that while Lag-1 sparing did occur when T2 appeared in the same spatial location as T1, it did not occur when T1 and T2 appeared in different locations. They concluded that that if the attentional system is involved in processing a stimulus at one location, it cannot be switched to attend to a new location.

Dual-Stream AB Paradigm

Jefferies, Ghorashi, Kawahara, and Di Lollo (2007) noted one study in the literature in which Lag-1 sparing occurred when T1 and T2 appeared in different locations (i.e., Shih, 2000). In that study, two RSVP streams were presented, one on either side of a fixation, and T1 and T2 were presented unpredictably in either stream (see Figure 2). Jefferies et al. (2007) suggested that Lag-1 sparing occurred to targets in different spatial location in Shih's study, but not in any other study, due to the unique way in which the focus of attention was deployed in Shih's experiment. Specifically, Shih's study employed two RSVP streams, one presented on either side of fixation. Observers had no advance knowledge of which stream would contain the targets--they could appear unpredictably in either stream. In order to perform the task, therefore, observers had to deploy attention broadly so that it encompassed both RSVP streams. Jefferies et al. further hypothesized that Lag-1 sparing does not occur only when T2 appears in the same location as T1; rather, Lag-1 sparing occurs whenever T2 falls within the focus of attention and can therefore pass through the attentional gate (see Figure 3). Since in Shih's study the focus of attention was broadly deployed and encompassed both streams, Lag-1 sparing occurred regardless of whether T2 appeared in the same stream as T1 or in the different stream. To reiterate, the critical factor was not whether T1 and T2 appeared in the same stream, but rather whether T2 appeared within the attentional focus, allowing it to pass through the attentional gate. Thus, when employing this type of dual stream paradigm, where the participant is naïve as to where T1 will appear, Lag-1 sparing will occur regardless of whether T2 appears in the same stream as T1 (same-stream condition) or in the opposite stream (Jefferies et al., 2013; Jefferies, Enns, & Di Lollo, 2014). This result and explanation account for the dissimilar findings between Shih (2000), who used a dual stream paradigm and the participants did not know where T1 would appear, versus the studies quoted by Visser et al. (1999) where the participants knew where the T1 would appear.

Similarly, Lunau and Olivers (2010) explored spatial attention by studying the AB with targets that continuously moved across numerous locations with the aid of a spatial cue. Like Jefferies et al. (2007), they too found an AB and Lag-1 sparing with targets that appeared in different locations. They also concluded that the AB and Lag-1 sparing depended on uncertainty regarding where the T1 would appear and the resulting distribution of the attentional gate.

Jefferies et al. (2014) tested the hypothesis regarding knowing in advance in which stream T1 would appear and the resulting lack of Lag-1 sparing, using a pair of letters and numbers in a revised dual-stream paradigm (see Kawahara & Yamada, 2007). In this paradigm, the T2 pair could be presented either within the streams, or in the space between the streams. This followed the T1 pair, which either always appeared within the stream (predictable) for the first task, or would appear either within the streams or between the streams (unpredictable) for the second task. Jefferies et al. found that when the participants were not told where the T1 would appear (unpredictable), then, when T2 appeared between the streams, Lag-1 sparing occurred, whereas it did not occur when participants knew where the T1 would appear (predictable).

However, despite the findings and explanation supporting the connection between unpredictability of T1 and Lag-1 sparing, recently it was shown that when targets in a RSVP stream appeared randomly in one of eight different locations on the screen and always involved a spatial switch of location between T1 and T2, a monotonic AB shape resulted with the largest deficit occurring when T2 appeared directly after Tl and there was no presence of Lag-1 sparing (Berthet & Kouider, 2012; Breitmeyer, Ehrenstein, Pritchard, Hiscock, & Crisan, 1999). This is problematic, because, while there was no expectation where T1 would appear, which, as discussed earlier, should have resulted in a broadening of the attentional spotlight to encompass all eight streams, yet there was no Lag-1 sparing. Accordingly, it might be posited that Berthet and Kouider (2012) did not find Lag-1 sparing because the presence of eight different potential locations for T1 and T2 was just too much, and the attentional resources cannot accommodate such a spread. Perhaps had they incorporated fewer locations, then they would have found Lag-1 sparing to be present in accordance with the broadening attentional spotlight as explained by Jefferies et al. (2007).

When Lag-1 sparing occurs in the same-stream condition (i.e., when T1 and T2 appear in the same stream), the magnitude of the Lag-1 sparing is typically greater than when Lag-1 sparing occurs in the opposite-stream condition (i.e., when T1 and T2 appear in different streams; Du, Abrams, & Zhang, 2011; Juola, Botella, & Palacios, 2004; Jefferies et al, 2014; Kawahara, 2002; Olivers, 2004). Jefferies and Di Lollo, (2009) looked to further explore the presence and magnitude of Lag-1 sparing in a dual-stream RSVP paradigm by assessing the combined consequences of spatial separation with temporal lag on T2 identification. To this end, they manipulated the SOA between the stimuli in the streams, with a special interest in the impact on those trials where T1 and T2 appeared in different streams. In the dual-stream paradigm, one's focal attention is initially set broadly to encompass both streams; however, it zooms-in rapidly to the stream in which T1 appeared. The hypothesis was that when both streams are set as potential locations for T1, and the SOA from T1 is short, there was not adequate time allowed for the participants' attention to zoom-in and focus on the stream in which

T1 appeared and to then withdraw as a result of the distractor that was presented in the opposite stream. When T2 appears in either of the streams, it will still fall within the initial focus of attention, resulting in Lag-1 sparing. However, when the SOA is longer, ample time has since elapsed for the zoomed-in attention to completely contract to the stream in which the T1 appeared. The result in this case will be that T2 does not fall within the focus of attention, resulting in Lag-1 deficit (i.e., accuracy for identification of T2 at Lag 1 is poorer than at Lag 2 or Lag 3--the opposite of Lag-1 sparing; see Figure 3.) The SOAs explored by Jefferies and Di Lollo (2009) were 53, 66, 80, 100, 118, and 133 ms. They found that for these SOAs, the Lag-1 sparing was consistently stronger and present when T2 appeared in the same stream, however when T2 appeared in the opposite stream, a diminished Lag-1 sparing occurred as long as the SOA was less than 100 ms, but not longer. This study is particularly interesting as the presence and magnitude of the Lag-1 sparing in TD individuals is clearly impacted by the SOA length.

Autism, Attentional Blink, and Lag-1 Sparing

Researchers have suggested that the cognitive profile in autism could be better identified and understood, by focusing on the specific problems experienced when processing complex information (Bertone, Mottron, Jelenic, & Faubert, 2005). Accordingly, the question that needs to be asked is whether the AB and Lag-1 sparing would be present in individuals with a developmental disorder such as ASD and whether Lag-1 deficit or sparing in ASD would be impacted by the length of the SOA as they were in typical development. Furthermore, the AB paradigm provides an opportunity to assess the zooming-in and zooming-out discussed above, from a different experimental approach, and might shed light on some of the aberrant findings discussed above regarding narrowing and broadening of attention in autism (i.e., Burack, 1994; Man &Walker, 2005; Ronconi et al., 2013).

Attention in Autism and Single-Stream Paradigms

The application of AB paradigms to the study of autism has been limited to single-stream paradigms. In three of those studies the authors used single-stream paradigms to better understand how socially-charged stimuli such as emotional words (Corden, Chilvers, & Skuse, 2008; Gaigg, & Bowler, 2009) and emotional faces (Yerys et al., 2013) are attended to and processed. In all these studies the actual AB effect was consistent between TD participants and those with ASD with no mention of Lag-1 sparing at all. Amirault et al. (2009) administered a traditional single-stream AB paradigm to a group of young adults with HF autism and compared results with TD adults with the aim of assessing whether the AB in autism is distorted as compared with TD individuals. The task consisted of a string of letters with two embedded target letters that needed to be identified. Before discussing the AB and Lag-1 sparing findings, it is important to note that the authors found differences between both T1 and T2 discrimination accuracy between the TD group and the group with autism, and especially for T2 over the course of the RSVP stream. This led them to suggest that individuals with autism displayed an altered AB because the AB duration lasted for longer, hence the lower identification rate for T2. However, they do note that the relative magnitude of the AB is typical, as compared to the TD group. Additionally, they found that both TD adults and adults with autism displayed Lag-1 sparing at the SOA of 85 ms. In a similar study, Rinehart, Tonge, Brereton, and Bradshaw (2010) to examined whether there was a difference between TD young people and those with Asperger's disorder and autism. An important methodological difference between this study and the one by Amirault et al. (2009) was that when participants were not able to correctly identify T1, they were not included in the analyses for the AB. Rinehart et al. (2010) found that individuals with ASD (both Asperger's and autism) displayed a typical AB for an SOA of 99 ms but they make no mention of whether there was Lag-1 sparing or deficit.

Current Study

The focus of the current study was to explore the presence or absence of AB and Lag-1 sparing, when a dual-stream RSVP paradigm was used. The nature of the task allows for an exploration of the broadening and narrowing of attention among persons with ASD, and to apply the findings to better understand some of the discrepant findings in this domain of research. The added complexity of the dual-stream paradigm as opposed to more standard RSVP single-stream tasks, and the greater attentional resources required to complete such a task (see Keehn, Müller, & Townsend, 2013, for a review), combined with the atypicalities noted in narrowing or broadening of spatial attention in individuals with autism, were expected to result in an atypical attentional gate-closing mechanism. Specifically, the nature of the task was expected to cause hyper-attentional-arousal among the individuals with autism, as discussed earlier, due to the increased task complexity combined with the need to identify the specific target, leading to a snappier shutting of the attentional gate, regardless of the stream in which T2 appears. Therefore, although Lag-1 sparing could occur in a single-stream AB paradigm, it would not be present in a dual-stream paradigm regardless of the stream in which T2 would appear.

Method

Participants

Eleven participants with HF autism (ages 14 - 17 years of age, mean full scale IQ of the group was approximately 96 (*SD* = 15.82)) were recruited through the McGill Youth Study Team (MYST) lab, Giant Steps, and Lester B. Pearson School Board, all in Montreal. Eighteen young TD adults (ages 18 – 27 years of age) were recruited from the psychology undergraduate population at McMaster University in Hamilton who participated in order to obtain course credit. Participants with high functioning autism all met DSM-IV (APA, 2000) criteria for autistic or Asperger's disorder and had prior diagnoses based on clinically reliable scores such as the Autism Diagnosis Interview-Revised (ADI-R; Lord et al., 1989; Lord, Rutter, & Le Couteur, 1994; Lord, Storoschuck, Rutter, & Pickles, 1993) and the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, & Di Lavore, 1997). All of the participants were naïve regarding the purpose of the current study and had normal or corrected-to-normal vision. Two participants in the autism group were ultimately excluded from analyses on the 80-ms task, and one on the 133-ms task due to low T1 identification rates (less than 11% and 14% accuracy respectively.)

Stimuli and Apparatus

The participants sat approximately 57 cm from a computer monitor, in a dark room with the only light coming from a lamp that illuminated the computer keyboard. A fixation-cross (0.25˚ × 0.25˚) appeared in the centre of the screen and remained present for the duration of each of the trials. The stimuli consisted of capital letters of the alphabet (besides for I, O, Q, and Z), and white digits (0 - 9) and each of which subtended approximately 0.9˚ vertically. The screen refresh rate varied depending on the SOA between successive items in the display sequence. The screen refresh rate was set to 75 Hz.

Procedure

The methodology replicated the 80- and 133-ms SOA conditions of Jefferies and Di Lollo (2009). Participants began each trial by pressing the keyboard's spacebar. As each trial began, two synchronized RSVP streams consisting of the items described above were presented at an angle of 1.75° to the right and left of the fixation-cross. Before the targets appeared, between 8 and 14 randomly chosen distractor digits were presented. The same digits never appeared concurrently in each stream nor was the same digit presented twice within a two digit presentation span. The two different target letters appeared randomly in either the same stream or in the right or left stream with equal probability. Targets were presented on each trial. The two targets appeared randomly but with equal probability in either the left or the right streams and could appear in either the same stream or in different streams. Each stream concluded with a one digit distractor. The observers' task was to identify the two target letters by pressing the correct letters on the keyboard. The SOA between the items in each of the streams was 80 ms, or 133 ms and T2 appeared at one of three inter-target lags, namely at lag 1, 3, or 9. At Lag 1, T2 was presented directly following T1, at Lag 3 two distractors were inserted between T1 and T2, while at Lag 9, there were eight distractors inserted. The three inter-target lags could occur in any order but with the same frequency across the trials.

Results

Identification of the First Target

Average T1 identification accuracy was very similar for both groups in terms of overall percentage of correct responses, with T1 identification being slightly lower when T2 appeared in the Same-Stream at Lag-1 in both groups. This decrease in accuracy at Lag 1 in the Same-Stream condition is due to metacontrast masking, which will be discussed later (see Table 1 and Figure 4).

Identification of the Second Target

Trials were only included in the analyses if T1 was correctly identified. This is a commonly-adopted procedure in AB studies. The rationale behind this procedure is that on those trials in which T1 is not correctly identified, it is difficult to know why it was missed, making it impossible to know the source of the T2-deficit.

T2 identification accuracy (Table 2) was analyzed separately for each group and for each SOA with a 2 (Stream: Same-Stream, Different-Streams) × 3 (Lag: 1, 3, 9) within-subject repeated measures ANOVA. Results for the analyses of the TD group in the 80-ms SOA condition revealed significant main effects of Stream, $F(1,17) = 4.75$, $p = .044$, $\eta_p^2 = .218$, and Lag, $F(2,34) = 34.063$, $p < .001$, $\eta_p^2 = .667$, and a significant interaction effect between Stream and Lag, $F(2,34) = 18.41$, $p < .001$, $\eta_p^2 = .520$ (Table 3). Similarly, in the 133-ms SOA condition, there were significant main effects of Stream, $F(1,17) = 18.75$, $p < .001$, $\eta_p^2 = .524$, and Lag, $F(2,34) = 10.23$, $p < .001$, $\eta_p^2 = .376$, and a significant interaction effect between Lag and Stream, $F(2,34) = 14.46$, $p < .001$, $\eta_p^2 = .419$ (Table 4). These results closely replicate those of Jefferies and Di Lollo (2009); namely, for TD young adults, Lag-1 sparing was present in both the Same-Stream and the Different-Streams in the 80-ms SOA condition, but only in the Same-Stream in the 133-ms SOA condition.

For the group of individuals with ASD, in the 80-ms SOA condition, there was a significant main effect of Lag, $F(2,16) = 14.65$, $p < .001$, $\eta_p^2 = .647$ (Table 5) but neither the effect of Stream nor the interaction between Stream and Lag was significant, with the main effect of Stream being $F < 1$. In the 133-ms SOA condition, there was a significant interaction effect between Stream and Lag $F(2,18) = 6.38$, $p = .008$, $\eta_p^2 = .415$ (Table 6). These results indicate that, unlike the TD group, Lag-1 sparing did not occur in either the Same- or the Different-Streams condition at either SOA for the ASD group (see Figure 5).

Lag-1 Sparing. Lag-1 sparing is defined as the difference in T2-identification accuracy at Lag-1 and at Lag-3. In order to confirm the absence of Lag-1 sparing in the ASD group, therefore, analyses were restricted to T2-accuracy at Lags 1 and 3. To this end, a series of four, 2 (Group: TD, ASD) × 2 (Lag: 1, 3) repeated measures ANOVAs were performed with Group being the between-subject factor, and Lag being the within-subject factor. In the 80-ms condition, there were significant interactions between Lag and Group for the Same-Stream condition, $F(1,25) = 18.02$, $p < .001$, $\eta_p^2 = .419$ (Table 7), and for the Different-Stream conditions, $F(1,25) = 8.469$, $p = .007$, $\eta_p^2 = .253$ (Table 8). Similarly, in the 133-ms Same-Stream condition there was a significant interaction between Lag and Group, $F(1,27) = 4.31$, $p = .047$, $\eta_p^2 = .138$ (Table 9). These significant interactions indicate that Lag-1 sparing occurred for the TD group for both Stream condition when the SOA was 80-ms, and for the Same-Stream condition when the SOA was 133-ms, but it never occurred for the group with ASD. However, the interaction between Lag and Group was not significant in the 133-ms SOA Different-Streams, $F(1,27) = 2.62$, $p = .117$ (Table 10), which is interpreted to mean that there was no Lag-1 sparing that occurred for either the TD group or the group with ASD (see Figure 6).

Overall Performance by Individuals with ASD

The results clearly indicate that while TD individuals display a definite Lag-1 sparing, individuals with ASD do not display the phenomenon. The question then arises whether any other atypicalities were evident in the individuals with ASD in their performances throughout the paradigm. This can be addressed in two ways: first, mean T2 accuracy at Lag-9 for the two groups at both of the SOAs was compared. Results of independent samples *t*-test revealed that there was not a significant difference between the accuracy of the groups at Lag-9 for either SOA. Specifically, regarding the SOA of 80-ms, for the TD group, $M = 70.47$, $SD = 12.80$, and for the group with ASD, $M = 75.11$, $SD = 13.30$; $t(25) = -.877$, $p = .389$. By the SOA of 133-ms, for the TD group, $M = 81.54$, $SD = 3.80$, and for the group with ASD, $M = 81.58$, $SD = 14.68$; $t(27) = -.006$, $p = .907$.

Second, the performance of both groups was considered in terms of T1 identification accuracy. It has long been known that if a second stimulus is presented directly following a first stimulus in the same spatial location, the second stimulus impairs the visibility and identifiability of the first stimulus, a phenomenon known as backward masking (see Breitmeyer, & Ogmen, 2000; Enns & Di Lollo, 2000). It is noteworthy that the group of individuals with ASD displayed the same degree of masking as the TD group, as evidenced by the performances on T1 by both groups noted earlier. Specifically, T1 identification accuracy was lower when T2 appeared at Lag-1 directly following T1 in the same stream, than when it appeared at a different Lag or in a different stream (see Figure 4).

As a whole, the current findings indicate that individuals with ASD display both a typical pattern of T1 identification, and an intact performance on T2 identification at Lag-9, as compared to the TD group. However, when it comes to Lag-1 sparing, while the TD group exhibited Lag-1 sparing in all conditions, except for the 133-ms different-stream condition, yet the individuals with ASD did not display Lag-1 sparing in any condition, regardless of the SOA or the relative locations of the targets (Same-Stream or Different-Streams). This finding is unexpected, especially in light of the typical performances by the individuals with ASD in both streams at both SOAs, in terms of their T1 identification, and their efficient T2 identification at Lag-9.

Discussion

In the current study a dual-stream RSVP paradigm was applied to explore the AB in individuals with autism. The results confirmed our hypothesis that despite displaying Lag-1 sparing in a single-stream paradigm, young adults with autism would not show Lag-1 sparing in dual-stream tasks. Specifically, regardless of whether the SOA from T1 was shorter, namely 80 ms, or longer, namely 133 ms, and regardless of whether the T2 appeared in the same stream or in the opposite stream as T1, Lag-1 sparing did not occur. This contrasts with the TD comparison group who, as expected, always displayed Lag-1 sparing when the T2 appeared in the same stream, regardless of the SOA, and also displayed Lag-1 sparing when the T2 appeared in the opposite stream at the shorter SOA of 80 ms.

Lag-1 Sparing in the Group of Typical Young Adults

The AB generally would be expected to cause the individual to miss the second target if it is presented immediately after the first target. However, when the TD participant is not told in which stream the T1 will appear, the attentional focus zooms-out to encompass both streams. When T2 appears, the attentional spotlight that initially focused on both streams and then zooms-in to T1, is still large enough to capture T2, as long as the attentional-gate that captures the targets in the spotlight has not closed. In typical development, the attentional spotlight remains large enough to capture a second target at Lag-1 if it is in the same stream, even if the SOA is long (133 ms) and certainly if the SOA is short (80 ms). This is conceivably due the fact that the attentional gate has not yet had opportunity to shut. If the target appeared in the opposite stream, then, when the SOA was short, the spotlight was still large enough to capture T2, resulting in Lag-1 sparing; however, at the longer SOA, the attentional spotlight had already zoomed-in resulting in it missing T2 and Lag-1 deficit would occur.

Absence of Lag-1 Sparing in the Group with Autism

As in the TD group, in the group of individuals with autism, the spatial extent of the attentional spotlight and the speed of the shutting of the attentional gate, will determine whether the T2 is identified or not. As noted above, Lag-1 sparing did not occur in the group with autism regardless of the SOA and regardless of whether the two targets appeared in the same stream as one another or in a different stream. These results are indicative of an atypicality either with the spread of the attentional spotlight or with the resulting speed with which the attentional gate closes.

Limitation in attentional broadening. Ronconi et al. (2013) found that when a target was presented during the time of attentional focusing (SOA of 100 ms), and TD children were made to zoom-in their focus of attention to a small target, a gradient effect occurred for capturing other targets that appeared surrounding the central target (see Turatto et al., 2000). Thus, reaction times for locating these other targets increase because they are outside the spotlight of attention. However, when Ronconi et al. told the children to attend to a larger target, it evoked a zoom-out effect and the gradient effect was absent for the other targets due to an already wider attentional spotlight (e.g., LaBerge, 1983) resulting in the equal capture of all targets. The children with ASD, regardless of the nature of the cue (small or large), tended to deploy a narrower attentional spotlight that hones in on what is being attended (Ronconi et al., 2013). According to this understanding, there is a marked deficit in the broad distribution of the attentional spotlight and the associated resources in ASD. The resulting attentional gradient for the zooming-out task that Ronconi et al. found in the group with autism, is suggestive of a deficit in broadening attentional resources and probably means that they have a labored zooming-out mechanism of attention. At first glance, the reason that Lag-1 sparing in the individuals with autism was not found is because when they processed T1, the attentional spotlight was too narrow to also encompass the second stream and is characteristic of the sluggish zooming-out noted above. This explanation would also account for the finding of Lag-1 sparing in the single stream paradigm for individuals with ASD (Amirault et al., 2009) because once the attentional spotlight is zoomed in, it will still be able to capture T2 due to it being in the same spatial location as T1. This would also seem plausible according to Mann and Walker (2003), discussed earlier, who suggested that the attentional deficit in autism relates specifically to broadening the focus of the attentional spotlight, and, based on the explanation of Ronconi et al. (2013), this study therefore provides support for Mann and Walker's account of the attentional deficit in autism over the attentional lens deficit theory forwarded by Burack (1994). However, this approach cannot explain why Lag-1 sparing was absent in the dual-stream paradigm when the T2 was in the same stream as the T1. Thus, the dual-stream paradigm itself was key to the lack of Lag-1 sparing, and a more nuanced explanation is thus required.

Limitation in the narrowing of attention and attentional load. An additional possible option for explaining the lack of Lag-1 sparing in the group with autism might be attributable to a deviant narrowing of attention as compared to TD individuals. As individuals with autism tend to experience abnormally high levels of attentional arousal (hyper-attention-arousal) resulting in a narrowing of the spotlight around the stimuli (Tracy et al., 2000), this leads to superior visual search skills in individuals with ASD, as compared with TD individuals. Remington et al. (2012) suggested that this strength is due to the greater perceptual load capacity possessed by those with ASD. Interestingly, when a task is very challenging and demands increased attentional focus, the typically robust ASD responses shut down due to the increased perceptual capacity required (Hessels et al., 2013). This was demonstrated by Hessels et al. (2013) when after administering two visual search tasks to groups of TD adults and those with ASD, it was found that on one of the tasks there was no difference between the groups, while on the second task, individuals with ASD displayed a stronger visual search capacity. They hypothesized that this discrepant finding was due to the higher perceptual capacity required for the more challenging task, which negated the stronger visual search skills generally present in individuals with autism. Accordingly, when a task such as the dual-stream AB paradigm is used, the heavy perceptual load involved in monitoring both streams leads to an attentional dysfunction in individuals with ASD (Lovaas, Koegel, & Schreibman, 1979). In this case, the excessive focus typically displayed by individuals with ASD on the first stimulus and the other stimuli causes the attentional gate to shut very quickly. Accordingly, no Lag-1 sparing occurred at either SOA regardless of the stream. However, when a task is less complex, such as the single-stream AB task, the attentional gate of individuals with autism will function typically and Lag-1 sparing will occur with a typical AB magnitude (Rinehart et al., 2010). Thus, the quicker shutting of the attentional gate due to the T1 in the dual-stream paradigm would suggest that the narrowing attentional lens is indeed atypical when a task is challenging and could thus support the assertions by Burack (1994) discussed earlier regarding the inefficient attentional lens. In fact, Burack's use of the attentional window and distractors might be understood in terms of an easier and more difficult task as per Hessels et al. (2013) depending on whether the window was present or not, accounting for the atypical narrowing of the lens.

Ronconi et al. (2013) suggested that individuals with autism have a prolonged attentional zoom-in mechanism as per the greater capacity for perceptual load discussed by Remington et al. (2009). However, the findings of Rinehart et al. (2010) that AB magnitude in a simple single-stream paradigm was similar in both TD adults and those with autism and Asperger's, suggests that the zoom-in mechanism in these populations is similar. Furthermore, the findings here suggest that when the task is more complex, not only is the zoom-in mechanism not slower, but the attentional gate actually closes much quicker resulting in the absence of Lag-1 sparing even in the same-stream conditions. Accordingly, individuals with autism might display a limited attentional broadening (as discussed by Mann and Walker (2003) and Ronconi et al. (2013))

hence the lack of Lag-1 sparing at the faster SOA. However, the complex nature of the dual-stream paradigm caused attentional resources to be saturated leading to a quicker shutting of the attentional gate and is thus suggestive of an atypical attentional lens (similar to Burack, 1994).

Limitations and Future Research

While the findings and methodology of the study are quite robust there are a number of limitations. First, in order to properly understand the AB in ASD, the study should also include a task where a simple AB single-stream task is included. This would allow for better comparison between the tasks and participants and would help highlight the differences between an easy and difficult task, as in the studies by Hessels et al. (2013) and Kemner et al. (2007).

Due to the changing of the diagnostic criteria for ASD from the DSM-IV-TR (APA, 2000) to the DSM-5 (APA, 2013), the term Asperger's has been collapsed into the autism spectrum in general, and individuals who might have previously met DSM-IV-TR criteria for an ASD diagnosis might not meet criteria anymore (Mayes et al., 2014; Wing, Gould, & Gillberg, 2011). The participants in this study, and the other AB studies that involved participants with ASD, were all diagnosed based on DSM-IV criteria, and there is thus a need to draw inferences about a disorder in which all of the participants still meet diagnostic criteria.

Developmental theory points to the importance of comparing abilities and faculties with groups at the same developmental stage (e.g., Burack et al., 2001; Zelazo, et al., 1996). Indeed, the differences between a reported strength or weakness, even in groups of individuals with the same disorder, could be attributable to their being at different stages of development. Examples might include comparing groups based on differing chronological ages or more importantly different mental ages. Additionally, although the purpose of the study was to study the AB and Lag-1 sparing in individuals with high functioning autism, their performance was compared to that of TD young adults in order to better understand their performances. However, the TD and autism groups were not adequately matched for age (chronological or mental). This is problematic because age plays a role in the rate of narrowing attention to one stream in a dual-stream paradigm (e.g., Jefferies et al., 2013). Accordingly, the noted differences between the groups might be attributable to typical age-related issues, rather than to autism. Moreover, the unequal sizes of the groups of participants made statistical analyses difficult. In a follow-up study these issues should be properly accounted for, and addressed. Additionally, the small number of participants with ASD is a limitation that cannot be ignored.

It has been suggested here that individuals with autism experienced an increased perceptual attentional load, thereby leading to the faster closing of the attentional gate. However, all stimuli used in this study were non-social (letters and numbers) and thus are more likely to catch the attention of the individuals with autism than socially charged stimuli (e.g., Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Pruett et al., 2011; Sheth et al., 2011). What remains to be seen is how a socially driven dual-stream AB paradigm that incorporates faces with varying emotions would influence how individuals with ASD attend, and what the impact would be on the AB and Lag-1 sparing. Indeed, socially charged stimuli such as faces have traditionally been found to be an area of weakness for individuals with ASD (e.g., Weigelt, Koldewyn, & Kanwisher, 2012; Yerys et al., 2013) and should thus elicit less focused attending resulting in Lag-1 sparing as described above. This would help further explore and support the load-based theory and resulting fast attentional gate hypotheses proposed here.

Conclusion

In previous studies when a single-stream AB paradigm was administered to a group of individuals with autism, both the AB and Lag-1 sparing were present (Amirault et al., 2009;

Rinehart et al., 2010). However Lag-1 sparing did not occur when a dual-stream paradigm was applied in this study. This surprising finding might be the consequence of a combination of task difficulty and dynamic variations in the focused attention attributed to the nature of the dual-stream task, which prevented the Lag-1 sparing from occurring among the participants with ASD, but not among the TD comparison participants.

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Table 1

Percentage Correct Responses of Participants Across Lags and SOAs for T1

Group	SOA	Stream	Lag-1		Lag-3		Lag-9	
	80/133 ms	Same/Different	*M*	*SD*	*M*	*SD*	*M*	*SD*
TD	80	Same	61.54	13.78	72.61	10.85	72.78	9.31
TD	80	Different	69.68	13.49	76.88	22.32	77.72	20.31
ASD	80	Same	68.33	14.37	81.36	16.90	78.71	14.80
ASD	80	Different	80.02	10.96	82.41	13.86	75.67	14.96
TD	133	Same	75.49	15.53	83.23	18.73	77.91	19.63
TD	133	Different	78.54	16.70	83.06	18.16	78.99	16.58
ASD	133	Same	69.68	13.49	76.88	22.32	77.72	20.31
ASD	133	Different	68.33	16.37	81.36	16.90	78.71	14.80

Table 2

Percentage Correct Responses of Participants Across Lags and SOAs for T2

Group	SOA	Stream	Lag-1		Lag-3		Lag-9	
	80/133 ms	Same/Different	*M*	*SD*	*M*	*SD*	*M*	*SD*
TD	80	Same	82.42	11.92	52.04	18.34	68.85	16.45
TD	80	Different	58.54	13.75	49.85	18.08	72.09	16.43
ASD	80	Same	42.12	17.28	47.58	22.90	72.56	20.45
ASD	80	Different	31.93	21.84	52.46	25.96	77.67	12.62
TD	133	Same	82.21	14.62	67.47	23.06	81.48	17.84
TD	133	Different	52.48	17.17	61.41	19.31	81.60	19.40
ASD	133	Same	69.68	13.49	76.88	22.32	77.72	20.31
ASD	133	Different	48.31	22.50	72.34	23.41	85.43	16.04

Table 3

Results of the Repeated Measures ANOVA Conducted on Percentage Correct Responses at T2 for SOA of 80 ms by TD Participants

Variable	*df*	*MS*	*F*	*p*
Stream	1	1562.49	4.75	.044*
Error (Stream)	17	328.92		
Lag	2	4575.36	34.06	.000**
Error (Lag)	34	134.32		
Stream*Lag	2	1853.05	18.408	.000**
Error (Stream*Lag)	34	100.66		

*$p < .01$
**$p < .001$

Table 4

Results of the Repeated Measures ANOVA Conducted on Percentage Correct Responses at T2 for SOA of 133 ms by TD Participants

Variable	*df*	*MS*	*F*	*p*
Stream	1	4125.26	4.75	.000*
Error (Stream)	17	220.04		
Lag	2	2797.57	34.06	.000*
Error (Lag)	34	273.42		
Stream*Lag	2	2007.56	18.408	.000*
Error (Stream*Lag)	34	138.86		

* $p < .001$

Table 5

Results of the Repeated Measures ANOVA Conducted on Percentage Correct Responses at T2 for SOA of 80 ms by Participants with ASD

Variable	*df*	*MS*	*F*	*p*
Stream	1	.05	.00	.987
Error (Stream)	8	328.92		
Lag	1	6745.95	14.64	.000*
Error (Lag)	8	460.64		
Stream*Lag	1	346.11	1.44	.27
Error (Stream*Lag)	8	100.66		

$*p < .001$

Table 6

Results of the Repeated Measures ANOVA Conducted on Percentage Correct Responses at T2 for SOA of 133 ms by Participants with ASD

Variable	*df*	*MS*	*F*	*p*
Stream	1	552.07	.25	.987
Error (Stream)	9	365.67		
Stream*Lag	2	1065.80	6.384	.008*
Error (Stream*Lag)	18	166.94		

*$p < .001$

Table 7

Results of the Repeated Measures ANOVA Conducted on Percentage Correct Responses at T2 for 80 ms Same Stream

Variable	*df*	*MS*	*F*	*p*
Lag	1	1862.853	8.714	.007*
Lag*Group_80_Same	1	3851.367	18.016	.000**
Error	25	213.772		

$^{*}p < .01$
$^{**}p < .001$

Table 8

Results of the Repeated Measures ANOVA Conducted on Percentage Correct Responses at T2 for 80 ms Different Stream

Variable	*df*	*MS*	*F*	*p*
Lag	1	420.873	1.391	.249
Lag*Group_80_Different	1	2561.815	8.469	.007*
Error	25	213.772		

*$p < .01$

Table 9

Results of the Repeated Measures ANOVA Conducted on Percentage Correct Responses at T2 for 133 ms Same Stream

Variable	*df*	*MS*	*F*	*p*
Lag	1	186.619	.510	.249
Lag*Group_133_Same	1	2561.815	4.313	.047*
Error	27	365.868		

*$p < .05$

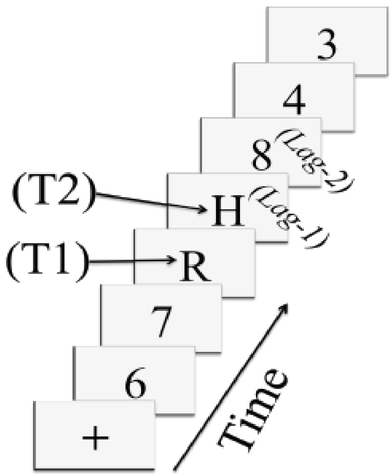
Table 10

Results of the Repeated Measures ANOVA Conducted on Percentage Correct Responses at T2 for 133 ms Different Stream

Variable	*df*	*MS*	*F*	*p*
Lag	1	186.619	12.492	.001*
Lag*Group_133_Different	1	746.653	2.620	.117
Error	25	213.772		

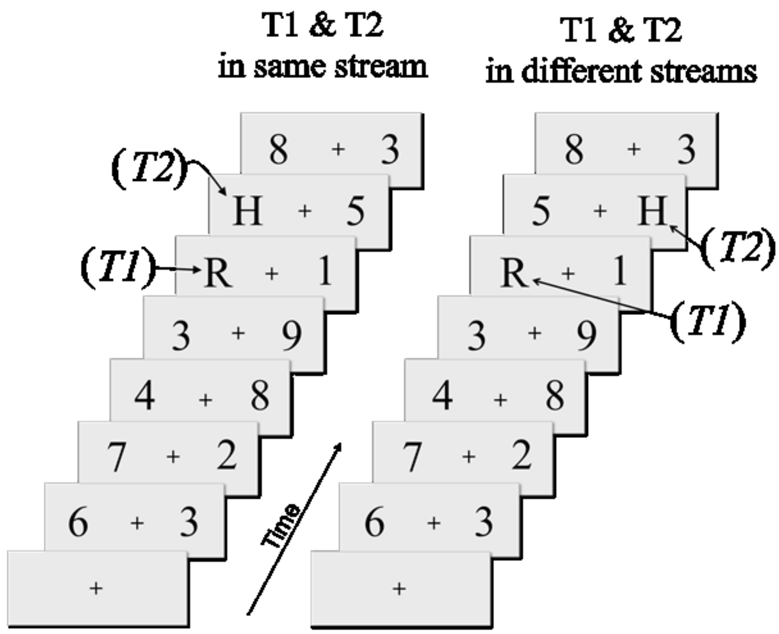
*$p < .01$

Figure 1



Single-stream RSVP AB paradigm where each new stimulus is presented in the same location as the previous stimulus

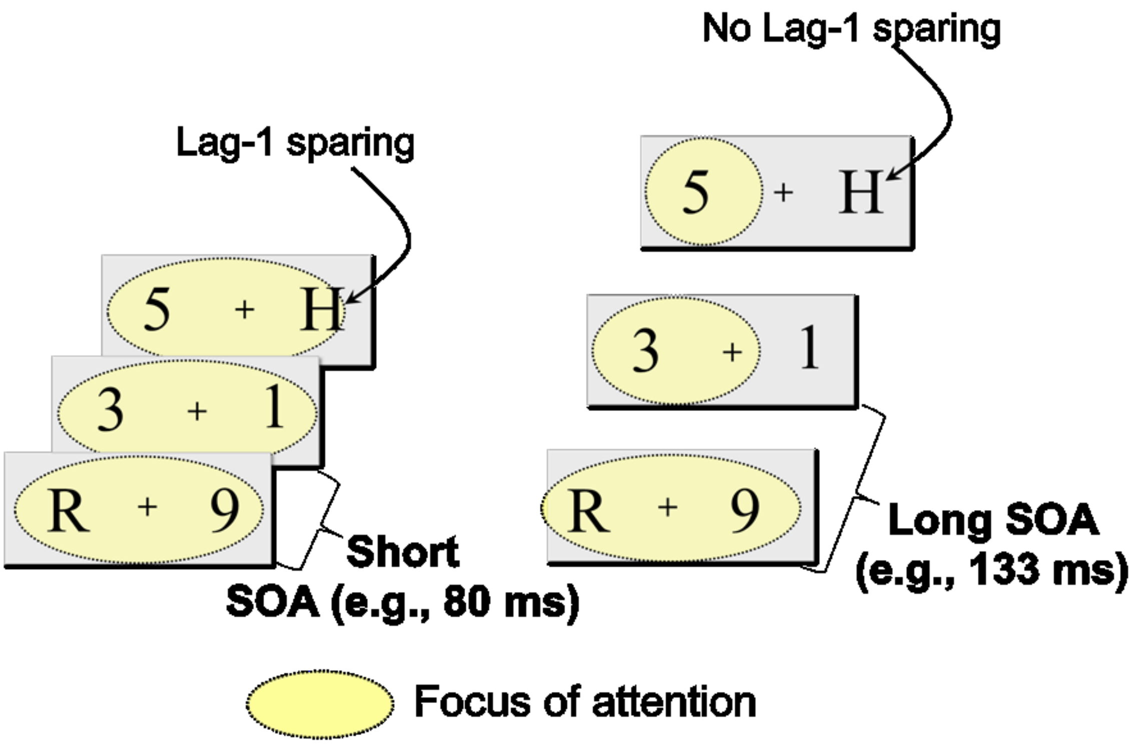
Figure 2



Dual-stream RSVP AB paradigm where each stimulus is presented in either of the streams

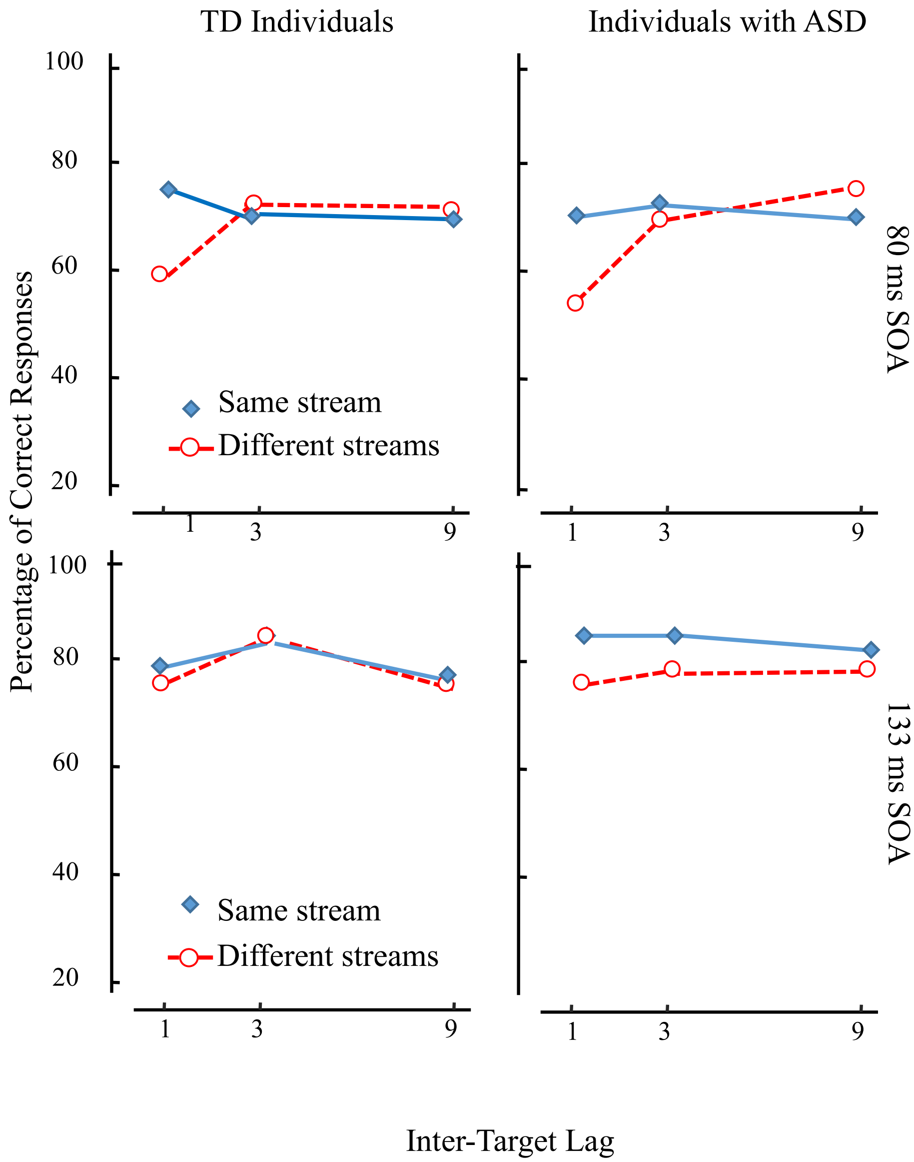
(Jefferies and Di Lollo 2009)

Figure 3



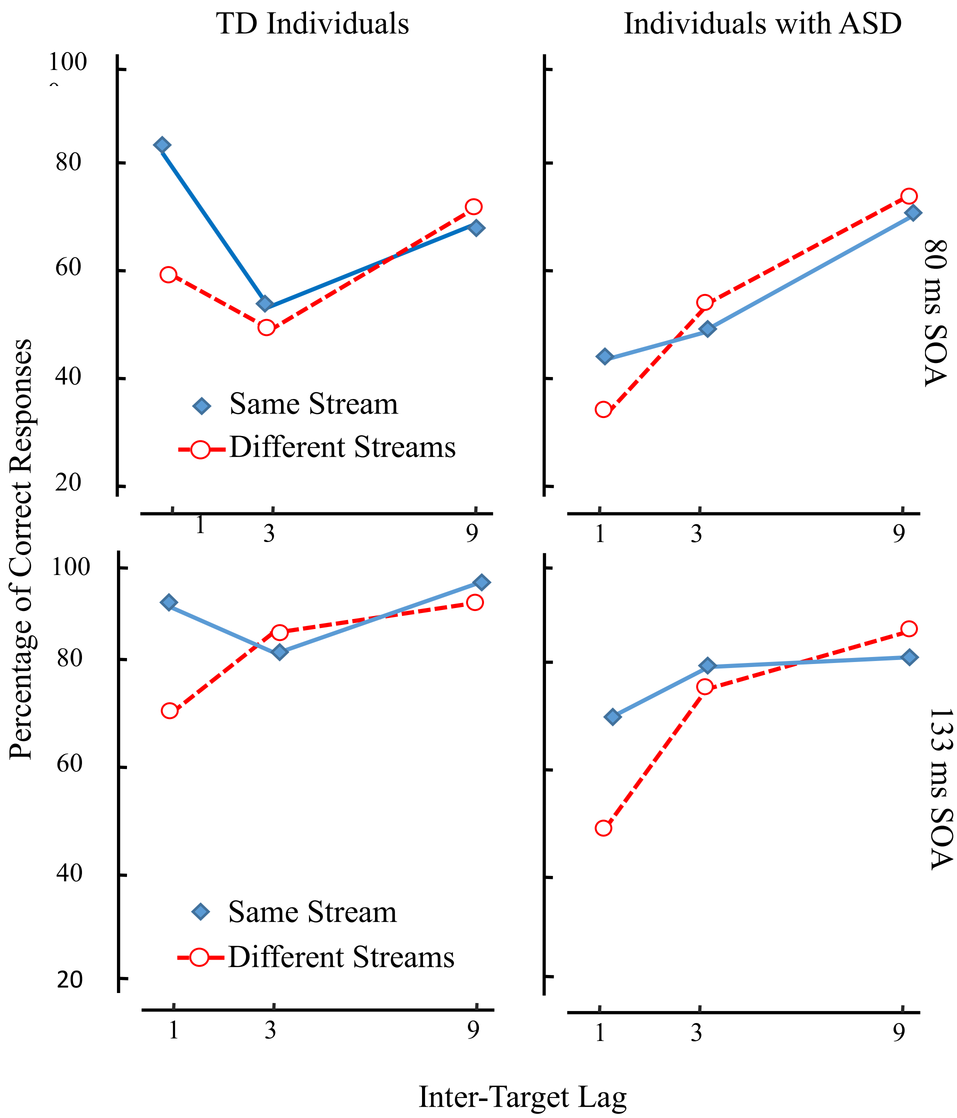
Schematic illustration depicting the progressive changes in the focus of attention as a function of SOA and Lag

Figure 4



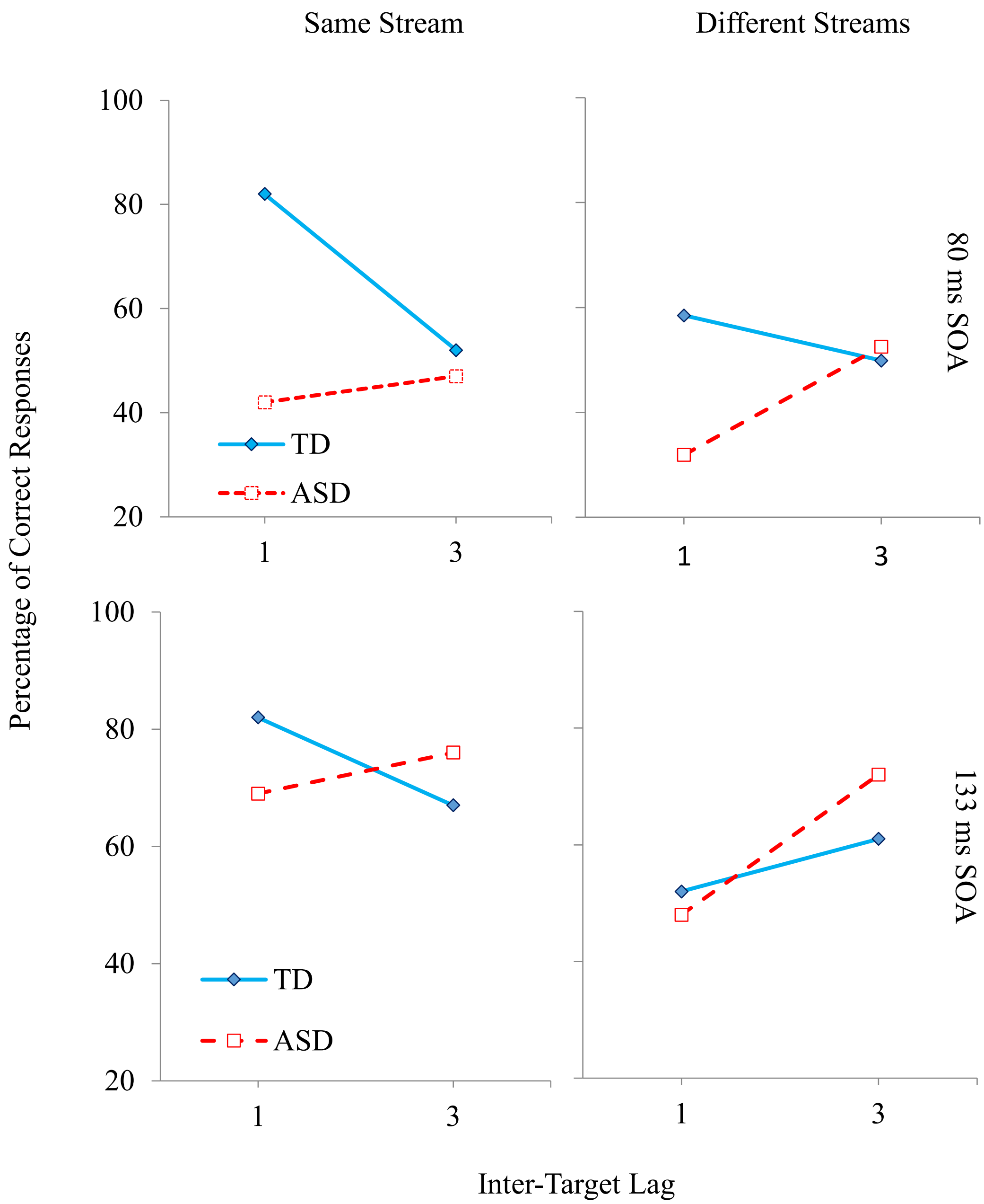
Correct responses of T1 for both groups in both streams of both SOAs

Figure 5



Correct responses of T2 (where T1 was correct) for both groups at both streams of both SOAs

Figure 6



Responses of T2 for both groups in both streams of both SOAs at Lag-1 and Lag-3. Graphs show a total absence of Lag-1 sparing for the group of individuals with ASD, and Lag-1 sparing being present for the TD group in all conditions except in the 133-ms Different Stream