A review of methods in the study of attention in autism

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Abstract: Atypical attention, while not a diagnostic feature, is common in individuals with autism spectrum disorders (ASD). The study of these atypicalities has recently gained in both quantity and quality, due in part to an increased focus on attentional atypicalities as one of the earliest signs of ASD in infancy. A range of attentional processes and components have been investigated, and the methods used are varied, from Posner-type paradigms, to the more recent use of eye-movement recording and change-detection techniques. This methodological complexity is one factor in the production of conflicting evidence on the topic of attention in ASD. This review uses a focus on methodology to clarify the literature to date and provide a resource for researchers wishing to study attention in ASD. Other factors that have contributed to the current discrepancies in findings are discussed, particularly the role of individual and group differences within the population of people with ASD.

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A review of methods in the study of attention in Autism

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Abstract

Atypical attention, while not a diagnostic feature, is common in individuals with autism spectrum disorders (ASD). The study of these atypicalities has recently gained in both quantity and quality, due in part to an increased focus on attentional atypicalities as one of the earliest signs of ASD in infancy. A range of attentional processes and components have been investigated, and the methods used are varied, from Posner-type paradigms, to the more recent use of eye-movement recording and change-detection techniques. This methodological complexity is one factor in the production of conflicting evidence on the topic of attention in ASD. This review uses a focus on methodology to clarify the literature to date and provide a resource for researchers wishing to study attention in ASD. Other factors that have contributed to the current discrepancies in findings are discussed, particularly the role of individual and group differences within the population of people with ASD.

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Introduction

Autism spectrum disorders (ASD) include autism, Asperger's syndrome (AS) and Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS) (APA 1994). These disorders are characterised by impairments in social interaction, communication and imagination (Wing & Gould, 1979; APA 1994). Though not a diagnostic feature, attentional atypicalities are often found among people with ASD. Increasingly, theoretical accounts have placed atypical attentional processes at the core of the narrative of the development of ASD (Leekam & Moore 2001; Mundy & Neal 2001; Mottron, Dawson, Soulieres, Hubert & Burack 2005). In particular, the attentional bias that leads typically-developing (TD) children and adults to look at and listen to people may be lacking or weaker in ASD (Klin, Jones, Schultz & Volkmar 2003; Schultz 2005). This lack of social attention is hypothesised to impact the development of more sophisticated social cognitive skills including joint attention (Mundy & Newell 2007) and Theory of Mind (Baron-Cohen 2000; Sodian & Thoermer 2008), and for the development of language (Mundy & Sigman 1990; Leekam, Lopez, & Moore 2000; Adamson, Bakeman, Deckner, & Romski 2009). In addition to impairments specific to the social domain, people with ASD also show atypical domain-general attention (Burack, Enns, Stauder, Mottron, & Randolph 1997; Allen, & Courchesne 2001). Such deficits, like those specific to social attention, could also produce a significantly diverted developmental pathway (e.g. van der Geest, Kemner, Camferman, Verbaten & van Engeland, 2001)

Before going on to further elucidate the importance of studying attention in ASD, it is first necessary to sketch out suitable definitions of relevant attention processes and to briefly describe typical attentional processes in TD children and adults. Attention can be defined as the process of concentrating on selected items from the environment, to the exclusion of other, unattended stimuli (Pashler, 1998). An item which is the focus of our attention is subject to preferential and enhanced perceptual and semantic processing. Within this broad definition we can also define a number of different types of attention, relevant to the study of ASD. For example, switching (or shifting) attention is the process of changing the focus of attention from one item (or group of items) in the environment to another. Broadening or narrowing the focus of attention is the process of increasing or reducing the number of items or area of space subject to enhanced processing. Attentional cueing is when our attention is directed to a particular location by a cue, such as a flashing light at the cued location, or an arrow pointing to the cued location (endogenous and exogenous cues, respectively). Finally, social attention refers broadly to the preferential selection of social items for attention. This can then be elaborated into shared, triadic, or joint attention, when two individuals jointly attend to an item and to each other.

The parallel, or perhaps interacting, development of attention control and social cognition is a central feature of typical development in infancy. The shift between the endogenous capture of attention and the exogenous control of attention is a landmark in the development of infant social cognitive development (Atkinson, Hood, Wattam-Bell & Braddick 1992; Hood, Willen & Driver 1998; Johnson, Posner & Rothbart 1994). The development of the ability to follow the gaze of another develops through infancy and early childhood (Butterworth & Jarrett 1991; Corkum & Moore 1998; Butterworth & Itakura 2000) and forms the basis of the development of shared attention, which is crucial for interactive communication between infant and caregiver and for the future development of language and communication (Bruner, 1983; Baldwin, 1993; Tomasello, 1999). Children's endogenous attention control also continues to develop through early childhood. Enns and Brodeur (1989) showed that whilst six-year-olds and adults had comparable levels of exogenous orienting, the children had less efficient endogenous orienting abilities than the adults. The distribution of attention across a complex scene also develops over childhood, not reaching adult levels until at least 11 years of age (Fletcher-Watson, Collis, Findlay & Leekam, 2009). Furthermore, the ability to control attention is also thought to have a role in emotion regulation (Rothbart, Posner, & Rosicky, 1994). Thus we can see how domain-general attention and social attention develop concurrently during infancy and early childhood, contributing to wider social and communicative development. As we will outline below, aspects of this process have been found to be atypical in the development of a child with ASD, but the precise pattern of this abnormality remains to be revealed.

As well as being of academic interest, furthering our understanding of attention in ASD is clinically important for three reasons. First, having a better grasp of the patterns of attentional atypicalities present in infants who later receive a diagnosis of ASD will help in the creation of tools for early diagnosis. Both social and domain-general attentional processes are among the earliest identifiable features of ASD (Zwaigenbaum et al. 2005; Merin, Young, Ozonoff, & Rogers 2006; Elsabbagh et al., 2009), and have clear consequences for wider social and communicative development. Indeed, attentional atypicalities are already incorporated into existing screening instruments for ASD (Lord, Rutter, DiLavore, & Risi 1999; Baird et al. 2000). Second, early diagnosis creates an opportunity for early intervention, in itself already demonstrably valuable (Woods & Wetherby 2003). Such early interventions might target attentional difficulties in ASD in order to avert the negative developmental consequences of such difficulties. At the same time, where attentional abnormalities are linked to abilities, such as enhanced local perception, a full understanding of these relationships may allow us to design intervention strategies which preserve the skills enjoyed by people with ASD while also compensating them for their difficulties. Third, where ASD is not diagnosed until later, as will surely always be the case for those children whose intellectual and language function is at the higher end of the spectrum, understanding atypical attention may help us design learning environments which play to their strengths while accommodating their weaknesses.

In the study of attention in ASD, the researcher is currently faced with not only a wealth of conflicting findings, but also a raft of potential methodologies for the study of attention. One source of conflict in the literature is subtle differences in the choice of methodology, hence it is essential to select the most appropriate methodology to address a particular research question. Some methods, such as Posner cueing paradigms, are very well established, but are nevertheless subject to subtle variations, such as the use of moving versus static cues, which can powerfully alter findings (Ristic & Kingstone 2005). Others, such as change blindness methods, are newly being applied to the study of ASD and as such the impact of methodological variation is not yet fully understood. This paper will review current experimental findings on attentional atypicalities in ASD, with specific reference to the methodologies used. Our intention is to provide a resource for the researcher wishing to choose an appropriate methodology for the study of ASD, and also to use this methodological focus as a novel starting point from which to explore the role of attention in the development of ASD. It is hoped that such a review will help to elucidate how choice of methodology has a significant impact on experimental findings, and thus contribute some degree of clarification to the literature.

In the interests of brevity, it has been necessary to exclude certain types of research from this review. First of all, though studies incorporating brain-imaging techniques (for a review see Sanders, Johnson, Garavan, Gill & Gallagher 2008) will not be systematically excluded, this review will not explore the functional or structural neural atypicalities which may underpin abnormalities in attention observed behaviourally. Second, again in the interests of brevity, this review will focus solely on attention in the visual domain. Though interesting work has been done in the aural modality this largely corresponds with findings from visual attention – for example that people with ASD exhibit enhanced local perception (Gomot, Giard, Adrien, Barthelemy & Bruneau 2002; Gomot et al. 2006) and that they do not prioritise social information for attention (Klin, 1991). The visual domain has been subject to the greatest investigation by researchers and is the area where clarification is most needed.

Eye-Gaze Cueing Paradigms

Social attention has been identified as being of particular significance in the development of ASD. In particular, very young children who are later diagnosed with ASD tend to show reduced eye-contact, pointing and sharing of attention, and gaze monitoring (Adrien et al., 1993; Charman, Baron-Cohen, Swettenham, Baird, Cox & Drew, 2000; Stone, Hoffman, Lewis & Ousley, 1994) and infant siblings of children with autism have been found to have atypicalitlies in eye contact (Zwaigenbaum et al., 2005). One aspect of successful sharing of attention is correctly orienting in response to eye-gaze cues, something that children with ASD are geometrically capable of doing, but which does not occur spontaneously in interpersonal experimental paradigms (Baron-Cohen, 1989; Dawson & Fernald, 1987; Leekam, Baron-Cohen, Perrett, Milders & Brown, 1997; Tan & Harris 1991). This is thought to be because children with ASD are not sensitive to the mentalistic significance or symbolic properties of eye-gaze (Baron-Cohen, Campbell, Karmiloff-Smith, Grant & Walker; 1995; Leekam, Hunnisett & Moore, 1998; Pierno, Mari, Glover, Georgiou & Castiello, 2006). Nevertheless, a number of studies have shown that children with ASD do orient automatically or involuntarily to dynamic eye gaze cues presented on a computer screen, even when eye-direction is not predictive of target locations (Chawarska, Klin & Volkmar, 2003; Swettenham, Condie, Campbell, Milne & Coleman, 2003; Vlamings, Stauder, van Son & Mottron, 2005).

Recent developments in the examination of social orienting in ASD have drawn particularly on the paradigms developed by Posner and his colleagues. Posner, Walker, Friedrich & Rafal (1984) developed a reaction time task in which participants are asked to detect a target that appears at one of two possible target locations positioned on opposite sides of a computer screen. In the period before the target appears on screen a cue may be presented. In the original Posner exogenous cueing paradigm this cue would appear at one of the possible target sites, and so orient attention away from central fixation towards the cued side. On the majority of trials the target would then be presented at the same target location as the cue (valid trials). However, on a proportion of the trials the target would appear at the un-cued side (invalid trials). These invalid trials require participants to move their attention away from the cued side before responding, thus increasing reaction time and providing a measure of the efficiency of orienting. This paradigm has since been developed to examine exogenous and endogenous orienting through the manipulation of the length of interval between presentation of cue and target. Further manipulations that have been particularly relevant to the study of ASD have involved the presentation of directional cues at central fixation in order to examine endogenous orienting in response to social and symbolic cues.

Studies that have adapted the Posner cueing paradigm to include centrally presented eye-gaze and arrow cues, have shown that children with ASD do orient reflexively in response to these cues (Chawarska et al., 2003; Kylliäinen & Hietanen, 2004; Senju et al., 2004; Swettenham et al., 2003; Vlamings et al., 2005). When a target appears in a location not predicted by the cue, children with ASD are slower to respond than when the location was accurately predicted. However, this cueing effect is comparable in size for both eye-gaze and arrow cues among participants with ASD, while control participants often show greater cueing in response to eye-gaze (Kylliäinen & Hietanen, 2004; Senju et al., 2004; Vlamings et al., 2005). On the other hand, the use of arrows as a 'control' condition for eye-gaze cueing has been questioned, since there is evidence that symbolic cues, such as arrows, produce reflexive orienting of the same magnitude as eye-gaze cues (Hommel, Pratt, Colzato & Godijn, 2001; Kuhn & Benson, 2007; Kuhn & Kingstone, 2009; Ristic & Kingstone, 2006; Tipples, 2002; 2008). This concern was avoided in a comparison of eye-gaze cues and non-biological "SimEyes" (Chawarska et al., 2003), which found that while control participants' reaction times were longer in response to gaze cues than to SimEyes, participants with ASD reacted similarly to both cues.

Ristic et al. (2005) have suggested that the differences between ASD and control groups observed in these studies reflect the failure of children with ASD to appreciate the social significance of gaze (see also Chawarska et al., 2003). They demonstrated that while TD individuals showed a cueing effect in response to eye-gaze when the cues were both predictive and non-predictive, participants with ASD only did so when cues were predictive. This is interpreted by the authors as indicating that whilst participants with ASD can use the physical appearance of the eye-gaze cues to assist them in detecting targets when these cues are informative, they do not appreciate the social significance of them and so are not distracted by them when they are non-predictive. In contrast, the TD participants attended to locations cued by eye-gaze, even when these gaze cues were non-predictive, because they orient automatically in response to such cues. This study follows on from work by the same authors indicating that whilst TD people do orient in response to arrow cues, this process is not the same one as elicited automatically by eye-gaze cues at both cognitive and neural levels of explanation (Ristic, Friesen & Kingstone, 2002; Friesen, Ristic & Kingstone, 2004). Ristic et al. (2005) used static cues, and suggest that the evidence of intact cueing in ASD in response to non-predictive cues that has been reported by other authors is a product of the motion, or motion induced through abrupt transients, present in the stimuli employed by these authors (Charwaska et al., 2003, Kylliäinen & Hietanen, 2004; Senju et al., 2004; Swettenham et al., 2003). If true, then this is an intriguing suggestion, as other work has shown that whilst infants require a moving cue to orient (Farroni, Johnson, Brockbank & Simion, 2000) adults do not (e.g. Driver et al., 1999). The need for an additional motion cue in individuals with ASD could then represent a similar dichotomy in attention as has been seen in behavioural studies, between sensitivity to the physical properties of gaze, without an appreciation of its conceptual significance.

However, the absence of an appreciation of the conceptual significance of cues has not been limited to the social domain, nor indeed have attentional difficulties. In an investigation of the impact of attentional factors on joint attention in ASD, Leekam et al. (2000) deployed both a human gaze cue and a non-social cue (an inanimate train). The cues were directed (on separate trials) towards one of two boxes in which a target stimulus appeared. The results of this study revealed that children with ASD experienced comparable difficulties reorienting in response to a non-human cue as to the human cue; suggesting that their difficulty in using cues is not an entirely social one. Importantly, the children with ASD did not have difficulty in disengaging and shifting their attention in response to the appearance of peripheral targets, but they did not use the central cues to direct their reorienting, unlike developmentally-delayed comparison participants. This suggests that these individuals' ability to make exogenous shifts of attention was intact but was accompanied by deficits in endogenous re-orienting. As a result, Leekam et al. (2000) argued that "it is specifically symbolic cues, or those which contain meaning and information, that may be difficult for the autistic child to process or respond to" (p. 272). This suggestion has been supported by recent findings reported by Ames and Jarrold (2007) that children with an ASD had difficulty using both a symbolic arrow as well as an eye-gaze cue to identify the target desired by a cartoon figure.

However, the question remains as to how this dichotomy develops. Chawarska et al. (2003) suggest that the failure of young children with ASD to utilise eye gaze cues naturalistically, despite their sensitivity to the directional information conveyed in eye gaze, may reflect a difficulty involving general attentional processing, or the absence of the typical preference for faces in infancy (c.f. Dawson, Meltzoff, Osterling, Rinaldi & Brown, 1998; Swettenham et al., 1998). In support of this possibility, Ristic et al. (2005) draw attention to functional abnormalities in the neural substrates of face-processing (Schultz et al.., 2003). However, since specialisation in the face processing regions of the brain has been described as being the result of developing expertise (Gauthier, Tarr, Anderson, Skudlarski & Gore, 1999; Grelotti, Gauthier & Schultz, 2002) abnormal specialisation of face processing regions of the brain may not be a suitable candidate for the 'cause' of atypical gaze orienting in ASD. How then could this lack of specialization for faces, or failure to appreciate the social relevance of gaze develop? One suggestion is that domain-general attentional impairments in ASD could adversely influence the development of social attention.

Spatial Attention Paradigms

Research has sought to explore whether deficits in orienting are specific to social stimuli or whether they reflect a more general attentional deficit. Research to date indicates that children with ASD do not have an all encompassing attentional deficit. They are able to focus and sustain their attention (Garretson, Fein & Waterhouse 1990; Burack et al. 1997; Allen & Courchesne 2001). However, there is growing evidence of difficulties related to disengagement and shifting, particularly in rapid attentional reorienting.

Difficulties in attentional control were reported in an early study of the attentional patterns of children with ASD (O'Connor & Hermelin, 1967). The authors found that children with ASD looked more briefly at all stimuli presented and showed fewer switches of gaze between displays than control groups. More recently, Swettenham et al. (1998) reported differences in shifting attention between infants with ASD, and TD and developmentally delayed infants. In showing that infants with ASD spontaneously engaged in more attention shifts between objects than between either pairs of people or between objects and people, they demonstrated that these infants can switch the focus of their attention, but that they do so in response to atypical aspects of the environment. However, Dawson et al. (1998) also examined the ability of children with ASD to shift their attention in comparison to children with Down's syndrome and others showing typical development. Dawson et al. report that although reorienting in response to social stimuli (hands clapping, name called) was particularly impaired in ASD, these participants also showed reduced reorienting to non-social stimuli (rattle, musical jack in the box).

These findings, together with evidence of subtle atypicalities in attention cueing to eye-gaze, have motivated studies of attention orienting outside the social domain, revealing deficits in the engagement, disengagement and shifting of attention. Early research reporting difficulties in shifting attention outside the social domain in ASD deployed tasks such as the Wisconsin Card Sorting Task (e.g. Liss et al., 2001; Ozonoff, Pennington & Rogers, 1991; Prior & Hoffman, 1990; but see also Minshew, Goldstein, Muenz & Payton, 1992) and the ID/ED test (Hughes, Russell & Robbins, 1994). However, more recently investigations of attention shifting have sought to examine attention independently of conceptual processes, using reaction time paradigms.

Wainwright-Sharp and Bryson (1993) examined difficulties of disengaging and shifting attention in a group of adolescents with high-functioning autism (HFA). They found that the HFA group had longer reaction times to invalidly cued targets. This was taken to indicate a deficit in the ability to disengage and shift attention. However, they also found that the HFA group did not show a cueing effect when the cue was presented for 100 milliseconds; implicating a deficit in the ability to process and act on rapidly presented cues. The disengagement aspect of these findings was further investigated by Landry and Bryson (2004) who measured latencies of eye-movements towards a peripheral target following valid or invalid cues. They again found that children with ASD had difficulties in disengaging attention, in response to non-social stimuli.

Courchesne et al. (1994) report a series of experimental and neurological investigations revealing difficulties experienced by individuals with ASD in voluntarily shifting attention both within and between sensory modalities, as well as in shifting between spatial locations in a task based on the Posner cueing paradigm. Casey, Gordon, Mannheim & Rumsey (1993) examined the ability to divide, shift, direct and sustain attention. They report that a group of autistic savants were less able to divide their attention to detect visual and auditory targets simultaneously. They were also less able than controls to shift their attention between stimulus locations. Casey et al. hypothesise that this difficulty in attention shifting is a reflection of over-selectivity of the modality of stimuli attended to and deficient orienting (cf. Courchesne et al., 1990) between locations. The work of Casey et al. provides further support for previous suggestions made by Courchesne, Akshoomoff & Townsend (1990) that individuals with ASD have a difficulty in their ability to disengage attention. Importantly Casey et al. suggest that the attentional difficulties in ASD do not result in a failure to detect targets, but instead that individuals with ASD take longer to respond to them. This is particularly interesting given Triesch, Teuscher, Deak and Carlson's (2006) finding that a slight timing difference in their computational model of gaze following gives rise to inefficient learning of the significance of gaze.

Brian, Tipper, Weaver and Bryson (2003) investigated spatial, or location based, negative priming with a task in which participants were required to detect a target which matched to a primed colour, inhibiting responses to a co-occurring distracter. Contrary to other reports of difficulties in shifting attention in ASD (e.g., Bryson, Landry & Wainwright, 1997; Casey et al., 1993; Courchesne et al., 1990; Landry & Bryson, 2004), Brian et al. did not find significant reaction time differences between the ASD and control groups in location priming. Individuals with ASD were as able as the control groups to disengage from the central cue in order to respond to the location of the target stimulus. However, the group of individuals with ASD in this study showed colour facilitation that was not evident in the performance of the control group. The authors suggest that this may be a reflection of attention to less relevant details in a display, which in the case of this task facilitated performance. Such over-attention to irrelevant details may hinder an individual's ability to efficiently identify, process and comprehend informationally significant aspects of the environment (see below for further consideration of attention to context and detail).

Two studies (Burack, 1994; Mann & Walker, 2003) have sought to explore the ability to shift the spatial focus of attention, using tasks in which participants are required to attend over space in order to make judgements about stimuli. In Burack's study participants were required to make a forced choice about the identity of a target that appeared in the same central location in each trial. The factors which were varied were the number of distracters and the presence or absence of a window which narrowed the attentional field. Whilst the individuals with ASD did benefit from the narrowing of the attentional field, this benefit was negated when distracters were present. Burack's work therefore suggests that rather than having a difficulty in disengaging from a stimulus location (cf. Casey et al., 1993) individuals with ASD have an "inefficient attentional lens" (cf. Enns & Akhtar, 1989) which results in difficulties in focusing on a target stimulus and filtering distracters. A contrasting hypothesis regarding attentional focus in ASD was presented by Mann and Walker (2003). They used a paradigm which required participants to make a judgement about which of two pairs of cross-hairs were the longest. Individuals with ASD were less able than comparison groups to make this judgement when the previous pair of cross-hairs presented was smaller than the one to be judged. Mann and Walker argue that their results indicate that the group of individuals with ASD had a difficulty in broadening their spread of attention and speculate that this could result in difficulties shifting attention to a target in the periphery. These apparently contradictory findings may reflect tasks which tap different aspects of attention; filtering or selecting items to attend to compared to changing the spatial area to which attention is given. However, other aspects of the tasks may also be contributing to these apparent contradictions. Burack's study required participants to push buttons corresponding to the stimuli (crosses and circles) presented on screen whereas Mann and Walker's task required a judgement based on comparison between the previously viewed crosshair and the currently viewed crosshair.

Greenaway and Plaisted (2005) have explored the ability of individuals with ASD to modulate attention to specific aspects of stimuli. In a series of spatial-cuing and visual search tasks they showed that attention modulation in ASD is impaired under certain conditions. In line with Brian et al.'s work, Greenaway and Plaisted demonstrated that children with ASD were able to modulate their attentional response to cued colour targets in visual search and showed typical responses to colour distracters. However, children with ASD were less able to modulate their attention in response to targets marked by onset. It is also worth noting that Greenaway and Plaisted's results, whilst developing the idea of a deficit in identification of significant aspects of stimuli (cf. Brian et al., 2003), are not explained by a deficit in the attentional lens of their participants with ASD (cf. Burack, 1994). In their first experiment, the difference between response to colour cued targets and onset cued targets may be explained by the difference in attentional window required. However, in their second experiment this was carefully controlled for and the ability to modulate attention was still stimulus-specific; whilst the reaction times of control groups were affected by both the colour distracters and the onset distracters (in the corresponding target conditions) the ASD group were only affected by the colour distracter, their attention was not captured by the onset distractors. A difficulty in prioritising attention to dynamic cues, or cues defined by onset is proposed by Greenaway and Plaisted as being a candidate deficit underlying the processing of social cues by individuals with ASD as these are frequently dynamic and temporally sensitive.

The ability to modulate attention to specific aspects of stimuli has been investigated more recently through the utilisation of paradigms developed by Lavie (2005). These paradigms are used to investigate perceptual load and distracter processing and integrate research on attention and executive function. In these paradigms, degree of perceptual load and form of distracters is manipulated, in order to identity the points at which attention is drawn to distracters. Typically, there has been reported to be a reduced effect of distractors under greater cognitive load, reflecting the allocation of attentional resources by participants. The relationship between impairments in executive functions and putative attentional impairments in ASD is an area which could benefit from the application of paradigms such as those of Lavie's that have been recently described with healthy adult participants. Early findings (Remmington, Swettenham, Campbell & Coleman, submitted) have indicated that individuals with ASD did not experience the same degree of distraction from social stimuli as did control participants; a finding that is congruent with other studies indicating that social stimuli are afforded a less privileged position in ASD than in typical processing (Kylliäinen & Hietanen, 2004; Senju et al., 2004; Vlamings et al., 2005). However, intriguingly Remmington et al. have also reported that people with ASD may have an increased attentional capacity, as evidenced by the processing of a greater number of distracters than controls. At this stage we do not know how this might interact with other cognitive features of ASD, though association with enhanced detail processing (cf. Happé, 1999), is plausible.

Attention cueing paradigms allowing manipulation of cue presentation and response selection facilitate fine grained analysis of the time course of attentional processing. This has enabled researchers to identify components of attention that are impaired in ASD. However, there are a number of inconsistencies in this body of research. Potential methodological sources of this inconsistency include precise cue - target timing, whether paradigms use endogenous or exogenous cues, whether the cues require symbolic understanding to be interpreted ('cue reading'), and whether two or more components of attention are adequately distinguished (e.g. switching and disengagement). Renner, Klinger and Klinger (2006) and Landry, Mitchell and Burack (2009) report recent examples of work that have sought explicitly to illuminate some of the inconsistencies described above.

Renner et al. (2006) explicitly compared exogenous and endogenous orienting abilities of a group of children with HFA. Previous research examining each of these had produced inconsistent results with some authors reporting impairments of exogenous (e.g. Townsend, Courchesne & Egaas, 1996) and endogenous (Wainwright-Sharp and Bryson; 1993) attention, whilst others reported intact exogenous (Iarocci & Burack, 2004) or endogenous (Senju et al., 2004) attention. Renner et al., report an impairment of exogenous attention, as measured by a peripheral cueing task alongside intact endogenous attention as measured by a central cueing task. While comparing these two explicitly is useful, the methodology somewhat complicates the finding. Renner et al. asked participants to make a judgement about the target, whilst completing an additional task. This was designed to disrupt endogenous but not exogenous processes. However, whilst a difference was found between conditions, it may be the case that the judgement task alongside the additional processing task placed greater strain on the ASD group, which may result in findings that are not entirely attributable to the attentional system.

Another way to conceptualise the inconsistencies in results derived from cueing paradigms has been to examine the contrast between cue reading (cf. Leekam et al., 1998; Burack et al,, 1997) and response selection. These hypotheses have been explicitly compared by Landry et al. (2009) in an elegant study which developed the Posner cueing paradigm to manipulate cue exposure time and response selection time within a series of stimulus onset asynchronies. The results of this study indicate that the difficulties experienced by children with ASD were at the response selection level.

The research outlined above points the way for future investigations of attentional orienting atypicalities in ASD, which should continue to explore systematically how variations in cue type, presentation and response format expose or mask differences between participants with and without ASD.

Eye-Movement Recording

One method that has been deployed in an attempt to remove confounds of higher order cognitive processes is the examination of the saccadic eye movements of participants. Analysis of eye-movements enables an assessment of attentional patterns at a much finer temporal and spatial level than it is possible to achieve using motor response measures. Saccadic eye-movement measurements provide a wealth of information that it is not possible to obtain confidently when merely inferring an association between attention and motor response. Although processing benefits can be obtained from directing covert attention to a certain spatial location, these benefits are small compared to those obtained by placing the object of interest onto the high resolution fovea (Findlay & Gilchrist, 2003).

There is also good evidence that covert and overt orienting by means of a saccadic eye movement are inextricably linked in healthy participants (Kowler, Anderson, Dosher & Blaser, 1995). Tasks measuring eye-movements used in research with participants with ASD have included the anti-saccade task, memory guided saccade task, gap-overlap task (for a detailed review see Rommelse, Van der Stigchel & Sergeant, 2008) and a variety of scene-viewing tasks.

In the anti-saccade task, participants are required to fixate a central point. A stimulus is flashed to one side of the screen and participants must inhibit a reflexive saccade to fixate the stimulus and instead generate a volitional saccade to the opposite side of the screen. Fixations to the side the stimulus was presented are considered to be errors (for a review see Hutton & Ettinger 2006). A number of studies have reported that participants with ASD exhibit an elevated number of these response suppression errors on an anti-saccade task (Benson, Piper & Fletcher-Watson, 2009; Goldberg et al., 2002; Luna, Doll, Hegedus, Minshew & Sweeney, 2007; Minshew, Luna & Sweeney, 1999). The resilience of these effects is emphasised by data that show increased error-rates in individuals with ASD even when the stimulus to be ignored is a face, a circumstance in which participants with ASD might be expected to be better able to ignore the stimulus compared to a TD group due to their lack of interest in faces (Benson, personal communication). Minshew et al. (1999) argue that results from anti-saccade tasks indicate that problems in shifting attention are a reflection of difficulties in higher-order volitional shifts, and that, in contrast to previous suggestions based on behavioural and neuro-anatomical work (Courchesne et al., 1994), the low-level, cerebellum-controlled, shifting attention is intact in ASD.

This contention is supported by evidence from a scene-viewing task in which participants viewed the same picture twice, under two conditions (Benson et al., 2009). The conditions were distinguished by participants being asked one of two questions before scene-viewing, designed to direct attention (and fixations) to different parts of the scene. The lack of difference in the scan-paths of participants with ASD between the two viewing conditions indicates that these participants were less able to modify their eye-movements according to the task at hand. A similar finding is reported by Loth (2007) who investigated the extent to which participants' scan paths were influenced by prior knowledge. Participants were presented with a story followed by a scene, and the extent to which fixations fell on items relevant to the story or neutral items was assessed. Participant groups showed no differences in fixation location over time, nor in memory for items depicted, but the ASD group showed fewer fixations on story-relevant items in the first ten fixations, indicating a reduced ability to direct eye-movements according to prior knowledge early on in scene viewing.

In the memory guided saccade task participants fixate a central point while a stimulus is presented to one side. They are required to inhibit a saccade towards the direction of the stimulus until the central fixation point is removed. This task is used to assess memory, inhibition, accuracy and saccade latency. However, findings with participants with ASD have been inconsistent. Goldberg et al. (2002) report that their group of adolescent with autism (IQ > 80) had intact accuracy with slowed latencies in comparison to a group of typically developing adolescents, when differences in performance IQ were statistically controlled for. Minshew et al. (1999) compared a group of age matched adolescents and young adults to a group of adolescents with autism (all IQ>80) and did not observe similarly slowed latencies but do report reduced accuracy and increased response suppression errors. One possible explanation for this discrepancy is the age of participants in the studies. Goldberg et al.'s participants were adolescents aged 12-18 years while Minshew et al. worked with adolescents and young adults aged 11-28 years. Luna et al. (2007) have reported age-related changes in performance on the memory guided saccade task. They report a lack of developmental in the latency to initiate memory guided saccades in participants with autism, which appears to reflect a plateau in adolescence, in comparison to the age and IQ matched comparison group which showed continuing improvements to early adulthood. Luna et al. (2007) suggest that this may be the result of a difficulty of disinhibition in childhood which is resolved by adolescence in participants with autism. This then suggests that variation in findings in earlier studies may be a reflection of the cross-sectional sampling methods chosen to assess processes of oculomotor control which continue to develop into adulthood.

The Gap-Overlap paradigm allows for the investigation of engagement, disengagement and shifting of attention. As in the Posner cueing paradigm, participants are shown a central fixation point which precedes the appearance of a stimulus presented to either side of a screen. In the gap condition the central fixation point is removed before the lateral presentation of the stimulus. In the overlap condition the central fixation point remains on display when the target stimulus is presented. Individuals' eye-movements are used as a proxy measure for the (dis)engagement of attention and shift between fixation point and target stimulus. Saccadic latencies tend to be longer in the overlap condition as attention is still engaged at the fixation point and must be disengaged before the shift towards the target. In contrast, latencies tend to be shorted in the gap condition as attention is already disengaged when the target stimulus is presented.

The gap-overlap paradigm has been deployed in autism research as a direct measure of the proposed difficulties in disengaging attention (Landry & Bryson, 2004; Wainwright-Sharp & Bryson, 1993). In studies with both children (van der Geest, Kemner, Camfferrman, Verbaten & van Engeland, 2001) and adults (Kawakubo, Maekawa, Itoh, Hashimoto &

Iwanami, 2004) with ASD it has been reported that both groups of control and ASD participants displayed longer saccadic latencies in the overlap condition (though see also Goldberg et al., 2002). However, the difference between gap and overlap conditions has been reported to be reduced in ASD groups compared to control groups. This has been interpreted by van der Geest et al. (2001) as a reflection of lower attentional engagement in the ASD groups as the need to disengage from the fixation point in the overlap condition slowed their response to the target stimulus less than was observed in the control group. This is in contrast to previous suggestions of attentional disengagement difficulties in autism (Wainwright-Sharp & Bryson, 1993; Wainwright & Brown, 1996). Van der Geest et al. argue these discrepancies in findings may reflect the higher order cue processing difficulties experienced by individuals with autism in previous studies using cueing paradigms, and so apparent difficulties in disengagement may not reflect disengagement of the visual attention system per se.

The gap-overlap paradigm has also been used in the studies of infant siblings of children with ASD (aged 6 months, Zwaigenbaum et al.; 2005; aged 9 months, Elsabbagh et al., 2009), who are at greater risk of developing the condition than the general population. Elsabbagh et al. report reduced disengagement as well as reduced facilitation (the gap effect) in the infant siblings of children with ASD in comparison to siblings of children without ASD. Zwaigenabuem did not see differences in their younger participants. However, together these studies demonstrate the methodological versatility of this paradigm as it can be manipulated to be appropriate for very young children. Furthermore, it provides evidence of a broader autism phenotype associated with differences in visual attention modulation which may impact both on social cognitive development and on the narrowed focus of attention observed in some cognitive tasks (Happé, 1999; Happé & Frith, 2006).

Eye-movement recording in scene viewing tasks

Eye movement recording techniques have also been used to explore social attention, largely using ‘scene-viewing’ methodology in which participants are presented with complex, naturalistic pictures or moving images, which may be accompanied by a soundtrack, and their eye-movements recorded. Such methods have much greater ecological validity than most attentional paradigms and can tell us about how the attention of people with ASD may be distributed in the real world.

Klin and colleagues first introduced the idea of using eye-tracking to investigate the social deficits of ASD in an influential paper which presented TD participants and those with ASD with clips from the film “Who’s Afraid of Virginia Woolf?” (Klin, Jones, Schultz, Volkmar & Cohen, 2002). They divided up each still frame of the film into regions of interest: mouths, eyes, bodies and objects. The authors painstakingly coded the location of fixation for every frame of the 2 minute, 42 second clip, excluding those frames in which the regions of interest were too small for fixation location to be accurately identified. Group differences were found for the proportion of fixations in each region, such that the participants with ASD fixated less on the eyes and more on every other region analysed. There was also a relationship between social competence, as measured by the Vineland Adaptive Behaviours Scales (Sparrow, Cicchetti & Balla, 2005) and the Autism Diagnostic Observation Schedule (Lord et al. 1999), and fixation time on the mouth and on objects, such that increased fixation on the mouth region was associated with greater social competence, while the opposite pattern was found for fixation on objects.

Other eye-tracking studies presenting images of isolated faces to people with ASD tend to agree that attention to the eye-region in particular is atypical in ASD (Pelphrey et al., 2002; Trepagnier, Sebrechts & Peterson, 2002; Dalton et al., 2005; Dalton, Nacewicz, Alexander & Davidson, 2006; Nacewicz et al., 2006; Boraston, Corden, Miles, Skuse & Blakemore, 2008; Corden, Chilvers & Skuse, 2008; Jones, Carr & Klin, 2008; Sterling et al., 2008). Pelphrey and colleagues, for example, demonstrated reduced fixation on all ‘core features’ of faces showing emotional expressions in people with ASD (Pelphrey et al., 2002). Likewise an innovative ‘bubbles’ task, demonstrated less reliance on the eye-region of isolated faces in an emotion-recognition task (Spezio, Adolphs, Hurley & Piven, 2007). Tasks presenting faces in a naturalistic setting are inevitably less precise in monitoring fixation on different areas of the face, but they do have greater ecological validity. These have revealed reduced fixation on faces and people in general from participants with ASD compared to TD comparison groups (Riby & Hancock, 2008a; 2008b; 2008c).

However, there is also evidence of normal face-scanning in eye-tracking tasks depicting isolated faces on screen (van der Geest, Kemner, Verbaten & van Engeland, 2002; de Wit, Falck-Ytter & von Hofsten, 2008; Rutherford & Towns, 2008). This pattern is reproduced in two studies which presented people as part of a realistic, complex scene. Van der Geest and colleagues (van der Geest et al., 2002) found no group differences in attention to human figures in a cartoon scene and a preferential-looking task, which depicted pairs of scenes with and without a person, showed no differences in fixation over time to different regions of the face and to bodies (Fletcher-Watson, Leekam, Benson, Frank & Findlay, 2009). Likewise a cueing-paradigm in which targets appeared on either the eye-region or mouth-region of a face indicated normal attention to these areas in people with ASD (Bar-Haim, Shulman, Lamy & Reuveni, 2006). Furthermore, findings demonstrate that even though participants with ASD are less accurate than controls when required to identify mental states from pictures of faces, when they are accurate they do use information from the eyes (Back, Ropar & Mitchell, 2007).

How then can we reconcile this apparently contradictory evidence? One hypothesis raised is that attention to social information in people with ASDs is only impaired when stimuli are sufficiently complex/realistic. In particular, Kemner and colleagues (Kemner & van Engeland, 2003) point out that the seminal study by Klin et al. (2002) presented various extra challenges to the viewer with ASD which could have influenced their scan-paths: concurrent multi-modal information (image and soundtrack), moving images, and film-cuts. It has been suggested that people with ASD atypically process motion (Milne, Swettenham & Campbell, 2005) and multi-sensory information (Iarocci & McDonald, 2006) and so atypical scan-paths in ASD could have been due to these processing differences, rather than a social attention deficit.

This hypothesis is supported by a systematic study of the effect of both stimulus complexity and social content on eye-movements in adults with ASD (Speer, Cook, McMahon & Clark, 2007). The authors showed participants stimuli which varied according to social content (one or three people) and sensory complexity (static and silent versus moving with a soundtrack). They found that only moving stimuli featuring interacting individuals produced atypical eye-movements in their ASD sample. Likewise, there is evidence that while face-scanning is broadly normal in ASD, it may vary according to the emotional content of the faces presented (de Wit et al., 2008; Rutherford & Towns, 2008). Another study exploring the effect of stimulus complexity on eye-movements presented children with line drawings of faces, clocks and nonsense objects which were either complex or simple. ‘Complexity’ here was defined by the number of single-line or dot components which made up the drawings. Results showed that both children with ASD and TD children fixate for longer and more often on complex objects, and that this has a greater impact on eye-movements than the object’s semantic or social category (Kemner, van der Geest, Verbaten & van Engeland, 2007).

In a pair of studies of a young child with ASD, Klin and colleagues found reduced attention to biological motion, except when a visual-aural contingency was apparent (e.g. sound and visual signals for clapping) suggesting a sensitivity to physical contingencies but not social/affective contingencies (Klin & Jones, 2008). This once again demonstrates how the use of multi-sensory information may produce unusual responses in people with ASD, due to their difficulty integrating information from different sensory channels (Iarocci & McDonald, 2006). In this light, we might re-interpret increased fixation on mouth-regions in participants with ASD, as reported by Klin et al. (2002) as evidence of effortful processing of information from both visual and aural modalities, in the absence of an appreciation of social/affective context.

Adults with ASD may take slightly longer to fixate on social regions of a static image, showing longer latencies for the first saccade in a trial, and more non-social landing positions for that saccade (Fletcher-Watson et al., 2009). This finding is echoed in work by Freeth, Chapman, Ropar and Mitchell (in press) who presented images which depicted a person either looking at an object or directly at the camera and recorded participants eye-movements while scanning these images. Participants with and without ASD showed similar spatial distributions of total gaze duration to different regions of interest. However, this gaze duration was distributed differently over time, with participants with ASD being slower to fixate on faces and faster to fixate on objects. These findings are relevant to the debate about the influence of stimulus complexity on scan-paths in ASD. Tracking a moving stimulus requires that eye-movements are both precise and rapid. If people with ASD are delayed in the fixation of their attention to social information, then in a study presenting moving images, this delay could appear as a severe reduction or total lack of attention to social information. One recent study in adults (Klein, Zwickel, Prinz & Frith, 2009) paves the way for investigation of such difficulties in autism. Klein et al presented animations of moving triangles to participants and observed longer fixations in animations evoking mental state attributions than random or goal-directed animations, though goal-directed animations also elicited some longer fixations. This was taken to indicate greater processing depth when mental state attributions were made to the animations, particularly in comparison to the random animations. Deployment of methods such as this, with examination of scan paths as well as fixation durations, in studies of autism would allow disentanglement of social attention and attention control difficulties in autism.

A great deal of debate has focussed on the possibility that abnormalities in attention, and particularly social attention, may in fact reflect stimulus processing deficits. However, this cannot explain the presence of contradictory data from paradigms which present static, isolated faces with neutral expressions on screen (Pelphrey et al. 2002 vs. van der Geest, Kemner, Verbaten et al. 2002). While social, and indeed non-social, information is presented in the real world in multiple sensory modalities, moving, and loaded with social complexity, it is crucial in experimental studies to investigate these components separately and then together. In this way, we can distinguish the effects of perceptual processing requirements from social attention atypicalities.

Change Detection Paradigms

In change detection methods the participant is presented with a pair of images in which a single change has been introduced (Simons, 2000). These are shown in such a way that the change is made hard to detect. The most common presentation method is the ‘flicker’ paradigm, when images are presented alternating in the same location on a computer monitor, but separated by a brief (minimum 80ms) blank screen (Rensink, O'Regan & Clark, 1997). This blank screen serves to obscure the apparent movement cue that would otherwise draw attention to the location of the change (Rensink, O'Regan & Clark, 2000). Other ways of indirectly obscuring the change include introducing it during a saccadic eye-movement (Grimes, 1996), a blink (O’Regan, Deubel, Clark & Rensink, 2000) or a film-cut (Angelone, Levin & Simons, 2003), using ‘mud-splashes’ to distract attention from the change (O’Regan, Rensink & Clark, 1999), or making the change occur very gradually (Simons, Franconeri & Reimer, 2000). The most low-tech way of obscuring the change is to present scenes on cards side-by-side, such that an eye-movement is required to switch between the two scenes (Shore & Klein, 2000). It is even possible to make changes to people in the real-world without these being noticed (Simons & Levin, 1998; Levin, Simons, Angelone & Chabris, 2002).

All of these methods do not obscure the changing item: changes are highly visible when pointed out. Instead they serve to prevent the participant from noticing the change – a phenomenon known as change blindness. While there has been much debate about the significance of change blindness for our understanding of typical adult visual attention (Henderson & Hollingworth, 2000; Noe, Pessoa & Thompson, 2000; Shapiro, 2000; Rensink, 2001; Tse, 2004), there seems to be consensus that focused attention must be directed to the site of change in order for the change to be detected (Rensink, 2002). It should also be noted that although attention, or at least fixation, in this area is necessary, it is not a sufficient condition for change detection (Henderson & Hollingworth, 1999). Nevertheless, change detection methods have been used successfully with various populations to illustrate the influence of expertise and preference on the direction of attention (Werner & Thies, 2000; Jones, Jones, Smith & Copley, 2003). The method has the potential to elucidate the attentional preferences of different groups when viewing naturalistic and complex scenes and can therefore increase understanding of attention in the real-world.

Recently, a number of papers have appeared describing change detection abilities in people with ASD. The first of these examined how change detection varied according to the semantic and contextual role of items within a scene (Fletcher-Watson, Leekam, Turner & Moxon, 2006). In the first experiment, changes were made to items previously rated as being of either ‘central’ or ‘marginal’ importance within a scene (Rensink et al., 1997). Adults with normal-range IQs with and without ASD detected changes to items of central importance more accurately and rapidly than those of marginal interest. The ASD group responded particularly slowly to changes of marginal importance in this experiment, a finding which was attributed to a difficulty switching attention between items in the scene, as is required to successfully search for a change.

In a second experiment, Fletcher-Watson et al. (2006) compared changes to items which were either contextually appropriate or inappropriate (e.g. a teapot in a kitchen, or a teapot in a garden). Here, both participant groups detected changes to contextually inappropriate items more rapidly, and there were no group effects, in contrast to predictions based on the weak central coherence theory of autism (Happé & Frith, 2006). A similar study by Loth, Gomez & Happé (2008) also investigated change detection for items which were either appropriate or inappropriate to the scene context. This study presented a scene containing an appropriate object (e.g. a telephone in an office) which was replaced by either another appropriate object in the same location (e.g. a hole-punch), an inappropriate object (e.g. a shampoo bottle) or an object of the same original object-category (a different telephone). This elegant design permitted assessment within a single paradigm of the effect of context and of attention to detail on change detection: attention to context would produce quicker detection of inappropriate objects; detail-focused processing would result in enhanced detection of object-category changes. The typical group showed a pattern of response indicating poor attention to detail but a strong influence of global-level contextual information on attention. In contrast, the participants with ASD had equal response times to all conditions, indicating neither an effect of context nor enhanced attention to local detail. Loth et al.'s result instead seems to indicate a lack of attention to the global level without enhanced detail processing.

These findings contrast with recent evidence for enhanced local processing by children with ASD in a change blindness paradigm (Smith & Milne, 2008). Changes were either to central or to marginal items in the film, and were also either social (changes to the actor featured) or non-social (changes to objects). First, the authors found no differences between detection of social and non-social changes in either participant group. However, as 'social' changes were to the actor's clothes and accessories in all but one case, it is debateable whether this study truly compared social with non-social changes. There were differences in detection of central versus marginal changes, though the participants with ASD showed less effect of marginality. Moreover, participants with ASD detected all kinds of changes more frequently than the TD control group. This finding is interpreted as indicating enhanced local processing in ASD, supporting the predictions of weak central coherence theory (Happé & Frith, 2006). Unlike the studies by Fletcher-Watson, Loth and their colleagues, Smith and Milne introduced changes to a short film. One possibility is that the film itself constitutes a scenario (it featured a woman doing a cooking demonstration) which participants with ASD were more able to ignore than TD participants in the search for changes.

As well as using change detection methods to examine general issues in attention (local processing, contextual effects, attention switching), they have recently begun to be adapted specifically to investigate attention to social information. One study found that changes to eye-gaze direction, a social cue, were detected more rapidly and accurately than changes to a matched set of control changes by adults with and without ASD (Fletcher-Watson, Leekam, Findlay & Stanton, 2008). Furthermore, Freeth, Ropar, Chapman and Mitchell (submitted) showed that a group of individuals with HFA were as adept at detecting changes to items being fixated by another person as TD participants. This indicates intact gaze-following in ASD, within a change detection paradigm, and together these studies seem to contradict evidence from eye-tracking of impairment in attending to the eye-region in people with ASD e.g. (Klin et al., 2002). These contradictory findings may, at least to some extent, reflect choices made by researcher in methodological design that create a range of experimental demands under some of which people with ASD demonstrate different abilities. Whilst paradigms that most closely resemble real life may be most informative in clinical terms, arguably these more complex paradigms may not be best suited to indicating which attentional processes are truly intact or impaired. Studies systematically varying social content, and stimulus complexity (e.g. motion, multi-modailty) are called for to help to identify the true locus (or loci) of difficulty in attention experienced by people with ASD.

Computational Modelling

Another new method for exploring attention in atypical development is the use of neural networks, which are computer models of learning designed to build and test hypotheses (Elman et al., 1998). The networks are particularly suitable for studying the developmental or learning process since a period of years can be modelled in a short time (Munakata & McClelland, 2003). These networks, made of individual neuron-like components, are subjected to some kind of interference, and the effect of this interference on an iterative learning process is assessed (Thomas & Karmiloff-Smith, 2002). The interference could take place at the start, part way through, or at the end of the learning process. It can take the form of a 'lesion', an abnormal pattern of connectivity, an atypical learning rule or growth pattern. For example, neural networks have been used to model the abnormal brain growth patterns observed in ASD, indicating an unforeseen link between neural growth and a range of ASD symptoms (Lewis & Elman, 2008)

Gustafsson and Paplinski (2004) compared the end states of four neural networks which had learned to distinguish between a set of stimuli. These networks all learnt under slightly different attentional conditions. The first was programmed to have a novelty preference (considered normal), the second an attention-switching deficit, the third a familiarity preference and the fourth a familiarity preference and an attention switching deficit. The end states of the networks indicated that an attention-switching deficit promoted enhanced stimulus discrimination. This result demonstrates how an early attention-shifting impairment could result in the commonly-found feature of enhanced discrimination in ASD (Plaisted, O'Riordan & Baron-Cohen, 1998; Kemner, van Ewijk, Van Engeland & Hooge, 2008).

In another neural network study of the development of gaze-following, Triesch and colleagues reduced the reward value of looking to an adult caregiver, and found that the resultant model did not learn to follow gaze (Triesch et al., 2006). They conclude that “reduced reward for looking at the caregiver’s face or aversiveness of the caregiver is sufficient to explain delays or complete failure in the emergence of gaze following” (p.137). The finding identifies a possible root cause of poor gaze-following in children with ASD. However, this finding is slightly weakened by the conflation of two potential causes of impaired gaze-following in ASD: aversion to other people (especially direct gaze) and lack of motivation or reward value from attention to other people. Moreover, the finding cannot explain the central contradiction in the literature: intact or near-normal gaze following in ASD in response time paradigms, with poor gaze-following in interpersonal scenarios.

Final Comments

This review of literature, while focusing on methods deployed, has revealed the array of theoretical standpoints and range of, often contradictory, findings in this field. The future of attention research in ASD will require a careful appreciation of literature pertaining to attention in typical as well as atypical populations and the continuing deployment of tried and tested paradigms from colleagues working more exclusively in attention research as has been so successfully implemented to date. However, this will not be enough. It is intriguing that people with ASD may have different attentional capacities, and variation in their sensitivity to cue types, however at present we do not know how these interact with each other and with the emergence of the clinical features of ASD. Working with the specific questions that arise when researching this developmental disorder, which has such clear social cognitive deficits alongside many other differences in cognitive processing, raises its own challenges and own particular questions. Paradigms developed in the general population may not be able to address these questions as minutely as required. Two significant complicating factors in the study of attention in ASD have been frequently touched upon in this review, but not fully-explored. The first is the choice of social stimulus content the second is the selection of participants.

The choice of stimulus content for experiments exploring attention to social information is an easier obstacle to overcome, but less acknowledged among the research community. We use the word 'social' to describe a dazzling array of potential stimuli from cartoon pictures of faces to moving images of people conversing. The word 'social' could also be used to describe a number of images or items which contain no visible human whatsoever. For example, a picture of a war memorial or the Titanic gains its meaning from the social stories and histories which accompany that object. Even a simple building is man-made, perhaps someone's home. Next to these examples, a cartoon image of isolated moving eyes appears to be socially sparse. People with ASD may find our reactions to non-human, but socially meaningful things as baffling as our behaviour to each other. Any truly comprehensive examination of attention to social information by people with ASD needs to encompass the full range of social input available.

A new approach to the study of typical attention, called Cognitive Ethology, is highly relevant here (Smilek, Birmingham, Cameron, Bischof & Kingstone, 2006). These authors call for the use of more realistic tasks and stimuli as well as the gathering of participants' subjective reports about attention. Such an approach would be particularly valuable in exploring the subtle attentional atypicalities which may underpin some of the social difficulties faced by people with high-functioning autism. A further challenge for those using realistic methods however, is to control for the potentially confounding impact of social anxiety and other related feelings. People with ASD may show atypical responses to more realistic stimuli because of the social anxiety they provoke rather than core processing difficulties or any sense of aversion or lack of interest.

The second issue is selection of participants. Studies to date have tended to take a cross sectional approach to studying attention in ASD. Indeed, the demands of many paradigms described have necessitated the selection of higher functioning adolescents or adults. However, the choice of participants has the potential to influence the results reported. As mentioned above, Minshew et al. (1999) and Goldberg et al. (2002) report apparently inconsistent findings from the memory guided saccade task. However, Luna et al. (2007) report developmental changes which both serve to clarify previous findings and also demonstrate the necessity of taking a developmental approach to the study of developmental disorders (Karmiloff-Smith, 1998).

Developmental approaches to the study of attention have been deployed in research focused on Williams Syndrome, Downs syndrome and Fragile X (Cornish, Scerif & Karmiloff-Smith, 2007). The modelling of developmental trajectories (Thomas et al., 2009; Astle & Scerif, 2009) of attention and its interaction with social cognition or symptom severity has the potential to clarify some of the contradictory or incomplete findings that result from the more traditional cross-sectional approaches to attention research in ASD (Astle & Scerif, 2009; Karmiloff-Smith, Scerif & Thomas, 2002). Attention may be a particularly fruitful arena in which to deploy these methods as it is known to show developmental change, has been the topic of successful research in other developmental disorders and has methods that have the sensitivity to measure change across the life-span (e.g. Elsabbagh et al.., 2009).

One barrier to conducting research into ASD early in development has been the relatively late stage at which it is typically diagnosed in comparison to developmental disorders which have clear genetic markers. However, recent awareness of the broader phenotype within both families and the general population, in addition to the heritable nature of the disorder, allow for creative solutions using infant siblings at high risk of a later diagnosis, unaffected siblings and parents and examination of autistic-like traits in the general population. Each of these provides the scope for further developing our understating of the relationship between disruptions to attention development and both social cognition and the presentation of ASD.

A further factor which has not been dwelt on in this review is the concept of an ASD. Autism Spectrum Disorder, as the word ‘spectrum’ implies, encompasses a wide variety of disorders and even within one diagnostic category it is possible to observe a wide range of verbal, non-verbal and social abilities. However, perhaps even more significantly, within the wider field of ASD research there has been a recent move to explore the extent to which the triad of impairments is fractionable (Happé, Ronald & Plomin, 2006). While it is clear that in clinical samples the features of the triad cluster together, in the wider population this is not always the case. As such there may be differing genetic, neurological and cognitive pathways that lead to behaviours associated with ASD. If this is the case then characterising participants carefully according to the specific presentation of their skills and impairments may be crucial for the furthering of research in ASD, including our understanding of the impact of attentional processes on social cognitive development.

Another issue, which has not been addressed widely in attention research in ASD as yet is that of the specificity of attention profiles reported. Lincoln, Lai and Jones (2002) report deficits in shifting attention in a study of a very small group of individuals with Williams syndrome. In this case, attention shifting problems are present in the absence of the joint attention or social deficits associated with ASD. Though the social presentation of individuals with Williams syndrome is not typical, it is qualitatively different than that of individuals with ASD. This highlights the need to carefully delineate not only attentional features but of their interaction with other cognitive and developmental features of disorders. Indeed, it is perhaps this developmental approach that provides one of the most exciting future paths for research in attention in ASD. Work with the infant siblings of children with ASD (e.g. Elsabbagh et al., 2009; Zwaigenbaum et al., 2007) will allow for truly developmental, longitudinal rather than cross-sectional, research to be conducted. This will allow the interaction between social, attentional and other cognitive processes to be observed and analysed.

However, despite all the issues raised above, a central consideration for those working within attention research with participants with ASD is the extent to which an interesting attentional question is able to answer theoretical questions about the aetiology of ASD. For example, Diamond (2006) has proposed that the ability to make conceptual connections between objects that are not physically connected may be a particular problem for at least a subset of children with ASD. This is a question that may be addressed through the careful construction of tasks that measure the focus of attention during conceptual learning. Thus attention methodologies may be deployed in ASD research to address questions wider than those that are concerned purely with the attentional processing capabilities of the population.

In summary, attention research with people with ASD has flourished in recent years. Paradigms used in research with the general population have been appropriated and adapted both to be suitable for use with people with ASD and to answer specific questions posed by the disorder. Many intriguing, and often contradictory findings have been reported and an increasingly clear picture of the strengths and weaknesses of attention in ASD is emerging. This picture includes differences in the control of attention that reflect slowing rather than absolute inability to disengage or shift and differences in the use of contextual, memorised and symbolic information in the top down control of attention. This review has sought to identify the main methods used, to describe important findings and methodological issues. On completion of this review a lack of a clear theoretical position uniting (or indeed separating) attention with other cognitive and clinical features of ASD is apparent. Future work to develop our understanding of attentional processes alongside work which traces development, relationships with other syndromes and within ASD promises to be fascinating.

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