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FOCUS REVIEW

Visual Orienting Among Persons with Autism Spectrum Disorders

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INTRODUCTION

Atypical attentional behaviour is emerging as a robust marker of ASD in children as young as 12 months in both retrospective (1, 2) and prospective longitudinal studies (3). Young children as well as high-functioning adults with ASD exhibit unusual looking behaviour not only to people but to objects as well (4), suggesting atypical looking behaviour is not strictly a social problem but rather a broader problem with the strategic control of visual attention. This atypical attentional behaviour could contribute to many impairments that are characteristic of ASD. For example, failure to attribute meaning to eye gaze as a cue to direct attention could lead to a failure to engage in joint attention, a social activity in which two people share an experience about a commonly attended object that is considered to be an important precursor to language acquisition (5, 6). An impairment of joint attention is thought to reflect social difficulties, however it may be one of many manifestations of impaired strategic control of visual attention (7, 8). Klin *et al.* (9) suggest that from a very young age children with ASD misdirect attention in their environment, which would consequently impede learning, as the acquisition of skills and knowledge depends on how well children pay attention to their environment (10). This impairment in strategic control over the orientation of visual attention compromises the ability of the child to selectively direct attention to pertinent and relevant locations in the visual field. Thus, we suggest that visual orienting is intact in ASD but that the control of it is impaired. This specific impairment is also supported by similar patterns of findings in visuomotor coordination.

Visual Orienting

Visual attention can be directed either by focusing the eyes, or foveating, on a specific location or by choosing to attend to a location in peripheral vision. One model of visual attention is based on the metaphor of a spotlight beam that is directed to a specific location, and events within the beam are detected with enhanced efficiency (11, 12). Within this context, Posner (11) introduced the notion of the orienting of attention in which the directing of attention to a given location facilitated detection of a target at that location, but impeded detection of a target at another location. Visual cues are used to direct attention to the cued location either overtly, with eye movements, or covertly, without eye movements (11). Cues that elicit shifts of attention automatically, or unconsciously, are considered to be exogenous, as the shift is in response to the physical properties of the stimulus. An example is a flash of light, which attracts attention to the location of the flash. Cues that elicit voluntary shifts of attention are endogenous as the shift is in response to the symbolism or meaning of the cue. An example is an arrow, which directs attention to a secondary location away from the actual arrow. Deficits in exogenous orienting would suggest a basic problem in attending, whereas deficits in endogenous orienting, with spared exogenous orienting, would suggest a problem in the control of attention (13).

Exogenous Orienting among Persons with ASD

The findings from two studies of exogenous orienting were taken as initial evidence of general orienting deficits among persons with ASD. Casey *et al.* (14) found that a group of adults with ASD were slower overall to respond but that the facilitation effects with stimulus onset asynchronies (SOAs) at both 100 ms and 800 ms were even larger than those of the comparison group on an exogenous orienting task with predictive peripheral cues. Similarly, Harris *et al.* (15) found that children with ASD (mean age 7.5 years) showed a larger facilitation effect at 1000 ms SOA, whereas typically developing children showed a larger effect at 200 ms SOA. However, the implications of these two studies are limited by methodological concerns regarding the participants and the tasks. With regard to

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the participants, in both experiments, participants with ASD were matched to typically developing persons only on the basis of chronological age, and had mean full scale IQ scores that were 45 (14) and 28 (15) points lower. Thus, the differences in performance were likely associated with the a priori differences in IQ, and subsequently of developmental level(16, 17). With regard to the tasks, none of the groups in either of the studies showed the typical inhibition of return (IOR) effects, in which participants are slower to detect a target at the cued location following a long SOA, because attention has drifted away from the cued location in the absence of a target and which are a hallmark of exogenous orienting. The failure to elicit an IOR effect may have been because the maintenance of the peripheral cue on the screen during the full duration of the trial, before and during target onset, may have held attention longer at the cued location than if the cue was a brief flash (18, 19). In addition, the long duration of the cue, coupled with its predictability that may actually make it meaningful suggests that the tasks were effectively endogenous rather than exogenous.

Differences were not found in studies of exogenous orienting when the problems with the initial studies were eliminated. For example, Iarocci and Burack (20) found that low functioning children and adolescents with ASD (mean CA 11.6 years; mean MA 7.2 years) and typically developing children matched on mental age performed similarly on an exogenous orienting task in which the peripheral cue and central fixation did not overlap with target onset. A 50 ms peripheral cue, followed by 150 ms blank screen, which served to elicit disengagement, was presented before the target appeared. Peripheral cues were non-predictive as the ratio of congruent to incongruent cues was 1:1. There were no significant differences between the groups on overall reaction time (RT) and no interaction between facilitation effects and group, as both groups demonstrated the expected benefits of congruent cues.

Similarly, Randolph *et al.* (21) found facilitation effects in exogenous orienting among both a group of high functioning adolescents with ASD and a group of comparison participants matched on chronological age and IQ. The duration of the peripheral cue was 30 ms, and targets could appear in one of four locations instead of the standard two. Peripheral cues were non-predictive as the ratio of congruent to incongruent cues was 1:3. Both groups showed similar facilitation effects at an SOA of 100 ms and IOR at an SOA of 800 ms. Thus, the patterns of findings across studies of exogenous orienting in which issues of group matching and stimulus presentation are appropriately controlled do not support a general impairment in shifting of attention among persons with ASD.

Endogenous Orienting among Persons with ASD

In contrast to the findings on exogenous orienting tasks, persons with ASD display consistent impairments in shifting attention on endogenous orienting tasks. For example, Wainwright-Sharp and Bryson (22) found different facilitation effects in the two groups between high functioning adults with ASD and age and IQ matched typical adults on a Posner task in which centrally located arrow cues remained onscreen for 100 ms or 800 ms and were predictive with a congruent-incongruent ratio of 4:1. The persons with ASD did not show facilitation effects to rapidly presented cues when a voluntary shift of attention was required. Regardless of cue duration, the typical adults responded faster to congruent than to incongruent trials and the magnitude of this effect was the same at both cue durations, whereas the adults with ASD only displayed facilitation effects in the long cue duration, and the magnitude of this effect was larger than for the typically developing group at the same duration. Wainwright-Sharp and Bryson (22) concluded that the participants with ASD were impaired in either disengaging or shifting of attention, or in the voluntary coordination of attention and motor systems. The finding of facilitation effects at the longer SOA on the endogenous task suggests that the process of orienting to symbolic cues is not absent, but merely slowed down.

Burack *et al.* (13) suggested that the deficit exhibited on endogenous orienting reported by Wainwright-Sharp and Bryson (22) might indicate that persons with ASD are slower to interpret the meaning of the symbolic cue. Consistent with this hypothesis, Randolph *et al.* (21) found no ASD-related deficits on an endogenous orienting task in which predictive arrows (75% congruent) appeared on screen for 280 ms or 980 ms; these trial durations were long enough for the participants with ASD to demonstrate facilitation effects.

Perception versus Response Selection in Visual Orienting

The evidence does not appear to support a general orienting deficit among persons with ASD, but rather a delayed orienting effect to endogenous cues. The presence of the orienting effect at longer SOAs could reflect a slower reading of the cue (13), but reports of slower overall reaction times (14, 21-23) should not be dismissed as irrelevant. It may be indicative of other slowed responses that are not observed. For example, Landry *et al.* (24) found that children with ASD were able to read rapidly presented cues as well as typically developing children, but were less able to execute a fast enough response in terms of shifting visual attention and required longer trials to exhibit effects. Accordingly, Landry et al. suggested that if a person with an ASD were slower at executing that endogenous shift of attention in response to the cue, the onset of the target might disrupt the in-progress endogenous shift and begin a new exogenous shift directly to the target.

Visuomotor Planning in Autism Spectrum Disorders

The finding that endogenous cues may not be defective among persons with ASD when they are superseded by the appearance of the peripheral target is consistent with findings of impairments in the voluntary control of motor responses, rather than of motor impairments, on reach-to-grasp (25), visual pursuit (26), and saccadic eye movements (7, 27). The findings with these other visuomotor skills indicate that the problems exhibited by persons with ASD on endogenous visual orienting tasks reflect general impairments in strategic goal-oriented behaviour. For example, Mari *et al.* (25) reported that lower functioning children with ASD were slower than higher functioning children with ASD or typically developing children, though accurate, in their performance on a reach-to-grasp task. The lower functioning children showed less simultaneous activation of reaching and grasping, and this delay increased as a function of the precision needed to perform the task. Mari *et al.* further reported that higher functioning children with ASD, relative to typically developing children, executed very fast movements, as though once the action plan was finalized it must be performed quickly in order to avoid any disruptive feedback mechanisms. Concordantly, Masterton and Biederman (28) found that children with ASD were unable to visually guide reaching movements very efficiently. These findings broadly suggest that children with ASD have difficulty using external feedback to guide behaviour, at least with respect to visuomotor activity.

Eye movements also appear to be atypical among children with ASD. For example, in a study of visual pursuit, Takarae *et al.* (26) found that children with ASD were impaired relative to typically developing children on both the open loop stage of visual pursuit which entails the initiation of eye movement and is sensory driven, and the closed loop stage which entails the ability to sustain the movement, and is feedback driven (26); although the impairments differed as a function of stage. In the open loop stage, the impairments were only found for pursuit in the right hemifield, whereas closed loop stage impairments were found bilaterally. For children with ASD, visual pursuit performance was correlated with motor praxis, as measured with the Grooved Pegboard, however for typically developing children, visual pursuit performance was correlated with motor speed, as measured by Finger Tapping. This suggests the presence of multiple impairments, both in visual perception for the right hemifield and in motor coordination that might impact control over both eye movements and shifting visual attention.

Kemner *et al.* (7) speculated that poor control over eye movements might underlie abnormalities in visual attention among children with ASD. Based on Hermelin and O'Conner's reports of atypical looking behaviour during the course of experiments, Kemner et al. (7) measured the eye movements during a visual oddball task among children with ASD, ADHD or dyslexia, and typically developing children. The children were presented frequent, rare, and novel, stimuli, and were familiarized with the frequent and rare stimuli at the beginning of the task. The children with ASD made more eye movements between stimuli than all other groups, and during the presentation of the frequent stimuli than ADHD and typical groups. Further, unlike the typical children and children with dyslexia, the frequency of eye movements of children with ASD did not differ as a function of stimulus type. Although the children with ASD appeared to look at all stimuli as though it were novel, the high frequency of eye movements between stimuli suggests that they had a generalized difficulty controlling eye movements.

In a followup, Kemner *et al.* (29) found no differences between children with ASD and typically developing children in a sample with a mean age of 10 years on smooth pursuit and saccadic eye movements. Minshew *et al.* (30) also found no differences between high-functioning young adults with ASD and typically developing peers on a visually guided saccade task, finding instead that the participants with ASD made more errors on an anti-saccade task and an oculomotor delayed response task. However, Takarae *et al.* (27) found reduced saccade gain, defined as the ratio of saccade amplitude over target distance, with normal saccade latencies in high-functioning adolescents/young adults with Asperger syndrome, but not autism (mean age 16 years), suggesting that the deficit might be highly specific, subtle, and differ across ASD subgroups.

CONCLUSION

If persons with ASD exhibited generalized impairments in visual saccades, this would indicate impairment in oculomotor control. However, the findings of the experiments on visual saccade suggest that oculomotor control is generally intact, and like the findings on tasks of visual orienting discussed previously, excludes any bottom-up explanations of atypical visual attention behaviour. Similar conclusions were drawn by Hadjikhani *et al.* (31), who reported that early sensory visual areas are normally organized in the brains of persons with ASD. Rather, the evidence suggests that visuomotor control falls apart when it is goal-driven and/or feedback dependent rather than simply sensory driven. Visual orienting differences exhibited by persons with ASD stem from poor strategic control over visual attention and eye movements, and are a symptom of poor control over visuomotor coordination in general. With the emergence of orienting difficulties in ASD by 12 months old as well as the specificity (3), visual orienting may provide paediatricians with new symptoms to watch for and neuroscience with new clues to the early neurological manifestation of ASD.

ACKNOWLEDGEMENTS

Funding provided by a SSHRC grant to Prof. J. A. Burack.

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