Neuroscience 307 (2015) 273–280

DIFFERENCES IN THE USE OF VISION AND PROPRIOCEPTION FOR POSTURAL CONTROL IN AUTISM SPECTRUM DISORDER

S. L. MORRIS,* C. J. FOSTER R. PARSONS, M. FALKMER, T. FALKMER AND S. M. ROSALIE

Faculty of Health Sciences, Curtin University, GPO Box U1987, Perth, Western Australia 6845, Australia

Abstract—*Background*: People with autism spectrum disorders (ASDs) also have poorer fundamental motor skills. The development of postural control underlies both social and motor skills. All three elements are facilitated by the active use of visual information. This study compares how adults with ASD and typically developed adults (TDAs) respond to a postural illusion induced using neck vibration. Adults with ASD unlike the TDA, were not expected to correct the illusion using vision. *Methods*: The study used intermittent (15off, 5on) posterior neck vibration during 200 s of quiet stance to induce a postural illusion. In TDAs and only in the absence of vision this protocol induces a forward body lean. Participants (12 ASD, 20 TDA) undertook four conditions combining vibration and visual occlusion. *Results*: As predicted, TDA were only affected by the postural illusion when vision was occluded (vibration condition: vision occluded ($n = 1$) $p = 0.0001$; vision available ($n = 3$) $p > 0.2466$). Adults with ASD were affected by the postural illusion regardless of the availability of vision (all conditions $p < 0.0007$). *Conclusions*: Our findings indicated the adults with ASD did not use visual information to control standing posture. In light of existing evidence that vision-for-perception is processed typically in ASD, our findings support a specific deficit in vision-for-action. These findings may explain why individuals with ASD experience difficulties with both social and motor skills since both require vision-for-action. Further research needs to investigate the division of these visual learning pathways in order to provide more specific intervention opportunities in ASD.

Key words: postural control, autism spectrum disorder, vision-for-action, vibration, sensory integration.

INTRODUCTION

Autism spectrum disorders (ASDs) are neurodevelopmental disorders present from early childhood which are characterized by atypical development of social interaction and communication with restricted or repetitive interests and behaviors (Lai et al., 2014). ASD is commonly used as an comprehensive umbrella term and includes among others the diagnoses of Autistic disorder, Asperger syndrome (AS) (American Psychiatric Association, 2000). The term high-functioning autism (HFA), usually refers to individuals within the spectrum with an IQ score within or above the normative average range (Volker, 2012). ASD (previously known as pervasive developmental disorder) is one of the most common childhood disorders with 1 in 68 children being diagnosed (Lord and Bishop, 2015). Despite being predominantly a social disorder, at least 79% of individuals with ASD are reported as having difficulties with fundamental motor skills (Ghaziuddin and Butler, 1998; Pan et al., 2009; Fournier et al., 2010a). Fundamental motor skills are important in the development of skills in play, interaction with others, communication and language (Gernsbacher et al., 2008; Blaesi and Wilson, 2010; Clearfield, 2011). Therefore, the motor difficulty in those with ASD may contribute to the significant social difficulty associated with this disorder (Bhat et al., 2011).

The ability to control posture is critical to the typical development of fundamental motor skills (Miyahara, 2013; Travers et al., 2013). If individuals with ASD experience difficulties with postural control at key time points during their development of fundamental motor skills, such difficulties may be a causative factor in the atypical development of motor and social skills characteristic of ASD (Bhat et al., 2011). Studies have shown that children and adolescents with ASD demonstrate differences in postural control with increased anteroposterior and mediolateral sway when standing still compared to their typically developing peers (Molloy et al., 2003; Fournier et al., 2010b; Memari et al., 2013). Evidence suggests that underdevelopment of postural control in the setting of ASD continues into adulthood (Kohen-Raz et al., 1992; Minshew et al., 2004; Travers et al., 2013); however, the mechanisms for the differences are not known.

Visual information usually dominates other forms of sensory information in the control of posture (Peterka and Benolken, 1995; Nolan et al., 2005). Differences in visual processing have been commonly reported in ASD (Simmons, 2009). Studies comparing the effect of a visual illusion of motion on the posture of young children with and without ASD have shown that both younger children (Gepner et al., 1995) and older children (Gepner and Mestre, 2002) with ASD change their posture less in response to the perception of motion than typically

*Corresponding author. Tel: +61-0892669226.
E-mail address: s.morris@curtin.edu.au (S. L. Morris).
Abbreviations: AS, Asperger syndrome; ASDs, autism spectrum disorders; HFA, high-functioning autism; TDAs, typically developed adults.

http://dx.doi.org/10.1016/j.neuroscience.2015.08.040
0306-4522/

developing children. These findings suggest that children with ASD are less dependent on the perception of motion to maintain a balanced posture. Interestingly, in the same study children with AS as opposed to children with autistic disorder were shown to be more reactive to the perception of motion than both children with autistic disorder and typically developing children (Gepner and Mestre, 2002). This raises the possibility that children with the AS are more, rather than less, dependent on the perception of motion to maintain a balanced posture than typically developing children. Conversely, spatial and motion integration tests that have compared the abilities of children with autism and typically developing children to verbally respond to the perception of motion have shown no differences (Del Viva et al., 2006).

Although visual information is the dominant source of sensory information used in the control of posture, it is not the only source of information. Information from the somatosensory and vestibular systems also contributes to the maintenance of an optimal body position (Peterka and Benolken, 1995; Nolan et al., 2005). Thus, either primary deficits in somatosensory and/or vestibular information (Weimer, 2001), or an inability to integrate visual information with somatosensory and vestibular information (Baranek, 2002; Cascio et al., 2012) could lead to the difficulties in motor control experienced by individuals with ASD. Evidence for both primary somatosensory and/or vestibular deficits and deficits in integration is inconsistent. It has been reported; however, that children with ASD have difficulties in standing on one leg with their vision occluded and this has been attributed to a proprioceptive deficit that caused an over-reliance on visual information to balance (Weimer, 2001). It has also been reported that adolescents with ASD do not have a primary proprioceptive deficit (Fuentes et al., 2011) and in fact are proprioceptive learners (Haswell et al., 2009). Conversely, children with ASD have been shown to experience greater postural sway than typically developing children when balance is perturbed by standing on an unstable surface (i.e., foam) both with and without the availability of visual information. This greater sway has been attributed to impaired integration of information from the visual, somatosensory and vestibular systems (Molloy et al., 2003). Though informative, in the foregoing study postural sway was examined under conditions where visual control of posture was directly inhibited through blindfolding the participants; whereas, somatosensory control of posture was inhibited through manipulation of the environment conditions. That is, balance was perturbed via changes in the surface (platform versus foam). To our knowledge researchers are yet to examine differences in the integration of visual and somatosensory information for the control of posture between individuals with and without ASD in a single study that directly and independently inhibits sensory input from both the visual and somatosensory systems. Thus, evidence regarding differences between individuals with and without ASD in the integration of visual and somatosensory information for the control of posture on a stable surface is incomplete. Furthermore, previous studies of differences in postural control between individuals with and without ASD have focused on children and adolescents. Findings of studies including adults with ASD are mixed. Evidence both supports a deficit (Kohen-Raz et al., 1992; Minshew et al., 2004) and no deficit (Greffou et al., 2012; Travers et al., 2013) in the use of visual information for postural control in adults with ASD. Thus, it is unclear whether the difficulties that children and adolescents with ASD experience in postural control persist into adulthood, which has implications with respect to learning and performance of vocational skills.

Bove and colleagues (2009) recently pioneered a method of examining the integration of visual and somatosensory information for posture control in quiet standing. This method uses sequential periods of vibration of posterior neck muscles interspersed with vibration-free periods to produce a transient proprioceptive illusion of movement of the head which is interrupted as a backward lean of the truck due to constant vestibular input (Bove et al., 2009). This illusion results in a ‘‘corrective" transient forward movement of the center of pressure coinciding with periods of vibration. Posture is typically normalized once the illusion is removed. When participants were instructed to close their eyes across successive periods of vibration, thereby denying themselves a visual reference for the position of the head, the forward movement of the center of pressure was not only observed to increase but participants were unable to correct their posture in the absence of vibration until vision was restored (Bove et al., 2009). This result highlights the importance of visual information for typically developing individuals in setting the postural reference point and returning to a neutral position after posture is perturbed (Bove et al., 2009). The method used by Bove et al. (2009) required the participants to open or close their eyes in response to a verbal command, which meant that the availability of visual information was controlled by the participant and not the experimenter. This limitation can be overcome by using liquid crystal spectacles that allow the precise control of the availability of vision across time (Rosalie and Müller, 2013). These spectacles are particularly useful for controlling vision in individuals with ASD whose difficulties with communication and social interaction may make it problematic to follow a sequence of commands to open and close their eyes. By combining neck muscle vibration with visual occlusion, it is therefore possible to have tight experimental control of both the somatosensory and visual information available for postural control in individuals with ASD.

The purpose of this study was thus to determine whether adults with ASD use and integrate visual and somatosensory information to control posture during quiet standing differently from TDAs. Based on existing evidence (Weimer, 2001; Molloy et al., 2003; Fuentes et al., 2011) it was hypothesized that: (i) proprioception is processed similarly in typically developed adult (TDA) and ASD such that when vision is occluded, both groups will respond to the postural illusion by leaning forward; (ii) vision is processed differently in TDA and ASD such that TDA, but not adults with ASD, will normalize their posture when vision is restored during the postural illusion; and (iii) integration of vision and proprioception is different in