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Relationship of ocular accommodation and motor skills performance in developmental coordination disorder

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ABSTRACT

Ocular accommodation provides a well-focussed image, feedback for accurate eye movement control, and cues for depth perception. To accurately perform visually guided motor tasks, integration of ocular motor systems is essential. Children with motor coordination impairment are established to be at higher risk of accommodation anomalies. The aim of the present study was to examine the relationship between ocular accommodation and motor tasks, which are often overlooked, in order to better understand the problems experienced by children with motor coordination impairment. Visual function, gross and fine motor skills were assessed in children with developmental coordination disorder (DCD) and typically developing control children. Children with DCD had significantly poorer accommodation facility and amplitude dynamics compared to controls. Results indicate a relationship between impaired accommodation and motor skills. Specifically, accommodation anomalies correlated with visual motor, upper limb and fine dexterity task performance. Consequently, we argue accommodation anomalies influence the ineffective coordination of action and perception in DCD. Furthermore, reading disabilities were related to poorer motor performance. We postulate the role of the fastigial nucleus as a common pathway for accommodation and motor deficits. Implications of the findings and recommended visual screening protocols are discussed.

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1. Introduction

Children with developmental coordination disorder (DCD) struggle with many motor skills incorporating a visual component, including impairment of eye-limb coordination (e.g., grasping objects, reading and writing) and an increased frequency of bumping into things. Such tasks are found to take longer or are done with more difficulty than that of normal peers (Van Waelvelde, De Weerdt, De Cock, & Smits-Engelsman, 2004; Wilmut, Brown, & Wann, 2007), resulting in an overall difficulty with concentration and attention (Latash & Lestienne, 2006; Missiuna, Gaines, Soucie, & McLean, 2006). A commonality in many of the implicated tasks is that they occur at reachable or near-reachable working distances that require good dynamics of refocussing and maintaining clear vision, for which robust ocular accommodation and vergence systems are essential.

Many mechanisms of motor performance are controlled through the cerebellum as well as parietal lobe structures. The cerebellum is specifically involved in motor adaptation (Kagerer, Bo, Contreras-Vidal, & Clark, 2004), limbic control (Schmahmann, Weilburg, & Sherman, 2007), postural control (Geuze, 2005), error detection (Stowe, Paans, Wijers, & Zwarts, 2004) and the timing and sequencing of movements (Piek & Skinner, 1999). While motor and visual systems are interdependent, regulation and functioning of both systems occurs through common cerebellar structures (Nicolson et al., 1999; Thach, 1998). The role of the cerebellum is also understood in literacy, aspects of visual perception (Molinari et al., 1997), and notably the cerebellum projects to control ocular motor function (Gamlin, 1999). Therefore, in cases of motor impairment it is not unexpected that motor aspects of the visual system are also implicated (Stack & Minnies, 1989).

Accurate visual control plays an important role in motor skills (Duhamel, Colby, & Goldberg, 1992; Hulme, Smart, Moran, & McKinlay, 1984), including the ability to move in space (Cermak & Larkin, 2002; Latash & Lestienne, 2006), depth perception and figure-ground perception (Latash & Lestienne, 2006). These perceptual abilities require accurate feedback from clear retinal images and appropriate responses to changes in distances (Enright, 1986; Schor, Lott, Pope, & Graham, 1999). The generation of accurate eye movements is necessary to allow correct focus between objects at varying distances (Duhamel et al., 1992; Hulme et al., 1984). A significant contribution is provided by the 'near triad' systems, including ocular accommodation and vergence systems (Gamlin, 1999), in response to sensory stimuli of disparity and blur (Hung & Semmlow, 1980; Krishnan, Phillips, & Stark, 1973).

Vision is used for feedback in many ways; when we reach for an object we unconsciously pre-shape our hand to fit the object and perform a task from the visual quantities gained (Jeannerod, Arbib, Rizzolatti, & Sakata, 1995). These perceptual abilities are critical for action. For motor skills to develop, visual information must be perceived accurately, thus, functioning of motor systems is dependent on the visual system (Cermak & Larkin, 2002). It is critically important that the information from proprioception is matched with visual information for the correct rotation of movements. The matching of sensory information is highlighted in cases of hampered visual status, where a relationship of reduced accuracy in motor control and coordination are observed (Brambring, 2001).

The accommodation system is a vital component of the ocular motor system. Primarily, it functions to maximize retinal image contrast at the fovea, with considerable interaction with eye movement mechanisms (Maxwell, Tong, & Schor, 2012; Myers & Stark, 1990; Winn, Gilmartin, Mortimer, & Edwards, 1991). When an object proceeds towards us, or we proceed towards the object, the object image expands on the retina as it increasingly gets closer, and the rate at which this expansion changes provides information on the time to contact (Lee & Young, 1985). Moreover, in order to accurately perform visually guided daily tasks, it is necessary for the accommodation system to be dynamic, fast, and precise, to ensure a well-focussed image on the retina (Sterner, 2001).

Accommodative subsystems form the 'near triad' system with four components. (1) When accommodation is closed-loop, this is referred to as blur-driven or reflex accommodation (Winn et al., 1991). A response is initiated to optical blur, resulting in pupillary constriction to increase depth of focus and convergence occurs to minimize binocular disparity, all of which are elicited to provide an accurate retinal feedback system (Myers & Stark, 1990). This accommodation component is controlled