Human Movement Science 56 (2017) 1–10

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

Association between fine motor skills and binocular visual function in children with reading difficulties

Ewa Niechwiej-Szwedo[a,*], Fatimah Alramis[a], Lisa W. Christian[b]

[a] Department of Kinesiology, University of Waterloo, 200 University Ave. W., Waterloo N2L 3G1, Ontario, Canada
[b] School of Optometry and Vision Science, University of Waterloo, 200 University Ave. W., Waterloo N2L 3G1, Ontario, Canada

ARTICLE INFO

Keywords:
Fine motor skills
Reading
Binocular vision
Development
Accommodative facility

ABSTRACT

Performance of fine motor skills (FMS) assessed by a clinical test battery has been associated with reading achievement in school-age children. However, the nature of this association remains to be established. The aim of this study was to assess FMS in children with reading difficulties using two experimental tasks, and to determine if performance is associated with reduced binocular function. We hypothesized that in comparison to an age- and sex-matched control group, children identified with reading difficulties will perform worse only on a motor task that has been shown to rely on binocular input. To test this hypothesis, motor performance was assessed using two tasks: bead-threading and peg-board in 19 children who were reading below expected grade and age-level. Binocular vision assessment included tests for stereoacuity, fusional vergence, amplitude of accommodation, and accommodative facility. In comparison to the control group, children with reading difficulties performed significantly worse on the bead-threading task. In contrast, performance on the peg-board task was similar in both groups. Accommodative facility was the only measure of binocular function significantly associated with motor performance. Findings from our exploratory study suggest that normal binocular vision may provide an important sensory input for the optimal development of FMS and reading. Given the small sample size tested in the current study, further investigation to assess the contribution of binocular vision to the development and performance of FMS and reading is warranted.

1. Introduction

Emerging research suggests that normal binocular vision provides a key sensory input for the development of high-level skills that are critical for academic success, such as reading (Kelly, Jost, De La Cruz, & Birch, 2015; Kulp, 1999; Kulp et al., 2016; Lions, Bui-Quoc, Seassau, & Bucci, 2013; Simons & Grisham, 1987) and fine motor skills (Grant, Suttle, Melmoth, Conway, & Sloper, 2014; O'Connor et al., 2010a; Webber, Wood, Gole, & Brown, 2008). Studies have also shown that performance on clinical tests of fine motor skills in young children is predictive of reading success in older children (Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010; Pagani, Fitzpatrick, Archambault, & Janosz, 2010; Roebers et al., 2014; Son & Meisels, 2006). However, the nature of this association remains to be discovered because the association between fine motor skills and reading has been studied using a composite measure obtained from a large test battery, which makes it difficult to determine which aspects of fine motor skills are associated with reading. In addition, the types of motor tasks used to assess fine motor skills vary considerably among clinical tests of motor function. To better understand the association between reading and fine motor skills, a comparison of motor performance across different tasks is necessary. The primary goal of the current study was to assess fine motor skills using two manipulation tasks that rely differentially

* Corresponding author.
E-mail addresses: eniechwi@uwaterloo.ca (E. Niechwiej-Szwedo), falramis@uwaterloo.ca (F. Alramis), lisa.christian@uwaterloo.ca (L.W. Christian).

http://dx.doi.org/10.1016/j.humov.2017.10.014
Received 30 August 2017; Received in revised form 17 October 2017; Accepted 19 October 2017

on binocular vision in a cohort of school-age children with reading difficulty. A secondary goal was to explore the association between aspects of binocular visual function (i.e., stereoacuity, vergence and accommodation) and motor task performance. The following literature review aims to provide a brief summary of research in two areas: 1) the association between fine motor skill performance and academic achievement including reading, and 2) the contribution of binocular visual function to reading and fine motor skill performance.

Fine motor skills (FMS) are defined as a class of upper limb movements that demand a coordinated action of the eyes and hand(s) to achieve behavioral goals. FMS is an umbrella term encompassing several domains of distinct functional movements which can be differentiated based on the cognitive, perceptual, sensory, and motor requirements of the task. In general, FMS performance requires the ability to formulate a motor plan, which is dependent on one's ability to select, process, and integrate various sensory inputs, such as vision and proprioception. Movement execution involves spatiotemporal coordination among the oculomotor and manual systems to control movements of one or both hands simultaneously (i.e., hand-eye coordination). The most commonly used clinical tests to assess motor development in school-age children are the Movement Assessment Battery for Children (MABC) (Henderson & Barness, 2007), the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) (Bruininks & Bruininks, 2005), and the Beery-Buktenica Test of Visual Motor Integration (VMI) (Beery, Buktenica, & Beery, 2010). Examples of tasks used to assess FMS include placing pegs in a pegboard, posting or transferring coins, threading beads, and using a pencil to copy, trace, or draw. The standardized scoring system is either calculated based on the performance on all the tasks, or a subset of tests that evaluate a specific component, such as visual perception or motor coordination.

Cohort studies have shown that performance on standardized tests of fine motor skills is associated with academic achievement (Cameron et al., 2012; Grissmer et al., 2010; Pagani et al., 2010; Roebers et al., 2014; Son & Meisels, 2006). For example, in a cohort of > 12,000 children tested at the beginning of kindergarten and the end of grade one, Son and Meisels (2006) found visual motor skills were modestly, but significantly associated with academic achievement in reading and math. Additional analysis conducted to determine whether motor assessment could identify children who are more likely to have academic difficulties, showed moderate sensitivity (0.75 reading, 0.78 math) and specificity (0.63 reading, 0.63 math). This suggests pre-school children who score lower on tests of FMS are more likely to perform below expected norms on reading and math tests in grade one. Additional evidence to support the association between FMS and academic performance can be found in cross-sectional studies (Fernandes et al., 2016; Kulp, 1999; Pitchford, Papini, Outhawite, & Gulliford, 2016; Sortor & Kulp, 2003). To summarize, studies that assessed the association between FMS and reading used standardized tests and the motor performance scores were derived based on several tasks. Using such tests is beneficial when the goal is to compare individual's performance to normative data; however, it is possible that not all individual tasks included in standardized test batteries are associated with reading. In other words, it is possible that the association of FMS with reading may be evident for a particular type of motor task, but not across all tasks, which could explain why not all studies report an association between FMS and reading (Barth et al., 2010; Robinson & Schwartz, 1973; Tramontana, Hooper, & Selzer, 1988).

Given that some studies found FMS scores to have a significant and unique contribution to academic achievement (Cameron et al., 2012; Roebers et al., 2014), it is important to understand the nature of this relationship. Binocular visual function refers to the ability to process and integrate images seen by each eye, which provides important sensory input for the performance of perceptual and motor tasks (Howard, 2012). The clinical assessment of binocular vision includes tests of sensory and motor fusion, such as stereoacuity (i.e., the ability to integrate slightly different images from each eye into a single percept), and vergence movements (i.e., disjunctive eye movements performed to fixate on objects at different distances). Because the vergence system is neurally coupled with the accommodative system, assessment of binocular vision also includes measures of accommodative amplitude and facility (i.e., the ability of the eyes to focus at different distances). Normal binocular vision is important for many school-related tasks. For example, copying information from the board requires vergence and accommodation to be maintained to ensure clear vision, as well as the ability to repetitively change fixation between near and far objects. Deficits in the vergence or accommodative system can result in a range of symptoms such as blurred vision, diplopia, headache, fatigue, eye strain (with near work), and difficulties with focusing from near to far or vice-versa (Garcia-Munoz, Carbonell-Bonete, & Cacho-Martinez, 2014). Therefore, poor binocular vision may have adverse effects on reading and FMS.

Literature has shown an association between binocular visual function and reading (Goldstand, Koslowe, & Parush, 2005; Koslowe, 1991; Kulp & Schmidt, 2002). A large cross-sectional study by Kulp and Schimidt examined visual predictors of reading performance in 5–7 year old children (n = 181), and found accommodative facility and stereoacuity were the best predictors of reading performance on a standardized achievement test in children without a diagnosed reading problem (Kulp & Schmidt, 1996). Similarly, Palomo-Alvarez and Puell (2010) found an association between accommodative facility and reading in a cohort of children identified as poor readers. Additional studies have also reported an association between vergence facility and reading in children with identified reading problems (Quaid & Simpson, 2012), and in children diagnosed with dyslexia (Buzzelli, 1991). While these studies support the association between binocular vision and reading, it is important to note that not all studies report this finding. For example, the study by Kedzia et al reported no association between accommodative facility and measures of academic success (including reading) in 8-year old children (Kedzia, Tondel, Pieczyrak, & Maples, 1999).

Studies have also reported an association between binocular visual function and performance of FMS. For example, poorer FMS have been found in some children and adults with abnormal binocular vision due amblyopia and strabismus (O'Connor et al., 2010a; Webber et al., 2008). On the other hand, Rafique and Northway (2015) reported significantly reduced accommodative facility in children with developmental coordination disorder in comparison to a control group. Importantly, results also showed a significant correlation between accommodative function and FMS, assessed using the BOTMP, as well as, FMS and standardized reading scores. To summarize, emerging research indicates that normal binocular vision provides important sensory input for optimal performance of visuomotor skills in children with neurodevelopmental disorders.