Human Movement Science 62 (2018) 48–57

Contents lists available at ScienceDirect

Human Movement Science

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

Effects of dual tasking and methylphenidate on gait in children with attention deficit hyperactivity disorder

Wenke Möhring*, Stephanie Klupp, Alexander Grob

University of Basel, Department of Psychology, Missionsstrasse 62, 4055 Basel, Switzerland

ARTICLE INFO

Keywords:
Attention deficit hyperactivity disorder
Methylphenidate
Gait
Dual tasking

ABSTRACT

Effects of dual tasking on motor processes such as gait have been mainly investigated with healthy adults and clinical older samples whereas studies with clinical samples of children with attention deficit hyperactivity disorder (ADHD) are rare. Similarly, even though methylphenidate (MPH) is the most often prescribed medication for children with ADHD, the influence of MPH on children's gait under single-task and dual-task situations remains poorly understood. In the current study, children diagnosed with ADHD ($n = 26$) came twice to the laboratory, once without and once with MPH medication. They were asked to walk over an electronic walkway without a concurrent task (motor single task) and while solving different cognitive tasks (motor-cognitive dual task). Gait variability and cognitive performance were measured. Children's performance was compared to an age- and sex-matched control sample of typically developing children ($n = 26$) who were also tested twice. Results indicated considerable effects of dual tasking on children's gait irrespective of group (ADHD vs. controls), with children diagnosed with ADHD showing more pronounced gait alterations in dual-task situations as compared to controls. Furthermore, MPH medication in children with ADHD enabled them to substantially decrease their stride time variability to a level that was comparable to the level of typically developing children. Overall, our findings support the notion that higher cognitive processes such as attention and executive functions influence gait and that MPH can positively affect cognitive and motor processes such as gait.

1. Introduction

Walking requires an effective integration of visual, vestibular, and proprioceptive information and is human's most important locomotion (Adolph & Berger, 2006; Adolph & Robinson, 2013). For a long time, it has been thought that gait is rather automatic and requires minimal cognitive resources until research has shown that higher cognitive processes play a crucial role in keeping postural control while walking (Woollacott & Shumway-Cook, 2002; Yogev-Seligmann, Hausdorff, & Giladi, 2008). These higher cognitive processes are more closely circumscribed by processes of attention and executive functions with executive functions being defined as top-down mental processes that are used when relying on automatic behavior, instinct, or intuition would be insufficient or impossible (Diamond, 2013). A typical way of assessing the influence of these cognitive processes on human's gait is to use dual-task paradigms (Plummer et al., 2013). In such a paradigm, people are asked to simultaneously walk while solving a cognitively challenging task. Depending on the type of the concurrent task, it has been shown that cognitive and/or motor performance suffers (Al-Yahya et al., 2011; Beurskens & Bock, 2012; Schaefer, 2014). These performance reductions or so-called dual-task costs emerge

* Corresponding author.
E-mail address: wenke.moehring@gmail.com (W. Möhring).

https://doi.org/10.1016/j.humov.2018.09.007
Received 14 July 2018; Received in revised form 10 September 2018; Accepted 11 September 2018

because the cognitive as well as the motor task require resources and the pool of cognitive resources is limited (Kahneman, 1973; Wickens, 1984).

The impact of dual tasking on walking has been mainly studied in older, healthy adults so far (Ruffieux, Keller, Lauber, & Taube, 2015) or in clinical adult samples. For example, studies investigating cognitive-motor dual tasking in older adults with Alzheimer's disease or Parkinson's disease have shown that patients slowed down and showed higher stride-to-stride variability in dual-task situations (Camicioli, Howieson, Lehman, & Kaye, 1997; Yogev et al., 2005). Importantly, such higher variability has been linked to a higher risk of falling (Lundin-Olsson, Nyberg, & Gustafson, 1997). As these patient groups are known to suffer from deficits in executive functions and attention, these results lend further support to the notion that these cognitive processes are crucial for controlling gait. Whereas developmental research investigating effects of dual tasking on children's gait is rare in general (Abbruzzese et al., 2014; Hagmann-von Arx, Manicolo, Lemola, & Grob, 2016), even fewer studies have been conducted with children who are also known to suffer from deficits in executive functions and attention such as children with attention deficit hyperactivity disorder (ADHD) (Gillberg, 2003). This lack of research is surprising considering that studies would a) provide a unique chance to investigate the development of this motor-cognition coupling and b) increase our understanding of how children with ADHD cope with dual-task situations and thus, situations that children are faced with repeatedly in their daily life.

ADHD is one of the most prevalent neuropsychiatric disorders in children and affects approximately 6–11% of the school age children (Willcutt, 2012). Prevalence rates vary with age and males are more often diagnosed than females (Kaiser, Schoemaker, Albaret, & Geuze, 2015). Children with ADHD suffer from three main core symptoms: impulsivity, hyperactivity, and inattention (American Psychiatric Association, 2013). Furthermore, they show severe deficits in executive functions (Gillberg, 2003; Steger et al., 2001; Wilding, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Whereas the cognitive deficits have often received far more attention, children with ADHD also show motor deficits (e.g., Adi-Japha et al., 2007; Schoemaker, Ketelaars, van Zonneveld, Minderaa, & Mulder, 2005; Tucha & Lange, 2001). Approximately 30–50% of the children diagnosed with ADHD suffer from developmental coordination disorder (DCD, Fliers et al., 2008; Kadesjo & Gillberg, 1998; Sergeant, Piek, & Oosterlaan, 2006). They have more difficulties with keeping the balance and with producing rapidly alternating or correctly timed movements (Diamond, 2000), and are more prone to hurt themselves when falling (Pastor & Reuben, 2006). With respect to children's normal walking, several studies indicated that children with ADHD showed higher variability than typically developing children, with major effects found for their gait timing (Leitner et al., 2007; Manicolo, Grob, Lemola, & Hagmann-von Arx, 2016; Papadopoulos, McGinley, Bradshaw, & Rinehart, 2014).

Studies investigating how dual tasking affects gait in children with ADHD are rare and revealed mixed findings so far (Leitner et al., 2007; Manicolo, Grob, & Hagmann-von Arx, 2017). In a study from Leitner and colleagues (2007), 16 children with ADHD were tested in a dual-task situation in which children were asked to simultaneously walk and listen to a story and count the appearance of a target word. It was found that children with ADHD increased gait regularity from single- to dual-task situations and thus, showed *increased* gait regularity in the dual task. This result is contrasted by findings of another study (Manicolo et al., 2017), in which 30 children with ADHD were tested in single- and dual-task situations. Using two dual tasks in which children had to either listen to and recall digits or fasten and unfasten a button, children with ADHD showed *decreased* gait regularity in these dual-task situations as compared to the single task. Therefore, the two studies conducted so far, showed either increases or decreases in children's gait regularity from single- to dual-task situations.

Whereas results from Manicolo et al. (2017) were in line with studies investigating gait in older adults (for a review, see Ruffieux et al., 2015) and children (e.g., Hagmann-von Arx et al., 2016), results from Leitner et al. (2007) were unexpected. Leitner and colleagues (2007, p. 1336) discuss the possibility that an external focus may have promoted the usage of more automatic control processes in children's walking (i.e., an "automatic pilot"), resulting in a reduction of "noise" in children's motor functioning. However, given that Manicolo and colleagues used tasks with an external focus as well (i.e., listening to digits), it remains unclear in which situations children would use such external cues or not and ultimately, why these opposing results exist.

Furthermore, given that children with ADHD show deficits in executive functions (e.g., Gillberg, 2003), one would expect that dual-task situations affect gait in children with ADHD to a greater extent as opposed to typically developing children. However, neither of these two previous studies revealed evidence for such a difference between typically developing children and children with ADHD (Leitner et al., 2007; Manicolo et al., 2017). Considering these non-existing findings, the present study aims to extend previous studies and clarify effects of dual tasking on gait in children with ADHD.

Another question that has rarely been investigated so far, are effects of medication on children's gait performance. The most often prescribed medication for children with ADHD is methylphenidate (MPH), which is a stimulant medication that increases attention and executive functions in children with ADHD (Epstein, et al., 2006; Sharma & Couture, 2014). MPH also improves some of the motor deficits outlined above (Kaiser et al., 2015). For example, research indicated beneficial effects on children's fine-motor abilities and balance skills after taking MPH (Brossard-Racine, Shevell, Snider, Belanger, & Majnemer, 2012; Stray, Stray, Iversen, Ruud, & Ellertsen, 2009). Even though the mechanisms for this improvement are not yet clarified, previous research proposes that MPH particularly improves the attentional components of movement planning (e.g., Flapper & Schoemaker, 2008) which in turn results in more controlled motor performance.

Studies investigating effects of MPH on children's gait are scarce with the only study so far being conducted by Leitner and colleagues (2007). The authors found that children showed significant improvements in their variability of gait timing in single-task walking but showed no effects in the dual-task situations after taking MPH. One reason why MPH did not affect children's dual-task performance may be that children unexpectedly improved gait regularity in the dual-task situations as compared to the single task. Furthermore, the sample was relatively small ($N = 16$), which could have attenuated the power of the study to detect significant effects.