Heightened Attention Demand of the Walking Cancellation Task and Its Relation to ADHD Tendency in Young Adults

Ryotaro Saito1,2, *, Yoshifumi Ikeda3, Hideyuki Okuzumi4 and Mitsuru Kokubun4

1 United Graduate School of Education, Tokyo Gakugei University, Japan
2 Department of Elementary Education, Ibaraki Christian University, Japan
3 Graduate School of Education, Joetsu University of Education, Japan
4 Faculty of Education, Tokyo Gakugei University, Japan

People with attention-deficit/hyperactivity disorder (ADHD) are reportedly more prone to injury, especially nonfatal injuries such as sprains and strains of joints and adjacent muscles. However, the reasons underlying the increased incidence of injuries remain unclear. This preliminary study was conducted to elucidate attention mechanisms under circumstances that demand both visual search and walking, and those mechanisms’ relation to ADHD tendency in young adults. For this study, 30 young adults performed a walking cancellation task (involving visual search and walking) and a pointing cancellation task (involving visual search). Each task had two conditions manipulated for difficulty in terms of the target-to-distractor (TD) ratio. Results showed that (a) cancelling efficiency of the walking cancellation task was lower, (b) cancelling efficiency with a smaller TD ratio was remarkably lower in the walking cancellation task, and (c) ADHD tendency was correlated with cancelling efficiency only in the more difficult condition of the walking cancellation task. These results suggest that a threshold exists for attention demand, beyond which performance deteriorates extraordinarily when engaging in visual searches while walking.

Key Words: attention, visual search, gait, neurodevelopmental disorder, fall risk

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by inattentiveness, hyperactivity, and impulsivity (APA, 2013). Aside from behavioral deficits, not a few children with ADHD reportedly also show clumsiness deriving from developmental delay of motor performance (Karatekin, Markiewicz, & Siegel, 2003). One earlier report describes a study of comorbidity with developmental coordination disorder (Sergeant, Piek, & Oosterlaan, 2006). Several reports have described mild, but not severe, postural and gait abnormalities in people with ADHD (Buderath, Gärtner, Frings, Christiansen, Schoch, Konczak, Gizewski, Hebebrand, & Timmann, 2009; Leitner, Barak, Giladi, Peretz, Eshel, Gruendlinger, & Hausdorff, 2007).

People with ADHD are reportedly more prone to injury than those without ADHD (Merrill, Lyon, Baker, & Gren, 2009; Pastor & Reuben, 2006). A study conducted by Merrill et al. (2009) showed that the most common injuries in people with ADHD were sprains and strains of joints and adjacent muscles, that is, nonfatal injuries. Pastor and Reuben (2006) clarified external causes of nonfatal injury episodes: nearly a third of injuries resulted from falls, and another third from being struck, with another 10–16% associated with transportation. Moreover, children with ADHD have injuries more often at home (exterior of the house) and at school, and less often at sports facilities (Pastor & Reuben, 2006). Consequently, people with ADHD show increased incidence of nonfatal injuries that take place in usual everyday settings.

* Corresponding Author
Mailing Address: 6–11–1 Omika, Hitachi, Ibaraki 319-1295, Japan
E-mail Address: saitor@icc.ac.jp
Received August 15, 2016, Accepted August 26, 2017
DOI: 10.6033/specialeducation.6.81
Reasons for the increased incidence of injuries among people with ADHD are not fully understood. People with ADHD might be less likely to anticipate harmful outcomes of certain behaviors as readily as people without ADHD, and might be less able to use prevention strategies and observe safety rules (Farmer & Peterson, 1995). Another possible reason is that people with ADHD are less likely to devote attention to hazards or body movements when they walk or run in everyday settings such as playgrounds, considering both their attention difficulties and postural/gait abnormalities. People with ADHD might allocate too much attention to body movements for hazards to be noticed or might devote too much attention to hazards that they lose control of their body movements. In fact, difficulties of attention allocation between cognitive and motor functions have been regarded as important risk factors related to falls (e.g., Woollacott & Shumway-Cook, 2002), which is a major reason for injuries to people with ADHD. Additional research is necessary to investigate whether people with ADHD have more problems of attention allocation between cognitive and motor functions.

Interaction between cognitive and motor functions is investigated typically in dual-task paradigms in which the two tasks can mutually compete (Woollacott & Shumway-Cook, 2002). Specifically, many studies have examined how postural control or gait affects the performance of concurrent cognitive tasks (Boonyong, Siu, van Donkelaar, Chou, & Woollacott, 2012; Dault, Geurts, Mulder, & Duyssens, 2001; Ikeda, Okuzumi, & Kokubun, 2014). Particularly, these studies examined the influence of postural control on different stances or support surfaces, the influence of gait properties, and the influence of cognitive tasks on different task loadings. Recently, attempts have been undertaken to develop innovative dual tasks to examine the relation between cognition and stepping accuracy, especially for detecting mild cognitive impairment in elderly people: the walking Stroop carpet (Perrochon, Kemoun, Watelain, & Berthoz, 2013), the Stroop walking task (Perrochon, Kemoun, Watelain, Dugué, & Berthoz, 2015), the walking trail-making test (Alexander, Ashton-Miller, Giordani, Guire, & Schultz, 2005; Perrochon & Kemoun, 2013), and the modified walking Corsi test (Perrochon, Kemoun, Dugué, & Berthoz, 2014). Similar attempts have also been undertaken for detecting fall risks: the multitarget stepping task (Yamada, Higuchi, Mori, Uemura, Nagai, Aoyama, & Ichihashi, 2012; Yamada, Higuchi, Nishiguchi, Yoshimura, Kajiwara, & Aoyama, 2013; Yamada, Higuchi, Tanaka, Nagai, Uemura, Aoyama, & Ichihashi, 2011), the Stroop stepping test (Schoene, Smith, Davies, Delbaere, & Lord, 2014), and the choice stepping reaction time test (Lord & Fitzpatrick, 2001). Adaptations of traditional neuropsychological tests to walking or stepping show greater power to predict mild cognitive impairments or fall risks than the original versions of neuropsychological tests.

The cancellation task, a visual search task, is commonly used to assess attention or planning in the field of neuropsychology. A paper-and-pencil version of this task requires subjects to place a mark, as quickly and accurately as possible, through each occurrence of a specific target displayed in an array of distractors on a sheet of paper (e.g., Nakajima, Ikeda, & Okuzumi, 2013; Saito, Ikeda, Okuzumi, Kobayashi, & Kokubun, 2015). Performance is usually measured as visual search patterns, number/position of errors, time to complete a task, and the performance score (efficiency of cancelling) measured by accuracy and time. Performance can be influenced by several factors: a stimulus material (e.g., letters vs. shapes), a stimulus array (random vs. orderly), and the target-to-distractor (TD) ratio (e.g., 10 targets and 40 distractors vs. 10 targets and 90 distractors). Reports have described lower accuracy and increased time as the proportion of distractors increased (Geldmacher, 1996; Huang & Wang, 2009; Nakajima et al., 2013). Although cancellation tasks have been used as sensitive measures for detecting patients with visual neglect (e.g., Weintraub & Mesulam, 1988), recent studies have used these tasks as an assessment of attention ability in people with developmental disabilities such as ADHD (Jones, Craver-Lemley, & Barrett, 2008; Sandson, Bachna, & Morin, 2000). Reportedly, young adults with ADHD produce more errors than control subjects (Jones et al., 2008). Considering that the cancellation task is a sensitive measure for detecting patients with visual neglect, and attention deficits in people with ADHD, an adaptation of the cancellation task to walking or stepping would make the task a more powerful measure for attention difficulties related to ADHD.

This preliminary study was conducted to investigate whether performance on a walking cancel-
lation task developed for this study is related to ADHD tendency, as indicated by the Japanese version of Conners Adult ADHD Scales-Self Report (CAARS-S), in young adults. Given that attention demand is an important factor in the interaction between cognition and movement (e.g., Woollacott & Shumway-Cook, 2002), this study manipulated task difficulty in the cancellation task as in a study by Geldmacher (1996), who used two TD ratio conditions: 1:4 (10 targets and 40 distractors) and 1:9 (10 targets and 90 distractors). Specifically, this study examined how adaptation of walking influences the cancelling efficiency in the cancellation task and whether the performance is correlated with ADHD tendency (CAARS-S).

Method

Participants

Participants were 30 right-handed university students (10 men, 20 women; mean age 22.43 years, SD=2.53 years, age range=19–31 years) who volunteered for the study after recruitment from a university in Tokyo, Japan. Participants self-reported that they were free of any physical illness, visual or motor problem, and perceptual or cognitive disorder. All participants showed visual acuity of more than 1.0 on a near visual acuity test performed at 30 cm distance.

Cancellation Task

A random array letter cancellation task was administered with two task difficulties and two task modes: a total of four conditions. For task difficulties, two conditions with different target-to-distractor ratios were used: the 1:4 ratio condition with 10 targets and 40 distractors and the 1:9 ratio condition with 10 targets and 90 distractors. For task modes, two tasks were used: the pointing cancellation task, for which each participant was required to select targets from a task sheet placed on a desk by pointing with index fingers while seated at the desk; and the walking cancellation task, for which each participant was required to select targets by stepping on them while walking through a task sheet placed on a walkway.

Across all conditions, targets were capital alphabet “I”; distractors were capital alphabet “L”. All targets and distractors were printed in black Arial font of different sizes: 24 points for the pointing cancellation task and 240 points for the walking cancellation task. The targets and distractors were arranged on a small white paper (portrait, 50×10 cm) for the pointing cancellation task and on a large white paper (portrait, 500×100 cm) for the walking cancellation task.

The targets and distractors were arranged on a task sheet in the following manner. First, a task sheet was divided into five large squares in the direction of travel. Second, each large square was divided to make 100 small squares in a grid pattern; each small square was 1×1 cm for the pointing cancellation task and 10×10 cm for the walking cancellation task. Third, the stimuli were arranged within the small squares so that each large square had 2 targets and 8 or 18 distractors. All stimuli were arranged so as not to be in mutually adjacent small squares. The targets were arranged left and right alternately in the direction of travel to avoid crossing fingers or feet. The distances between every two adjacent targets were 2.915–6.403 cm in the pointing cancellation task and 29.15–64.03 cm in the walking cancellation task.

To prevent participants from learning the patterns, each of the four conditions used a different task sheet: two task sheets for the 1:4 ratio condition and two task sheets for the 1:9 ratio condition (see Fig. 1). The means and standard deviations of distances between every two adjacent targets were comparable between the two task sheets: pointing, M=58.16 cm, SD=1.07 cm; walking, M=581.6 cm, SD=10.7 cm. Task sheets were allocated among participants randomly for each condition.

For the pointing cancellation task, participants were required to work upward from the lower (front) side of the task sheet (see the start line in Fig. 1), pointing only to targets as quickly and accurately as possible using index fingers alternately from the left hand. First, participants were instructed to be seated in a comfortable chair at the desk, on which the task sheet had been placed face down. Then, at the moment the experimenter turned the task sheet face up, participants had to put both hands to the start position at the lower (front) side of the task sheet and then start the task. The time to complete the task was measured in seconds using a stopwatch from the start as soon as a participant put a finger across the start line until the finger crossed the goal line.

For the walking cancellation task, participants were required to walk through the task sheet as quickly and accurately as possible by stepping only
on targets. They were instructed to step on all targets alternately with both feet, starting from the left foot. After participants received a description of the task while sitting in a chair, participants wore socks that the experimenter had prepared, standing and facing opposite to the direction of travel at the start position. Subsequently, the participants turned around at the start signal and began walking; the walking path stimuli were not visible before they began to walk. The time was measured in seconds using a stopwatch from the start as soon as the legs had swung beyond the start line until they crossed the goal line. Red tape was placed next to the task sheet marking the start and goal positions.

Across all conditions, each participant was instructed not to go back to correct mistakes. No time constraint was imposed. Numbers of errors, numbers of correct responses, and the time to complete the task were recorded. Items were counted as errors when a participant did not cancel a target (i.e., an omission error). Stepping on a distractor was not counted as an error. Additionally, performance scores (PS) were calculated using the formula shown below.

\[
PS = \frac{\text{number of correct responses}}{\text{number of total items}} \times \frac{\text{number of correct responses}}{\text{time to complete a task}}
\]

As shown above, PS is found by multiplying the correct response rate (accuracy) and the number of correct responses per unit of time (accuracy and speed). PS has been used frequently as an index of cancelling efficiency to evaluate both the accuracy and speed of the performance simultaneously (Geldmacher, 1996, 1998; Huang & Wang, 2009; Saito et al., 2015). Higher PSs signify a larger number of correct responses per unit of time. They reflect more efficient performance.

**ADHD Tendency (CAARS-S)**

The Japanese version of CAARS-S (Conners, Erhardt, & Sparrow, 1999; Nakamura, Someki, & Onishi, 2012) was used to assess ADHD tendencies of participants. This scale assesses ADHD symptoms in adults (18 years and older). Of its three forms (long, short, and screening), this study used the long
version, consisting of 66 items. Symptoms were rated using a 4-point Likert-style format: 0=Not at all, never; 1=Just a little, once in a while; 2=Pretty much, often; 3=Very much, very frequently. The raw score and T scores were calculated in four factor-derived subscales (inattention/memory problems, hyperactivity/restlessness, impulsivity/emotional lability, and problems with self-concept), three Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV™) ADHD subscales (DSM-IV inattentive symptoms, DSM-IV hyperactive-impulsive symptoms, and DSM-IV total ADHD symptoms), and two indexes (ADHD index and inconsistency index). T scores (M=50, SD=10) were calculated both by gender (male, female) and by age (18–29 yr, 30–39 yr, 40–49 yr, 50 yr or older). A higher T score indicates a stronger ADHD tendency. This study used T scores of the ADHD index, composed of 12 items, as a measure of ADHD tendency.

Procedure
Participants were tested individually in a well-lit, quiet room at a university. Participants underwent the cancellation task first. The order of the two tasks (pointing cancellation task and the walking cancellation task) was counterbalanced among participants. The order of the two conditions (1:4 condition, 1:9 condition) was randomized within the tasks. A video of the cancellation task performance was recorded. Subsequently, participants responded to the Japanese version of the CAARS-S. The session took no more than 20 min for each participant.

Statistical Analyses
To assess the time to complete a task and PS, a 2 (task difficulty; TD ratio of 1:4, TD ratio of 1:9)×2 (task mode; pointing, walking) two-way analysis of variance (ANOVA) was conducted. For the number of errors where the data were not normally distributed, no statistical analysis was conducted. The number of errors was reflected in PS. Moreover, Pearson product moment correlations were conducted between the time to complete a task in the cancellation task and ADHD index of the CAARS-S and between PS in the cancellation task and ADHD index of the CAARS-S. SPSS Statistics ver. 22.0 for Windows; IBM Corp. was used for statistical analyses.

Ethical Approval
Our experimental protocol was administered in accordance with the guidelines of the Declaration of Helsinki. It was approved by the institutional review board. Informed consent was obtained from all participants before the assessment session.

Results
Cancellation
Table 1 presents the numbers of participants who showed one or more errors in the respective conditions. Nine participants showed one or more errors in the 1:9 TD ratio condition for the walking cancellation task: six participants showed one error, two participants showed two errors, and one participant showed three errors. The last showed an error in the 1:4 TD ratio condition for the walking cancellation task. No participant showed any error in the pointing cancellation task, irrespective of the TD ratio.

Figure 2 presents means and standard deviations of the time to complete a task for each condition. For the time to complete a task, two-way ANOVA showed significant effects for task difficulty (F1,29=37.705, p<.001, partial η2=.565), for task mode (F1,29=18.312, p<.001, partial η2=.387), and for their interaction (F1,29=8.119, p<.01, partial η2=.219). The main effect of task difficulty revealed that the time to complete a task was longer in the 1:9 TD ratio condition than in the 1:4 TD ratio condition. The main effect of task mode showed that the time to complete a task was longer in the walking cancellation task than in the pointing cancellation task. The interaction effect between task difficulty and task mode showed that cancellation in the 1:9 TD ratio condition for the walking cancellation task demands more effort than the other condition.

Figure 3 presents means and standard deviations of PS for the respective conditions. For PS, two-way
ANOVA showed significant effects for task difficulty ($F_{1,29}=56.861, p<.001, \text{partial } \eta^2=.662$), for task mode ($F_{1,29}=23.772, p<.001, \text{partial } \eta^2=.450$), and for their interaction ($F_{1,29}=4.491, p<.05, \text{partial } \eta^2=.134$). The main effect of task difficulty showed that PS was lower in the 1:9 TD ratio condition than in the 1:4 TD ratio condition. The main effect of task mode showed that PS was lower in the walking cancellation task than in the pointing cancellation task. The interaction effect between task difficulty and task mode showed that cancellation in the 1:9 TD ratio condition for the walking cancellation task demands greater efforts than the others.

**Correlation Between Cancellation and ADHD Tendency**

Pearson product moment correlations were conducted between the performance (time to complete a task and PS) for respective conditions in the cancellation task and T scores of the ADHD index in the CAARS-S. Results showed significant correlation between the T score of the ADHD index and the performance in the 1:9 TD ratio for the walking cancellation task (Fig. 4; time to complete a task, $r=.491, p=.006, \text{PS}: r=-.406, p=.026$). No other performance in the cancellation task was correlated with the T score of the ADHD index: a 1:4 TD ratio for the walking cancellation task (time to complete a task, $r=.285, p=.127, \text{PS}: r=-.010, p=.958$), a 1:4 TD ratio for the pointing cancellation task (time to complete a task, $r=.258, p=.169, \text{PS}: r=-.042, p=.824$), and a 1:9 TD ratio for the pointing cancellation task (time to complete a task: $r=.199, p=.291, \text{PS}: r=-.027, p=.887$). These results show that participants who demonstrate higher ADHD tendency are inclined to show increased time to complete a task and lower PS in the 1:9 TD ratio for the walking cancellation task.
Discussion

This study investigated how adaptation of the cancelling task to walking would decrease cancelling efficiency and whether the performance would correlate with an ADHD tendency in young adults. Results revealed that (a) cancelling efficiency was lower for the 1:9 TD ratio condition than for the 1:4 TD ratio condition, (b) cancelling efficiency was lower in the walking cancellation task than in the pointing cancellation task, (c) decreases of cancelling efficiency with smaller TD ratio were remarkable in the walking cancellation task, and (d) ADHD tendency was correlated with cancelling efficiency only in the 1:9 TD ratio condition for the walking cancellation task.

This study developed the walking cancellation task in accordance to the pointing cancellation task, except for its response mode (pointing vs. walking). Results showed that no error was observed in the pointing cancellation task, which is inconsistent with results of the standard cancellation task (Geldmacher, 1998), which reported some participants with one or more errors (omissions). This inconsistency might be attributable to differences between the pointing cancellation task and the standard cancellation task. These tasks differ in the following three points. First, the pointing cancellation task requires pointing by fingers rather than placing marks with a pen. Second, participants in the pointing cancellation task were required to execute visual searches in an organized manner, i.e., in a bottom-to-top direction. Third, the pointing cancellation used a portrait task sheet, whereas the standard cancellation task used a landscape task sheet. Apparently, these differences made it easier to detect targets in the pointing cancellation task.

Adaptation of the cancellation task to walking presumably lowered the cancelling efficiency in the walking cancellation task. Indeed, results showed that cancelling efficiency was lower for the walking cancellation task than for the pointing cancellation task, irrespective of task difficulty. However, several possibilities remain in relation to this finding. On the one hand, the cancelling efficiency decreased probably because the walking cancellation task demanded attention allocation between visual search and postural control while walking (Woollacott & Shumway-Cook, 2002). On the other hand, it decreased probably because the walking cancellation task heightened attention demand for visual search as a result of enhanced distance between the participant’s eyes and the task sheets and/or movement of a participant’s gaze from place to place while walking through the task sheets. Although it remains unclear why the cancelling efficiency was lower in the walking cancellation task, it seems reasonable to say that adaptation of the cancellation task to walking heightened attention demand.

Manipulation of task difficulty enables us to examine the interaction between visual search and physical movement and/or postural control during gait. Results showed that cancelling efficiency was significantly lower in the 1:9 TD ratio condition than in the 1:4 TD ratio condition, irrespective of the task mode, supporting the idea that task difficulty can be manipulated in terms of the TD ratio (Geldmacher, 1996, 1998). In addition, results showed that the cancelling efficiency was lowest in the 1:9 TD ratio condition of the walking cancellation task. These results indicate that a threshold for attention demand exists, beyond which the performance deteriorates extraordinarily in a dual-task paradigm of visual search and walking.

This study demonstrated that ADHD tendency in young adults correlated with the performance in the 1:9 TD ratio condition in the walking cancellation task. Given their greater abnormalities related to visual search (Aliabadi, Borhani, Alizadeh, & Amiri, 2011; Jones et al., 2008) and postural/gait performance (Buderath et al., 2009; Leitner et al., 2007), people with higher ADHD tendency might devote more attention to visual search or walking than people with lower ADHD tendency. Therefore, it is plausible that participants with higher ADHD tendency have a lower threshold for attention demand, as described above and that their performance is therefore lower. The absence of correlation between ADHD tendency and three other conditions (other than the 1:9 TD ratio condition in the walking cancellation task) might be attributable to small attention demands in these conditions, partly evidenced by the small number of participants who showed one or more errors. There might have been such correlations if these conditions imposed greater attention demand burdens.

This study has some important limitations. First, this study did not manipulate task difficulty in terms of gait. Such manipulation would further elucidate
the attention mechanism for dual tasks of cognition and movement in people with ADHD. Second, no participant in the study had received a diagnosis of ADHD. Therefore, for better elucidation of these results, it will be necessary to make a comparison of performance with people who have been diagnosed as having ADHD.

In conclusion, this study demonstrated that attention demand was heightened in the cognitively high demanding condition of the walking cancellation task. Performance in that condition was found to be correlated with ADHD tendency in young adults. Future studies are expected to elucidate attention mechanisms in a dual-task paradigm of cognition and movement in ADHD and their relation to their increased incidence of injury.

References

Alexander, N. B., Ashton-Miller, J. A., Giordani, B., Guire, K., & Schultz, A. B. (2005) Age differences in timed accurate stepping with increasing cognitive and visual demand: A walking trail making test. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 60, 1558–1562.

Aliabadi, F., Borhani, K., Alizadeh, M., & Amiri, N. (2011) Visuospatial attention in ADHD children: Investigating the asymmetry. *Iranian Rehabilitation Journal*, 9, 19–21.

American Psychiatric Association (2013) *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Association, Washington, D.C.

Boonyong, S., Siu, K. C., van Donkelaar, P., Chou, L. S., & Woollacott, M. H. (2012) Development of postural control during gait in typically developing children: The effects of dual-task conditions. *Gait & Posture*, 35, 428–434.

Buderath, P., Gärtner, K., Frings, M., Christiansen, H., Schoch, B., Konczak, J., Gizewski, E. R., Hebebrand, J., & Timmann, D. (2009) Postural and gait performance in children with attention deficit/hyperactivity disorder. *Gait & Posture*, 29, 249–254.

Connors, C. K., Erhardt, D., & Sparrow, E. (1999) *Connors’ adult ADHD rating scales (CAARS) technical manual*. Multi-Health Systems, North Tonawanda, New York. (Nakamura, K., Someki, S., & Onishi, M. (Trans.) (2012) CAARS Japanese Version. Kanekoshobo, Tokyo. (in Japanese))

Dault, M. C., Geurts, A. C., Mulder, T. W., & Duyfens, J. (2001) Postural control and cognitive task performance in healthy participants while balancing on different support-surface configurations. *Gait & Posture*, 14, 248–255.

Farmer, J. E. & Peterson, L. (1995) Injury risk factors in children with attention deficit hyperactivity disorder. *Health Psychology*, 14, 325–332.

Geldmacher, D. S. (1996) Effects of stimulus number and target-to-distractor ratio on the performance of random array letter cancellation tasks. *Brain and Cognition*, 32, 405–415.

Geldmacher, D. S. (1998) Stimulus characteristics determine processing approach on random array letter-cancellation tasks. *Brain and Cognition*, 36, 346–354.

Huang, H. C. & Wang, T. Y. (2009) Stimulus effects on cancellation task performance in children with and without dyslexia. *Behavior Research Methods*, 41, 539–545.

Ikeda, Y., Okuzumi, H., & Kokubun, M. (2014) Dual task performance of the Stroop color-word test and stepping in place. *Motor Control*, 18, 76–87.

Jones, K. E., Craver-Lemley, C., & Barrett, A. M. (2008) Asymmetrical visual-spatial attention in college students diagnosed with ADD/ADHD. *Cognitive and Behavioral Neurology*, 21, 176–178.

Karatekin, C., Markiewicz, S. W., & Siegel, M. A. (2003) A preliminary study of motor problems in children with attention-deficit/hyperactivity disorder. *Perceptual and Motor Skills*, 97(3 suppl), 1267–1280.

Leitner, Y., Barak, R., Giladi, N., Peretz, C., Eshel, R., Gruendlinger, L., & Hausdorff, J. M. (2007) Gait in attention deficit hyperactivity disorder. *Journal of Neurology*, 254, 1330–1338.

Lord, S. R. & Fitzpatrick, R. C. (2001) Choice stepping reaction time a composite measure of falls risk in older people. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 56, M627–M632.

Merrill, R., Lyon, J., Baker, R., & Gren, L. (2009) Attention deficit hyperactivity disorder and increased risk of injury. *Advances in Medical Sciences*, 54, 20–26.

Nakajima, Y., Ikeda, Y., & Okuzumi, H. (2013) Target-to-distractor ratio effects on detection time in the orderly array shape cancellation task. *Psychological Reports*, 113, 353–361.

Pastor, P. N. & Reuben, C. A. (2006) Identified attention-deficit/hyperactivity disorder and medically attended, nonfatal injuries: US school-age children, 1997–2002. *Ambulatory Pediatrics*, 6, 38–44.

Perrochon, A. & Kemoun, G. (2013) The walking trail-making test is an early detection tool for mild cognitive impairment. *Clinical Interventions in Aging*, 9, 111–119.

Perrochon, A., Kemoun, G., Dugué, B., & Berthoz, A. (2014) Cognitive impairment assessment through visuospatial memory can be performed with a modified walking Corsi test using the ‘magic carpet’. *Dementia and Geriatric Cognitive Disorders. Extra*, 4, 1–13.

Perrochon, A., Kemoun, G., Watelain, E., & Berthoz, A. (2013) Walking Stroop carpet: An innovative dual-task concept for
detecting cognitive impairment. Clinical Interventions in Aging, 8, 317–328.
Perrochon, A., Kemoun, G., Watelain, E., Dugué, B., & Berthoz, A. (2015) The "Stroop walking task": An innovative dual-task for the early detection of executive function impairment. Neuropsychologie Clinique. Clinical Neurophysiology, 45, 181–190.
Saito, R., Ikeda, Y., Okuzumi, H., Kobayashi, I., & Kokubun, M. (2015) Effect of visual field constriction on visual search in orderly array and random array cancellation tasks. Psychology (Irvine, Calif.), 6, 1873–1878.
Sandson, T. A., Bachna, K. J., & Morin, M. D. (2000) Right hemisphere dysfunction in ADHD: Visual hemispatial inattention and clinical subtype. Journal of Learning Disabilities, 33, 83–90.
Schoene, D., Smith, S. T., Davies, T. A., Delbaere, K., & Lord, S. R. (2014) A Stroop stepping test (SST) using low-cost computer game technology discriminates between older fallers and non-fallers. Age and Ageing, 43, 285–289.
Sergeant, J. A., Piek, J. P., & Oosterlaan, J. (2006) ADHD and DCD: A relationship in need of research. Human Movement Science, 25, 76–89.
Weintraub, S. & Mesulam, M. M. (1988) Visual hemispatial inattention: Stimulus parameters and exploratory strategies. Journal of Neurology, Neurosurgery, and Psychiatry, 51, 1481–1488.
Woollacott, M. & Shumway-Cook, A. (2002) Attention and the control of posture and gait: A review of an emerging area of research. Gait & Posture, 16, 1–14.
Yamada, M., Higuchi, T., Mori, S., Uemura, K., Nagai, K., Aoyama, T., & Ichihashi, N. (2012) Maladaptive turning and gaze behavior induces impaired stepping on multiple footfall targets during gait in older individuals who are at high risk of falling. Archives of Gerontology and Geriatrics, 54, e102–e108.
Yamada, M., Higuchi, T., Nishiguchi, S., Yoshimura, K., Kajiwara, Y., & Aoyama, T. (2013) Multitarget stepping program in combination with a standardized multicomponent exercise program can prevent falls in community dwelling older adults: A randomized, controlled trial. Journal of the American Geriatrics Society, 61, 1669–1675.
Yamada, M., Higuchi, T., Tanaka, B., Nagai, K., Uemura, K., Aoyama, T., & Ichihashi, N. (2011) Measurements of stepping accuracy in a multitarget stepping task as a potential indicator of fall risk in elderly individuals. The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 66, 994–1000.