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Associations Between Decreased Attentional Resources and Hand Function in Young Adults

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Abstract

Hand function is important for many everyday motor tasks and is commonly assessed using finger tapping tasks and the Grooved Pegboard Test. Age-related declines in attentional processes are well documented; decreased attentional resources, examined by increasing cognitive load with different types of dual task paradigms, may impair hand function. Many everyday activities also require coordination between both hands (i.e., bimanual dexterity). However, few studies have examined the effects of dual task type on unilateral versus bimanual dexterity. Thus, the purpose of this study is to examine the association between attention and manual dexterity in unilateral and bimanual tasks in young adults. Twenty-three healthy, right-handed adults (19-39 years) performed a unilateral tapping task by tapping with the left index finger on a touchscreen as quickly as possible. Participants also performed a bimanual task by completing the Grooved Pegboard Test with the right hand while performing the tapping task with the left hand. Two common types of cognitive dual tasks (visuospatial and non-visuospatial) were performed during the bimanual task to examine the effects of decreased attentional resources and differential effects of dual task type on bimanual dexterity. This study found the average number of taps was significantly lesser during all bimanual conditions compared to the unilateral tapping task ($p < .001$) and during the bimanual task with non-visuospatial task versus bimanual task with visuospatial task ($p < .001$). Results demonstrate that non-visuospatial cognitive tasks impair bimanual hand function to a greater degree than visuospatial tasks, indicating that non-visuospatial tasks may be beneficial to include in assessments of hand function.

Introduction

Manual dexterity is important for many daily activities such as typing, writing, and cooking. However, manual dexterity decreases with age (Heintz & Keenan, 2018), and impairments in manual dexterity are associated with difficulties performing everyday tasks of hand function (Kobayashi-Cuya et al., 2018). Attention is critical for many voluntary, goal-directed hand tasks. Cognitive dual tasks are used to examine the effect of decreased attentional resources on motor performance by increasing cognitive load (Heintz Walters et al., 2021; Keenan et al., 2017). Dual tasks ask participants to perform two simultaneous tasks, similar to many everyday functions (e.g., holding a conversation while driving). Two types of cognitive dual tasks are commonly used: visuospatial tasks and non-visuospatial tasks (Menant et al., 2014). Visuospatial tasks, such as imagining a star moving around a set of boxes, assess an individual's ability to mentally identify and manipulate objects in space (Baddeley, 2012). Non-visuospatial tasks, such as mathematical addition, assess an individual's ability to retrieve information stored verbally (e.g., numbers, names) (Baddeley, 2012). Two types of cognitive dual tasks have been shown to differentially affect motor performance. For example, gait speed in older adults was significantly slower with the addition of a visuospatial task compared to a non-visuospatial task, demonstrating that visuospatial tasks impair gait to a greater degree (Menant et al., 2014).

Many everyday tasks of hand function require coordination between hands, increasing task complexity when compared to unilateral tasks (Otte & van Mier, 2006; Petrigna et al., 2020). However, most manual dexterity tests are unilateral (e.g., the Grooved Pegboard Test and the Box and Block Test). Bimanual assessments of manual dexterity may be important to evaluate changes in hand motor control. Previous research has examined the effects of cognitive dual task type on motor performance (Menant et al., 2014), although it is unclear how dual task type influences upper extremity function (e.g., the ability to write and grasp objects). Furthermore, few studies have examined differences in performance regarding unilateral versus bimanual dexterity in young and older adults (Otte & van Mier, 2006; Petrigna et al., 2020). Thus, the purpose of this study was to examine the association between attention and manual dexterity in unilateral and bimanual tasks in young adults. Participants completed commonly used assessments of manual dexterity under unilateral and bimanual conditions with the addition of visuospatial and non-visuospatial tasks. Based on previous findings (Otte & van Mier, 2006; Menant et al., 2014), we hypothesized two outcomes: 1) a greater tapping performance, indicated by a greater number of taps, on unilateral versus bimanual tasks, and 2) the visuospatial task would impair bimanual dexterity to a greater degree than the non-visuospatial task.

Methods

Twenty-three healthy young adults (age: 21.8 ± 4.0 years; range: 19-39 years; gender identity: 10 males, 13 females) participated in this study. Written informed consent was obtained as approved by the Institutional Review Board at Seattle University. All participants were right-handed as measured by the Edinburgh Handedness Inventory (Oldfield, 1971). Exclusion criteria included a self-report of neuromuscular disorders, functional deficiencies, pain in the upper extremities that limits function of the arms or hands (e.g., difficulty performing everyday tasks, such as opening a jar), previous diagnosis of a disorder that may limit normal movement of the hands, or current use of medication that alters neuromuscular function. Vision was assessed using Snellen's handheld eye chart (Hallowell, 2008). Participants were asked to abstain from caffeine 12 hours before testing (Lorist, 1995).

Tests of Manual Dexterity

Tapping tasks and the Grooved Pegboard Test (Lafayette Instrument Company, Lafayette, IN) are two common measures of hand function (Wang et al., 2011; Rickards et al., 2018). The tapping task was designed based on the Finger Tapping Test done previously (Ashendorf et al., 2009; Otte & van Mier, 2006). Specifically, participants tapped on an iPad touchscreen (Apple Inc., Cupertino, CA) with their left index finger in a consistent location as quickly as possible for 30 seconds. No target was presented, thus removing the need to use vision across both motor tasks during bimanual task conditions (Petrigna et al., 2020). The number of taps was quantified by Tap Tool (McMenzie, 2015). The Grooved Pegboard consists of a board with 25 grooved holes arranged in five rows and 25 grooved pegs. To insert the pegs into the holes, each peg must be rotated to match its groove with the groove of the hole. Based on standardized procedures, participants were instructed to insert pegs one at a time and as quickly as possible from left to right and top to bottom (Wang et al., 2011). Prior to testing, participants practiced the task by filling the top row (Petrigna et al., 2020; Wang et al., 2011).

Cognitive Task Conditions

The visuospatial task used was based on Brooks' spatial memory task (Brooks, 1967) and visuospatial tasks previously used by Sturnieks et al. (2008), Menant et al. (2014), Peterson & Keenan (2018), and Heintz Walters et al. (2021). The task involved visualizing a star moving around four boxes arranged in a square. The sequence began when the examiner said "Start," followed by a series of four randomized directions that signified the star's movement (i.e., up, down, left, right, diagonal). The sequence ended when the examiner said "Location?", to which the participant stated the final location of the star. Prior to testing, participants completed five practice trials while viewing an image of the grid, followed by practice trials without the image until three consecutive correct trials were performed. The non-visuospatial task, based on previous work by Menant et al. (2014), involved summing three single-digit numbers. The non-visuospatial task began when the examiner said “Start,” followed by a series of four single-digit numbers (e.g., 5, 3, 1). The sequence ended when the examiner said “Answer?”, to which the participant stated the sum of the three digits. Prior to testing, participants completed practice trials in which three consecutive, correct trials were required before proceeding.

Experimental Set-Up

Participants began with their hands resting on a table, shoulder-width apart. The iPad was placed in line with their left shoulder for each trial. For the unilateral condition, participants performed the tapping task as detailed previously. The average number of taps was calculated as the number of completed taps, divided by 30 seconds, averaged across two trials. The bimanual tasks consisted of the following conditions: 1) Grooved Pegboard + Tapping, 2) Grooved Pegboard + Tapping + Visuospatial task, and 3) Grooved Pegboard + Tapping + Non-visuospatial task. During bimanual task conditions, the Grooved Pegboard was placed in line with the participant’s right shoulder (Fig. 1). The bimanual task conditions began when the examiner said “Go.” Participants then simultaneously tapped as quickly as possible while completing the Grooved Pegboard Test. The trial concluded when the last peg was inserted into the Grooved Pegboard. During trials with cognitive task conditions (i.e., Grooved Pegboard + Tapping + Visuospatial task and Grooved Pegboard + Tapping + Non-visuospatial task), participants simultaneously tapped as quickly as possible, completed the Grooved Pegboard Test, and performed the cognitive task. Using a stopwatch, Grooved Pegboard Test completion time was recorded from the moment the experimenter said “Go,” to the moment the last peg was inserted into the Grooved Pegboard (Wang et al., 2011). Bimanual conditions were randomized, and two trials were performed for each condition. The average number of taps was calculated as the number of taps completed, divided by the Grooved Pegboard completion time, averaged across two trials for each condition.

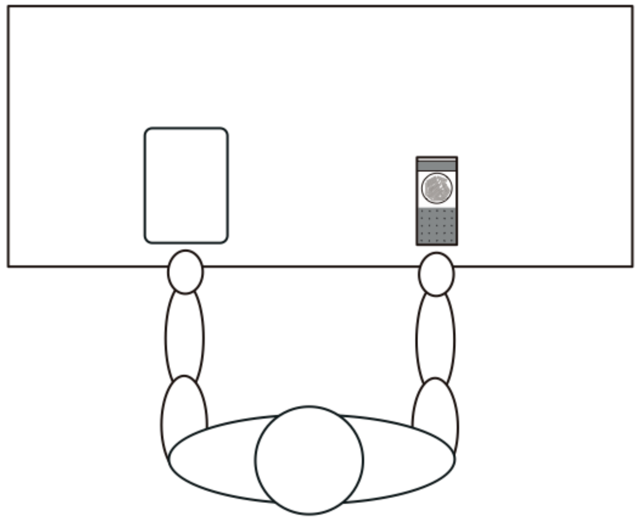

Figure 1. The experimental setup for the bimanual task. Participants sat with their fingertips rested on the edge of the table. The iPad was placed across from their left shoulder. The Grooved Pegboard was placed across from their right shoulder.

Statistical Analysis

A repeated measure ANOVA (Analysis of Variance) with statistical significance set at $p < 0.005$ was performed to examine differences in the average number of taps per second across conditions. All values are reported as mean ± SD in the text unless specified.

Results

The number of taps was significantly lower ($p < .001$) during all bimanual tasks, including Grooved Pegboard + Tapping (3.78 ± 0.90 taps/s), Grooved Pegboard + Tapping + Visuospatial task (3.77 ± 0.98 taps/s), and Grooved Pegboard + Tapping + Non-visuospatial task (2.44 ± 0.44 taps/s) compared to the unilateral tapping task (5.37 ± 0.68 taps/s) (Fig. 2). The average number of taps was significantly lower ($p < .001$) for the Grooved Pegboard + Tapping + Non-visuospatial task (2.44 ± 0.44) compared to the Grooved Pegboard + Tapping + Visuospatial task (3.77 ± 0.98) and Grooved Pegboard + Tapping (3.78 ± 0.90 taps/s). There was no significant difference ($p = 1.00$) in the number of taps for Grooved Pegboard + Tapping (3.77 ± 0.98 taps/s) versus Grooved Pegboard + Visuospatial task (3.78 ± 0.90 taps/s).

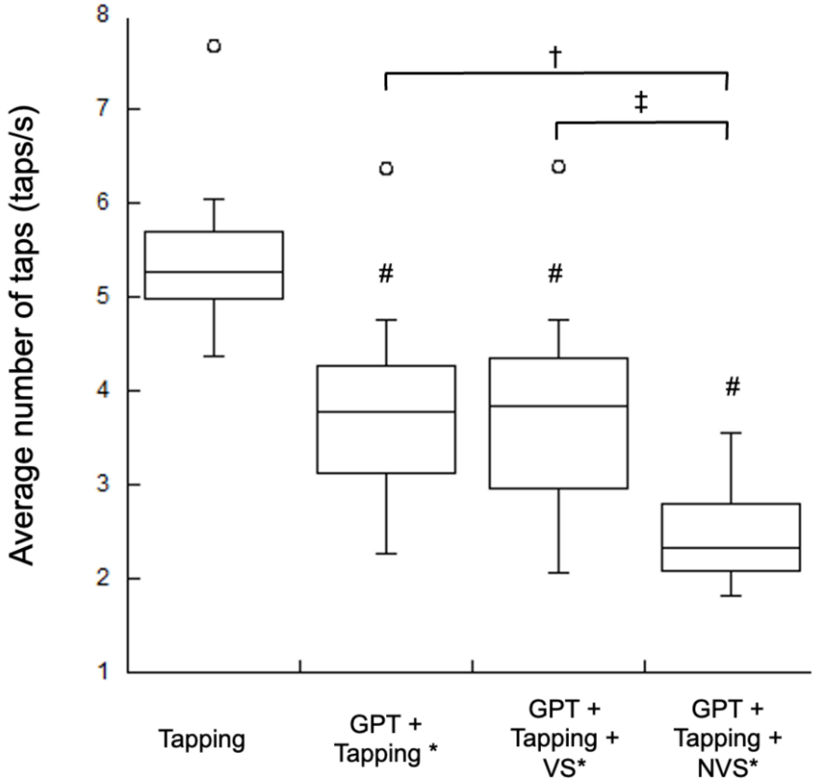

Figure 2. The average number of taps was significantly lesser for the unilateral task compared to all bimanual tasks (#$p < 0.001$). The average number of taps was significantly lesser for the GPT (Grooved Pegboard Test) + Tapping versus GPT + Tapping + NVS (non-visuospatial) (†$p < 0.001$) and the GPT + Tapping + VS (visuospatial) versus GPT + Tapping + NVS (‡$p < 0.001$). The graphed boxes indicate the first and third quartiles. The lines within the boxes indicate the median. The whiskers indicate the highest and lowest values, excluding the outliers. The circles indicate outliers. The asterisks indicate bimanual tasks.

Discussion

The purpose of this study was to examine the association between attention and manual dexterity in unilateral and bimanual tasks in young adults. The main findings of this study were differences in finger tapping performance in 1) unilateral versus bimanual task conditions and 2) visuospatial versus non-visuospatial task conditions. Compared to all bimanual tasks, hand motor performance was greater during the unilateral tapping task. Consistent with previous research (Otte van Mier, 2006), results demonstrate bimanual tasks impair hand function to a greater degree than unilateral tasks. This supports the idea that bimanual tasks demand greater access to limited attentional processes due to task interference between both hands (Schmidt & Lee, 2014). While many everyday activities require coordination between both hands, many tests of manual dexterity are unilateral. Thus, it may be important to include bimanual tasks in future assessments of hand function.

Finger tapping performance was impaired to a greater degree with the addition of a non-visuospatial task compared to a visuospatial task. Results contrast previous work that examined the effects of dual task type on gait performance in older adults, which found visuospatial tasks impaired older adults to a greater degree than non-visuospatial tasks (Menant et al., 2014). This suggests that the cognitive resources required for bimanual control differ from those required for locomotor control. Additionally, greater impairments in bimanual hand function with the addition of a non-visuospatial cognitive task compared to a visuospatial task have important implications for hand motor assessments. More specifically, non-visuospatial tasks may provide important insights into hand function important for everyday activities. Thus, an inclusion of non-visuospatial tasks may be beneficial in assessments of hand function by examining performance of a task of hand function (e.g. Grooved Pegboard Test, Tapping tasks, writing tasks) while performing a non-visuospatial task.

It is important to note the limitations of this study. The current study assessed bimanual dexterity using two common assessments of hand function. Unlike one's gait, hand movements do not follow a rhythmic pattern. Thus, a variety of approaches are used to assess hand function including the Box and Block Test and the Purdue Pegboard. As there is greater variance in hand movements, future studies could examine the effects of unilateral versus bimanual dexterity and the effects of dual task type using other assessments of hand function. Furthermore, attention is critical for many motor tasks of everyday function such as orienting an object, and attention is directly linked to eye movements (Heintz Walters et al., 2021). The current study examined the associations between attentional processes and manual dexterity using different types of cognitive dual tasks. However, simultaneous eye tracking recordings could further our understanding of how visual information is incorporated into hand motor control and changes in attentional processes. Deficits in attention and hand function are well-documented in older adults (Heintz Walters et al., 2021). Thus, future research could extend to the older adult population and examine the effects of dual task type on unilateral and bimanual dexterity in young versus older adults. Paired with finger and hand motion tracking and eye tracking, this could provide insight into age-related changes in hand function such as gross reaching and fine motor movement and attentional processes. Greater insight into hand movements may be applicable for developing interventions to improve hand function in older adults.

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