Enhancing Cognitive Function through Non-dominant Handwriting Tasks: A Potentially Promising Intervention for Alzheimer's Disease

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BRIEF. This study examines the impact of a short non-dominant handwriting tasks on immediate cognitive performance.

ABSTRACT. This research explores the immediate effects of a brief non-dominant handwriting task on cognitive performance, as measured by the Stroop test, in a sample of thirty-seven (37) cognitively healthy participants. Results indicate that participants who engaged in a non-dominant handwriting task showed statistically significant cognitive improvement compared to those using their dominant hand. Further analysis reveals intriguing nuances related to sports participation, age, biological sex, and video gaming. The findings provide valuable insights into potential interventions to mitigate cognitive decline in Alzheimer's Disease (AD) patients and offer avenues for further research in the intersection of hand dexterity and cognitive function.

INTRODUCTION.

An estimated 6.7 million Americans aged 65 or older are afflicted with Alzheimer's disease (AD), a form of dementia that is the most prevalent neurodegenerative condition [1]. This number is projected to rise as the population ages. AD is characterized by the accumulation of beta-amyloid and tau protein fragments, leading to synaptic dysfunction and synaptotoxicity, respectively [2]. A recent study found that individuals with AD exhibit decreased functional connectivity between their brain hemispheres, impacting memory in early-stage AD patients [3]. Such interhemispheric functional disconnections may accelerate neurodegeneration, exacerbating AD symptoms. Further, AD patients experience reduced interhemispheric homotopic functional connectivity and degeneration of the corpus callosum [4]. The corpus callosum serves as a channel that allows information to transfer between the two cerebral hemispheres. Older adults with mild cognitive impairment (MCI) who exhibit diminished interhemispheric connectivity tend to experience more pronounced motor impairments, including hand dexterity and bimanual coordination. This suggests a direct influence of interhemispheric connectivity in the corpus callosum on motor control [5].

There is limited research on how hand dexterity specifically impacts the cognition of AD patients. Evidence suggests mixed handedness is associated with greater interhemispheric interactions between the left hemisphere's encoding processes with the right hemisphere's retrieval processes [6]. This suggests that promoting mixed handedness, such as by completing a writing task with a non-dominant hand, may help mitigate memory deficits, including autobiographical recollection in AD patients.

As patients engage in activities that stimulate their hemispherical connections, particularly those involving hand dexterity, they are likely to experience greater interhemispheric interactions. Greater interhemispheric interactions could lead to improvements in their autobiographical recollection including sensory, perceptual, and emotions corresponding with their past. An example of this interplay can be observed in the Stroop tasks which assesses the ability to inhibit irrelevant word dimensions. This task assesses the interhemispheric connection as it requires the activation of the non-dominant hemisphere with the left hemisphere responsible for reading the words and the right hemisphere for processing colors [7]. While the direct correlation between intensity of handedness, interhemispheric interaction, and neurorehabilitation is well established [8], few studies have explored the immediate effects of short-term tasks on cognitive performance.

In this study, we explore how a brief ten-minute task performed with a non-dominant hand can impact cognitive function, as measured by the Stroop test. This neuropsychological test assesses the brain's ability to inhibit a habitual response in favor of an unusual one, thus testing cognitive function. We hypothesize that engaging in a short-term task using the non-dominant hand will lead to immediate enhancement in cognitive performance.

METHODS.

The study of 37 participants with typical cognitive function was conducted in August 2023, where they were asked to complete a Google survey of key demographic and behavioral information - sex, age, handedness, sports participation, and time spent gaming (Table 1) - and were asked to report the results of their Stroop tests (https://psycho-tests.com/test/stroop-test). The survey was emailed to a large group of participants representing a diverse age group and education level. Ambidextrous individuals were excluded from the study since they did not report a dominant hand. Participants were randomly assigned into one of the three groups: the control group, the dominant hand writing group, or the non-dominant hand writing group. The control group did not write, and instead waited for ten minutes; the dominant hand group copied a 458-character paragraph, writing it with their dominant writing hand; and the non-dominant hand group wrote the same paragraph with their non-dominant writing hand. After this stage was complete, all participants took the Stroop test for the second time to assess their improvement.

Stroop Test. Participants underwent two Stroop tests separated by a 458-character writing task, using either their dominant or non-

Table 1. Stroop Test Participant Profile (*N*=37)

		Control	Dominant Hand	Non-Dominant Hand
Biological Sex	Male	4	5	3
	Female	4	11	10
Age	0-24	5	6	4
	25-50	1	5	8
	51+	2	5	1
Handedness	Right	8	16	11
	Left	0	0	2
Sports Participation	Yes	6	11	8
	No	2	5	5
Weekly Gaming Hours	0-3	6	15	12
	4+	2	1	1

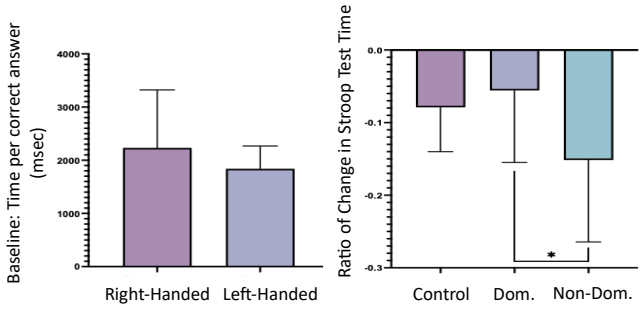

Figure 1. Handedness Stroop Test Results. On the baseline, there is not a statistically significant difference in time taken to answer each correct answer between the right-hand group and left-hand group; * $p > 0.05$, statistical analysis performed with t-test, post-hoc. On post-task performance, there is a statistically significant difference in response times between the dominant group and non-dominant group, but not the control group. The non-dominant group had a lower ratio of change compared with the dominant group; * $p > 0.05$, statistical analysis performed with ANOVA, post-hoc.

dominant hand, while a control group waited for 10 minutes. The initial Stroop test established a baseline, and the subsequent test indirectly measured cognitive change post-writing task. In the test, participants matched the color of the text to its corresponding button. They had 1 minute to answer as many questions as possible. After completing the test, key metrics were displayed including total responses, correct answers, errors, and average reaction time for a correct answer.

Analysis Methodology. To calculate the ratio of change in time taken per correct answer, we took the logarithm of the average milliseconds taken to answer each correct question of the second Stroop test divided by that of the initial Stroop test. Prism 10 Version 10.0.3 was used to analyze and create graphs for the data. Depending on the variable tested, either an ANOVA or a t-test was used to analyze the data. Additionally, all outliers were eliminated by an outlier test on Prism using ROUT at Q = 1%.

RESULTS.

Writing Handedness. While the dominant hand and the control groups exhibit a less than 5% difference in average time improvement, the non-dominant hand group improvement was double that of the dominant hand group (Figure 1). The lack of significance between the control and dominant groups confirmed that writing alone does not enhance cognition, while the significance between the dominant and non-dominant hand groups suggests that writing with the non-dominant hand improves performance. Additionally, normal writing preference had no discernible impact on initial Stroop performance indicating that handedness alone did not affect the Stroop task outcomes.

Sport Handedness. We did not find a statistical relationship between sport handedness and initial Stroop performance. However, the average time taken for each correct Stroop test answer by athletes who reported using both hands in sports was 1,634 msec, 28% faster than right-handed athletes (2,273 msec) and 26% faster than left-handed athletes (2,198 msec).

Biological Sex. We found that biological sex does not play a role in Stroop test performance prior to or following the writing task. For the initial test, while women took 12% longer on average to complete each question compared to men, the results were not statistically significant.

Age. Participants under the age of 24 exhibited statistically significant faster reaction time per correct answer in comparison to those 51 years old (Figure 2). However, the results showed no significant change in the improvement between the age groups.

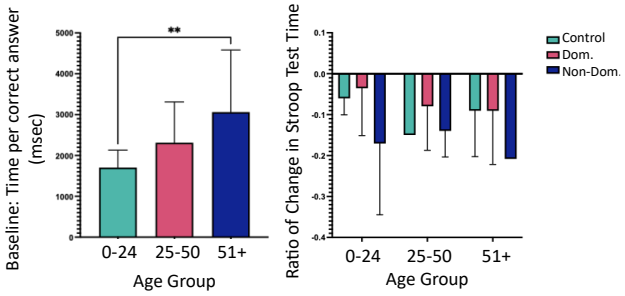

Figure 2. Age Group Stroop Test Results. On the baseline, there is a statistically significant difference in the average response times between the 0-24 group and 51+ group; * $p < 0.05$, statistical analysis performed with ANOVA, post-hoc. Post-task, though not statistically significant, there is a major difference in improvement between the non-dominant group and the dominant-handed group, but not the control group; * $p > 0.05$, statistical analysis performed with ANOVA, post-hoc.

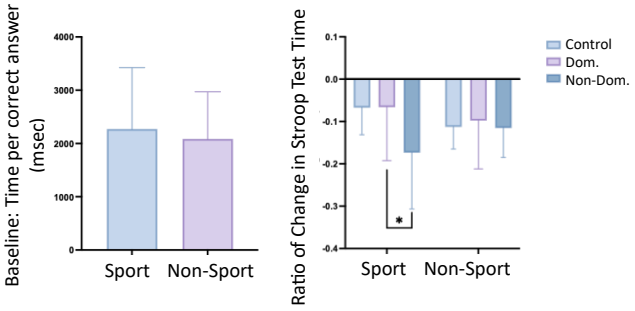

Figure 3. Sports Participation Test Results. The baseline did not demonstrate a statistical difference in performance between athletes and non-athletes. Post-task, the results demonstrated a statistically significant improvement for athletes between the non-dominant task group and dominant; * $p > 0.05$, statistical analysis performed with t-test, post-hoc.

Sports Participation. Our results revealed no statistically significant difference between athletes and non-athletes in the response times in either the initial Stroop test (Figure 3) or in the improvement after the writing task. However, we observed a notable distinction between the dominant and non-dominant handed groups among athletes. Specifically, there was a 17.4% decrease in time taken per correct answer for athletes who used their non-dominant hand in the task compared to a 6.6% decrease for dominant-hand athletes.

Video Gaming. Our study demonstrated that there was no significant difference between gamers (4+ hours) and non-gamers (0-3 hours) in their average time per correct question during the initial and final Stroop test, and their improvement after the task. However, there was a notable difference between gamers and non-gamers in their accuracy during the test (data not shown). Gamers had significantly higher errors than non-gamers in their initial Stroop test (data not shown).

DISCUSSION.

Writing Handedness. We observed statistically significant enhancement in cognitive function among participants who performed the writing task with their non-dominant hand as opposed to those who used their dominant hand. This suggests a potential link between using a non-dominant hand during a task and cognitive improvement. Since AD causes a decline in cognitive performance, this task may improve cognitive performance of those with AD. Importantly, the negligible disparity between the dominant and control groups implies that the act of writing itself did not influence cognition; rather, it was the engagement of the non-dominant hand that emerged as the key factor affecting cognitive outcomes.

Sport Handedness. Our results align with existing research [7] highlighting that mixed- handedness correlates with enhanced episodic memory, a facet significantly impacted by AD [9]. Given that AD prominently affects episodic memory, the promotion of mixed handedness through activities such as non-dominant handwriting tasks holds promise in enhancing this cognitive domain. This insight on mixed handedness may suggest potential benefits for AD patients, underscoring the importance of exploring mixed-handedness interventions to ameliorate episodic memory. However, this hypothesis has not been supported by experimental data on participants with AD, so further research is necessary explore the benefits of mixed-handed interventions on cognition.

Biological Sex. Contrary to our findings, a prior study suggested that women might exhibit an advantage in the Stroop test due to their enhanced inhibition behavior, rooted in the hunter-gatherer theory [10]. This theory posits that women, historically gatherers, developed superior spatial memory skills [10]. However, our study showed no significant correlation between biological sex and cognitive improvement, aligning with a contrasting study [11] that failed to support the inhibition hypothesis. This study emphasized the role of women's superior verbal abilities as the source of advantage, which may not be as relevant in tasks not demanding verbal skills such as our Stroop Test. Our Stroop Test could not be administered verbally, as is typically done, due to limitations in meeting every participant in-person.

Age. Age significantly impacts AD prevalence, doubling every 5 years after age 65 [12]. Aging induces cortical synapse changes, affecting working memory and executive functioning [13]. It also impacts the hippocampus, crucial for learning and memory, involving increased oxidative stress, neuroinflammation, and reduced neurogenesis and synaptic plasticity [14]. In our study, participants aged 51 and above were 79% slower than their younger counterparts in Stroop test responses. This aligns with research indicating decreased Stroop test responsivity with age, attributed to cognitive changes, particularly decreased response inhibition, rather than simple cognitive slowing [15] [16]. Response inhibition, evaluated through the Stroop test, involves suppressing a dominant behavior in response to stimuli. Therefore, our results indicate that participants above the age of 50 have reduced response inhibition in comparison to younger participants. However, the specific range of which response inhibition deteriorates cannot be determined from this study as our limited number of participants prevented us from sorting participants into more specific age groups.

While inhibitory control post-task between age groups was not statistically significant, all age groups showed larger improvement after the non-dominant hand tasks. With this, we conclude that regardless of age, the writing task involving the non-dominant hand may enhance reaction times and cognitive function.

Although not significant compared to those of other age groups, an illustrative example of this substantial improvement is our eldest participant, a 78-year-old improving cognitive performance by 110%, reducing response time from 6,000 to 2,857 msec. Future studies should be conducted with a larger sample size of older participants, and include those who are cognitively healthy as well as those with AD to assess the extent to which a non-dominant hand writing tasks can improve cognition in those experiencing cognitive decline.

Sport Participation. Prior studies advocate for cognitive benefits from sports and exercise training [17]. Surprisingly, the initial Stroop test showed no significant difference between athletes and non-athletes, challenging previous evidence on exercise activating the left dorsolateral pre-frontal cortex and enhancing the Stroop results [18]. A limiting factor was our survey questions' lack of specificity regarding the frequency and intensity of sports participation, possibly explaining the deviation from expected results, especially considering the impact of inhibitory function [19].

Within experimental groups, athletes showed a significant reduction in response times, suggesting enhanced performance. Notably, non-dominant hand tasked athletes showed statistically significant improvement in response times, demonstrating the activation enabled by the task. However, the insignificant improvement between the non-athletes in the dominant and non-dominant group, but the notable change for athletes indicates that their participation in the sport may indeed influence their cognitive performance.

Our findings highlight a significant Stroop test improvement for individuals using their right hand in sports compared to those using both hands for sports only, who exhibited an average decline. This discrepancy likely arises from the nuanced skill acquisition, as strongly right-handed individuals mastered the task to a greater extent. Consequently, the connections between hemispheres may not have increased as prominently for those participating in a sport with both hands, especially considering their initial 51.7% higher score.

The inclusion of non-active participants reporting theoretical sports engagement might have skewed the results, impacting data interpretation. Age may also contribute, as brain lateralization's association with cognition varies with age [20].

Video Gaming. Our findings echo a prior study on gamers' Stroop test performance. While no distinct cognitive inhibition difference was observed, gamers prioritized speed over accuracy [21], indicating enhanced processing speed and task-switching abilities. Internet Gaming Disorder (IGD) correlates with diminished inhibitory control and impulsive decision-making [22], contributing to the speed-accuracy trade-off in our results. Contrary to expectations, gamers did not show a statistically significant speed increase, despite answering five more questions on average. However, we should acknowledge the limitation of including only 13.5% of participants engaging in video games for over 3 hours weekly.

CONCLUSION.

This research demonstrated a statistically significant immediate benefit of a brief non-dominant handwriting task on cognitive performance, specifically inhibition response as assessed by the Stroop test. As AD patients have trouble suppressing this automatic inhibition response when reading, and show worsened performance in Stroop tests [15], the findings suggest that engaging the non-dominant hemisphere through such a task holds significant potential for enhancing cognitive function with AD patients. The observed improvement in cognitive function among participants using their non-dominant hand, compared to those using their dominant hand, underscores the importance of interhemispheric interactions, particularly in the context of hand dexterity. As interhemispheric interactions decline in patients with AD, the use of non-dominant hand writing tasks suggest potential interventions aimed at mitigating cognitive decline in AD patients. The exploration of factors such as sports participation, age, biological sex, and video gaming adds depth to the understanding of the context-dependent nature of the benefits associated with non-dominant hemisphere activation.

To bolster the validity of our findings and address potential limitations, it is recommended to replicate this study on a larger scale. This approach would increase the sample size and allow for a more diverse participant pool. The relatively small data pool limited our ability to separate participants into more specific age groups and analyze trends focused on older age groups. Additionally, we did not include participants with AD in the study so we cannot confirm that completing a non-dominant hand writing task will improve cognition in people already experiencing cognitive decline. Further studies will need to be conducted to validate this hypothesis. Acknowledging possible sources of error, such as human error in data entry and vague survey questions, is crucial for accurate data collection and interpretation. For

instance, the question regarding sports involvement lacks specificity and does not consider the intensity of engagement.

Future research should explore the application of the non-dominant handwriting task in individuals with AD to assess its efficacy in cognitive improvement amid cognitive decline. Examining the long-term effects of non-dominant hemisphere activation on AD symptoms is essential. Additionally, investigating variables like task duration and consistency in completion would enhance intervention optimization.

Comprehensive cognitive assessments, including the Montreal Cognitive Assessment (MoCA) and Mini-Mental State Exam (MMSE), should complement tests like the Stroop test. This multifaceted approach would provide a more nuanced understanding of the non-dominant handwriting task's broader impact on cognitive function in individuals with AD.

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