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Abstract

Background: Finger tapping tasks, which assess fine motor control, have emerged as potential digital biomarkers of cognitive function. With the widespread availability of smartphones, these tasks can be readily administered at home and other non-clinical settings. However, the relationship between smartphone-derived finger tapping metrics and cognitive performance remains underexplored.

Objective: This study aimed to examine the association between smartphone digital finger tapping features and cognitive performance in an aging population.

Methods: Participants were enrolled in the study as part of the electronic Framingham Heart Study (eFHS). They were instructed to perform a two-finger tapping task every two months over a one-year period. Each session lasted 20 seconds: participants alternated tapping with two fingers of the left hand for 10 seconds, followed by the right hand for 10 seconds. Cognitive performance was assessed using a standardized neuropsychological battery, evaluating global cognition and four domains: memory, executive function, language, and visuospatial function. Eighteen tapping features were extracted to capture aspects of motor performance, including the mean, median, standard deviation (SD), skewness, and slope of the inter-tap interval (ITI). Associations between tapping-derived features and cognitive outcomes were assessed using linear mixed-effects models, adjusting for age, sex, handedness, education, cohort, and the time interval between cognitive and tapping assessments.

Results: A total of 302 participants (mean age = 74.7 years; 56.0% women, 13.2% non-White) with cognitive performance data completed the digital finger tapping tasks. Thirteen tapping features were significantly associated with global cognitive function (all $P < .001$). Each one SD increase in the number of taps was associated with a 0.14-unit higher global cognitive function score (? = 0.14, 95% CI: 0.07, 0.21). Furthermore, finger tapping features were significantly associated with multiple cognitive domains, with the greatest number of associations observed for executive function (13 significant features), including a strong association with mean ITI (? = –0.27; 95% CI: –0.33, –0.20). Stratified analyses by hand showed consistent effect directions across both hands. The aggregated composite scores derived from finger tapping features demonstrated significant associations with their respective cognitive test scores with correlation coefficient ranging from 0.30 for memory to 0.55 for executive function.

Conclusions: Digital finger tapping features, particularly those reflecting ITI variability, are significantly associated with cognitive performance. These findings suggest that tapping tasks may serve as non-invasive, scalable tools for detecting cognitive decline, especially in domains of global cognition and executive function. Further research is warranted to validate their utility for early detection and longitudinal monitoring of cognitive health in aging populations.

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Abstract

Background: Finger tapping tasks, which assess fine motor control, have emerged as potential digital biomarkers of cognitive function. With the widespread availability of smartphones, these tasks can be readily administered at home and other non-clinical settings. However, the relationship between smartphone-derived finger tapping metrics and cognitive performance remains underexplored.

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Conclusion: Digital finger tapping features, particularly those reflecting ITI variability, are significantly associated with cognitive performance. These findings suggest that tapping tasks may serve as non-invasive, scalable tools for detecting cognitive decline, especially in domains of global cognition and executive function. Further research is warranted to validate their utility for early detection and longitudinal monitoring of cognitive health in aging populations.

Keywords: Finger tapping test, Smartphone, Digital features, Cognitive performance

Introduction

Motor performance has emerged as a promising indicator of cognitive aging, with growing evidence suggesting its potential utility as an early marker of cognitive decline[1]. While gait-related metrics have been extensively explored and consistently associated with impairments in memory, executive function, and visuospatial function [2, 3], there is increasing recognition of the need to broaden the scope of motor biomarkers to include upper limb function. Recent studies have shown that abnormalities in upper limb motor function—such as reduced movement speed and irregular rhythm—may serve as early indicators of neurodegenerative changes, and have been linked to conditions including mild cognitive impairment (MCI) and dementia[4-6].

Among upper limb assessments, the finger tapping test (FTT) is particularly noteworthy as a simple yet effective measure of psychomotor speed, motor coordination, and central nervous system integrity [4, 7]. Historically, the FTT was administered using a telegraph key device[8], though later adaption employed tools such as a computer mouse [9] and keyboard[10]. More recently, the widespread availability of smartphones has enabled the FTT to be conducted using touchscreen interfaces, offering a scalable, low-cost, and real-time solution for assessing fine motor function outside of traditional clinical environments[11, 12]. The ubiquity of smartphones also makes them ideal tools for population-level digital phenotyping, facilitating at-home assessments that are more convenient and accessible to diverse and underserved populations. Importantly, digital platforms allow for the collection of high-resolution temporal data, enabling extraction of a broad range of tapping-derived features that may enhance the detection of subtle motor abnormalities indicative of early neurodegenerative processes.

While neuropsychological (NP) testing remains the gold standard for assessing domain-specific cognitive performance, including memory, executive function, and language [13], integrating high-resolution digital motor measures may offer complementary insights into brain-behavior relationships. Understanding how fine motor measures, particularly those derived from widely accessible technologies, relate to cognitive performance could enhance early detection strategies for cognitive impairment and inform the development of novel, scalable digital biomarkers. Bridging the gap between accessible, real-world digital tools and rigorous neuropsychological assessment represents a critical step towards precision early detection in cognitive aging.

In this study, we examined the association between smartphone-based finger tapping performance and NP test outcomes across multiple cognitive domains in participants from the Framingham Heart Study (FHS), a well-characterized, multigenerational cohort. We hypothesized that lower tapping performance, as measured by digital tapping-derived metrics, would be significantly associated with poorer cognitive functioning. These findings may offer further support for the use of digital motor assessments as early, scalable biomarkers for cognitive decline.

Methods

Study Population

This study included Offspring and Omni 1 cohort participants from the FHS, a longitudinal and multi-generational cohort study initiated in 1948[14-16]. Offspring participants were enrolled from 1971 to 1975 (n=5124), and the multi-ethnic Omni 1 participants were enrolled from 1994-1998 (n=506) to reflect the increasing diversity of the city of Framingham, MA. Both cohorts were examined in the FHS research center every 4 to 8 years using the same protocols. Eligible participants were invited to enroll in the electronic FHS (eFHS) at the time of the last research exam (Offspring examination 10 and Omni 1 examination 5, 2019-2022). English-speaking participants who owned a smartphone (iPhone with iOS 10 or higher, or Android version 7 or higher) were invited to download the MyDataHelps app, which included a number of surveys and tasks. A research assistant assisted participants with app download in the research center and provided written instructions if participants preferred to download the app at home. Further details of the eFHS protocol have been previously described[17]. A total of 620 participants enrolled in the eFHS study. Of these, 9 participants who enrolled using a computer and 133 participants who enrolled using an Android device were excluded, as the two-finger tapping test was only available on the iPhone platform. Among the remaining participants, 445 completed at least one two-finger tapping test. For the present analysis, we further restricted the sample to individuals who had completed at least one two-finger tapping assessment and at least one neuropsychological (NP) assessment within a five-year window. This additional criterion yielded a final analytic sample of 302 participants. Participants provided electronic consent within the eFHS mobile application and gave written consent for the parent FHS at each in-person exam visit and NP testing session. **Figure 1** presents the graphical abstract of this study.

To characterize the general health and clinical status of participants, several measures were utilized. Cognitive status was adjudicated using a standardized diagnostic protocol. Diagnoses of dementia and MCI were determined by a review committee comprising at least one neurologist and one neuropsychologist[18]. Dementia diagnoses followed the criteria outlined in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) [19]. MCI was defined as cognitive decline in one or more domains without evidence of functional impairment or meeting criteria for dementia [20]. Additional clinical data included Mini-Mental State Examination (MMSE) scores, which were used as a general indicator of global cognitive function. Further details regarding the FHS diagnostic procedures have been described in a prior study [21]. The presence of Parkinson’s disease (PD) was determined by triangulating information from three sources: (1) participant self-report to the question “Have you been told by a doctor you have PD?”; (2) responses collected during examiner-led health history interviews; and (3) responses to the question “For what medical conditions do you use cannabis?” with PD listed as an option. Self-rated health was assessed using a question from the self-administered Short Form-12 (SF-12) Health Survey, which asked participants to rate their overall health on a four-point scale ranging from “poor” to “excellent”[22].

Ethical considerations

This research received ethical approval from the Institutional Review Board of Boston University Medical Center (Protocol number: H-32132). Participants provided electronic consent within the eFHS mobile application and gave written consent for the parent FHS at each in-person exam visit and NP testing session. The original informed consent and IRB approval allowed for secondary analysis of the data without requiring additional participant consent. All data analyzed in this study were de-identified, and no financial compensation was provided to participants.

Two-finger Tapping Test and Feature Extraction

As part of the eFHS Offspring and Omni 1 protocol, participants were sent the two-finger tapping test at enrollment and then every two months over the course of one year. The Two-Finger Tap task informed participants that the task measured tapping speed and instructed participants to put their phone on a flat surface to use two fingers to alternately tap the buttons on the screen while trying to time the taps to be as even as possible (**Supplemental Figure 1, screenshot of task**). Each test session lasted 20 seconds, during which participants alternated tapping on designated areas of the smartphone screen with two fingers of the left hand for 10 seconds, followed by two fingers of the right hand for 10 seconds, as quickly and consistently as possible. A few examples of finger tapping results are shown in **Supplemental Figure 2**. A comprehensive set of features was extracted from the inter-tap interval (ITI) data to capture various aspects of motor performance:

- **Basic temporal features** included the total number of taps per session (an indicator of effort and endurance), mean and median ITI (central tendency), and standard deviation (SD) of ITI (temporal variability). The coefficient of variation (CV) of ITI—SD divided by the mean—was calculated to normalize for overall tapping speed.
- **Asymmetry and coordination features** included the alternating tap ratio (proportion of left-right alternating taps), mean and SD of tap times for each hand, and the finger dominance ratio (difference in total taps between hands). Skewness and kurtosis of the ITI distribution were also calculated to identify irregular tapping patterns.
- **Speed and consistency metrics** included taps per second and ITI range (maximum minus minimum ITI), reflecting performance stability.

- **Fatigue and temporal drift** were assessed using the ITI slope (trend in ITI over time) and the last-to-first ITI ratio, indicating changes in tapping speed across the session.
- **Micro-fluctuation features** included the Micro-Fluctuation Index, defined as the standard deviation of successive ITI differences, to detect subtle neuromotor instability.

Neuropsychological (NP) Assessment

The methodology for administering NP tests in FHS has been previously described[23]. Cognitive testing was first introduced in 1976 through brief cognitive screenings and expanded to a more comprehensive NP battery beginning in 1999[13, 24]. In the present study, we utilized 21 commonly administered NP tests to evaluate cognitive function across four domains (**Supplemental Table 1**) [25]. To address missing values of NP tests, we employed multiple imputation by chained equations (MICE) [26]. Distributions of the Hooper Visual Organization Test (HVOT), Trail Making Test Part A (Trails A), and Part B (Trails B) were normalized using natural logarithmic transformation. To aid interpretation, the transformed scores were directionally adjusted so that higher values reflected better cognitive performance. All NP test scores were subsequently standardized to z-scores (mean = 0, SD = 1). These NP test scores were then summarized into four cognitive domains by averaging z-scores of NP tests within each domain: memory, executive function, language, and visuospatial function. A global cognitive score was further derived based on the mean values of all four cognitive domain scores.

Statistical Analyses

Linear regression models were used to assess the associations between finger tapping performance and cognitive domain scores. For each participant, the mean value of each finger tapping feature across all available trials was calculated and used as the independent variable. Global cognitive function served as the primary dependent variable. All finger tapping features were standardized to z-scores to enable comparability across metrics. Models were adjusted for age at the time of the tapping assessment, sex, education, cohort (Offspring or Omni 1), handedness, and the time interval (in years) between the NP assessment and the baseline tapping test. As secondary analyses, we further explored associations with four specific cognitive domains: memory, executive function, language, and visuospatial function.

To further characterize hand-specific relationships, we performed stratified analyses for right- and left-hand tapping data. Sensitivity analyses were also conducted within the subset of participants identified as right-handed to reduce heterogeneity due to hand preference. Within this group, we re-assessed the associations between each finger tapping metric and cognitive domain scores, additionally stratifying by the hand used during the tapping assessment (right vs. left). Bonferroni adjustment was used to correct for multiple testing, and a significance threshold was determined with $P < 0.05/N$, where N=18 with the total number of finger tapping features.

We further applied the Least Absolute Shrinkage and Selection Operator (LASSO) regression to derive a composite score for global cognitive function based on finger tapping features. A 5-fold cross-validation procedure was used to identify the optimal regularization parameter, allowing for variable selection by retaining only features with non-zero coefficients. The final composite score was computed as a weighted linear combination of selected features, with weights corresponding to their LASSO-derived coefficients. We assessed the association between the composite score and global cognitive function using Pearson correlation analysis. In addition, domain-specific composite tapping scores were constructed for each cognitive domain following the same procedure. All analyses were performed using R version 4.0.3 or Python version 3.6.8.

Results

Cohort Descriptive

This study included 302 eFHS participants with mean age was 74.7 ± 6.3 years, 56.0% of them were women, and 13.2% were non-White (**Table 1**). Nearly two-thirds of participants (63.6%) held a college degree or higher. As expected, the majority (81.8%) were right-handed, while 11.9% were left-handed and 5.0% were ambidextrous. On average, participants had completed 7 finger tapping tests (SD = 4). Neurologically, the sample was generally healthy: the prevalence of PD was 0.3%. The average MMSE score was 28.8 (SD = 1.3), with 2.3% of participants meeting criteria for MCI and 0.3% for dementia. Self-rated health status was favorable: 74.1% of participants rated their general health as “very good” or “excellent”.

Table 1. Demographics of the study participants.

Variable	**Total (n=302)**	**Global cognitive performance**		
		First tertile (n=101)	**Second tertile (n=100)**	**Third tertile (n=101)**
Age (years)	74.7 (6.3)	76.0 (7.0)	75.0 (6.0)	73.3 (5.5)
Sex				
Women	169 (56.0%)	52 (51.5%)	52 (52.0%)	65 (64.4%)
Men	133 (44.0%)	49 (48.5%)	48 (48.0%)	36 (35.6%)
Omni cohort	40 (13.2%)	27 (26.7%)	7 (7%)	6 (5.9%)
Education				
High school	30 (9.9%)	15 (14.9%)	10 (10.0%)	5 (5.0%)
Some college	80 (26.5%)	39 (38.6%)	23 (23.0%)	18 (17.8%)
College and higher	192 (63.6%)	47 (46.5%)	67 (67.0%)	78 (77.2%)
Handedness				
Right	247(81.8%)	81 (80.2%)	84 (84.0%)	82 (81.2%)
Left	36 (11.9%)	14 (13.9%)	11 (11.0%)	11 (10.9%)
Ambidextrous	15 (5.0%)	5 (5.0%)	4 (4.0%)	6 (5.9%)
Unknown/missing	4 (1.3%)	1 (1.0%)	1 (1.0%)	2 (2.0%)
Time interval between the finger	1.7 (1.2)	1.7 (1.2)	1.6 (1.1)	1.8 (1.3)

tapping task and the NP tests				
Number of finger tapping tests administered	14 (7)	13 (7)	14 (7)	17 (6)
Number of left-hand tests administered	7 (4)	6 (4)	7 (4)	8 (3)
Number of right-hand tests administered	7 (4)	6 (4)	7 (4)	8 (3)
MMSE	28.8 (1.3)	28.1 (1.6)	29.0 (1.1)	29.4 (0.8)
Prevalent MCI	7 (2.3%)	7 (6.9%)	0	0
Prevalent dementia	1 (0.3%)	1 (1.0%)	0	0
Prevalent Parkinson's disease	1 (0.3%)	0	1 (1.0%)	0
General health SF-12				
Poor	1 (0.3%)	1 (1.0%)	0	0
Fair	10 (3.3%)	6 (5.9%)	2 (2.0%)	2 (2.0%)
Good	67 (22.2%)	26 (25.7%)	25 (25.0%)	16 (15.8%)
Very good	146 (48.3%)	45 (44.6%)	47 (47.0%)	54 (53.5%)
Excellent	78 (25.8%)	23 (22.8%)	26 (26.0%)	29 (28.7%)

Note: Categorical variables are presented as counts (proportions), and continuous variables are presented as mean (SD).

When stratified by tertiles of global cognitive function, participants in the third tertile (n = 101) were younger (mean age = 73.3 vs. 76.0 years in the first tertile), more likely to be women (64.4% vs. 51.5%), and more highly educated (77.2% with college or higher vs. 46.5% in the first tertile). The proportion of participants from the Omni cohort—representing greater racial/ethnic diversity—was higher in the first tertile (26.7%) compared to the highest (5.9%). MMSE scores followed the expected gradient, increasing from 28.1 (SD = 1.6) in the first tertile to 29.4 (SD = 0.8) in the third tertile. Similarly, MCI and dementia cases were observed only in the first tertile group. Participants in the third tertile also completed more finger tapping tests on average (17 vs. 13), suggesting possible differences in adherence or engagement.

Participants who completed the digital finger tapping assessment were younger and more highly educated compared to those in the broader Offspring/Omni 1 cohort at Exam 10/5. Additional demographic comparisons with the full eFHS and Offspring/Omni 1 samples are presented in **Supplemental Table 2**. The distributions of finger tapping features and cognitive domain scores, including 25th percentile, median, and 75th percentile values, are shown in **Supplemental Tables 3** and **4,** respectively.

Association between Digital Finger Tapping Features and Cognitive Performance

Among the eighteen finger tapping features evaluated, thirteen were significantly associated with global cognitive function (all *P* < .001, **Table 2**). The strongest associations were observed for tapping variability metrics derived from ITI, such as SD, range, and Micro Fluctuation Index. For example, a 1 SD increase in mean ITI (average time differences between successive taps) was associated with a 0.23 decrease in global cognitive function score (β = -0.23; 95% CI: -0.30, -0.17, *P* < .001). In addition to variability-based features, performance-related features such as number of taps (β = 0.14; 95% CI: 0.07, 0.21) and tapping speed (β = 0.12; 95% CI: 0.05, 0.19, P < .001) were positively associated with global cognitive function.

Table 2. The association between digital finger tapping features and global cognitive function

Finger tapping features	Description	Beta	95% CI	P value
Number of taps	Indicator of effort and endurance	0.14	0.07, 0.21	<.001
Mean ITI	Average time differences between successive taps	-0.23	-0.30, -0.17	<.001
Median ITI	Median time differences between successive taps	-0.23	-0.29, -0.16	<.001
SD of ITI	Measures tapping variability	-0.22	-0.28, -0.15	<.001
CV of ITI	Coefficient of variation of ITI	-0.14	-0.20, -0.07	<.001
Skewness of ITI	Skewness of ITI	0.00	-0.07, 0.06	.95
Kurtosis of ITI	Kurtosis of ITI	0.03	-0.04, 0.09	.38
Alternating Tap Ratio	Fraction of alternating left-right taps	0.05	-0.01, 0.12	.11
Mean of Left ITI	Mean of tap times for the left finger	-0.22	-0.29, -0.16	<.001
SD of Left ITI	SD of tap times for the left finger	-0.18	-0.25, -0.11	<.001
Mean of Right ITI	Mean of tap times for the right finger	-0.20	-0.27, -0.14	<.001
SD of Right ITI	SD of tap times for the right finger	-0.12	-0.19, -0.05	<.001
Finger Dominance Ratio	Difference in total taps between left and right buttons	-0.05	-0.12, 0.02	.14
Tapping Speed	Number of taps per second	0.12	0.05, 0.19	<.001
ITI Range	Difference between the longest and shortest ITI	-0.23	-0.30, -0.17	<.001
ITI Slope	Change in ITI over time	-0.11	-0.17, -0.05	<.001
Last to First ITI	Ratio of last ITI to first ITI	-0.06	-0.13, 0.00	.054
Micro Fluctuation Index	SD of successive ITI differences	-0.16	-0.22, -0.09	<.001

Significant associations were claimed if P<0.05/18=0.0028.

Beyond global cognitive function, we further examined the associations between finger tapping features and four domain-specific cognitive outcomes: memory, executive function, language, and visuospatial function (**Table 3**, **Supplemental Table 5**). Similar to findings for global cognition, variability in ITI emerged as a consistent predictor across domains. Executive function demonstrated the strongest associations, with 13 out of 18 finger tapping features reaching significance. The most significant association was observed for mean ITI (β = -0.27; 95% CI: -0.33, -0.20; P < .001). Visuospatial function showed fewer associations (7 significant features), yet ITI range again emerged as the strongest predictor (β = -0.26; 95% CI: -0.38, -0.15; P < .001).

Table 3. The most significant digital finger tapping feature for each cognitive domain

Cognitive domain	Number of significant finger-tapping features	Most significant association			
		Finger-tapping features	Beta	95% CI	*P* value
Memory	10	ITIRange	-0.19	-0.26, -0.12	<.001
Executive function	13	MeanITI	-0.27	-0.33, -0.20	<.001
Language	10	MeanRightITI	-0.24	-0.32, -0.16	<.001
Visuospatial function	7	ITIRange	-0.26	-0.38, -0.15	<.001

Significant associations were claimed if P<0.05/18=0.0028.

Given the presence of multiple finger tapping features associated with cognitive performance, we constructed a composite tapping score for each cognitive test domain using LASSO regression. This approach enabled the selection of the most informative motor features for each cognitive outcome by applying regularization to minimize overfitting and enhance interpretability. As illustrated in **Figure 2**, the resulting composite tapping scores were significantly associated with their respective cognitive domain test scores (all *P* values < 0.001). The strength of these associations varied by cognitive domain, with Pearson correlation coefficients ranging from 0.30 for memory to 0.55 for executive function.

We further examined the associations between finger tapping features and cognitive function by analyzing finger tapping tests administered separately to the left and right hands (**Supplemental Tables 5-7**). Overall, the direction and significance of associations observed in the combined-hand models were largely consistent with those identified in hand-specific analyses, supporting the robustness of the findings across tapping conditions. For global cognitive function, 11 features remained significantly associated in both left-hand and right-hand models. For example, the mean ITI and ITI range—two key features of temporal control—were consistently associated with lower global cognition across all three models. Across domain-specific outcomes, effect directions were again broadly consistent. For executive function, the number of significant tapping features was similar across hands (12 in left-hand and 9 in right-hand models), with mean ITI or mean right-hand ITI consistently emerging as the most predictive features. Language and memory domains also demonstrated robust associations, particularly with right-hand tapping metrics such as ITI range and mean ITI. In contrast, associations for visuospatial function were more pronounced in the right-hand model (7 significant features) and absent in the left-hand model. This asymmetry may reflect functional lateralization of spatial processing or task engagement differences between hands. Additionally, the predominance of right-handed individuals in the sample (81.8%) may have contributed to the stronger associations observed in right-hand tapping performance.

To further examine the robustness of associations and minimize potential confounding from handedness, we conducted subgroup analyses restricted to right-handed participants (n = 247; **Supplemental Tables 8-10**). While differences in the number of significant tapping features emerged across cognitive domains, the direction of effects, particularly for temporal variability features, remained consistent.

Discussion

In this study of predominantly cognitively intact, community-dwelling older adults, we found several digital finger tapping features significantly associated with cognitive performance, reinforcing the potential utility of motor-based digital assessments in cognitive health evaluation. Notably, variability features such as the SD, coefficient of variation, ITI range, and the Micro-Fluctuation Index were consistently associated with cognitive domains. These results suggest that temporal features derived from simple tapping tasks may serve as sensitive and scalable indicators of general cognitive functioning.

Our findings align with prior research using the traditional method of assessing finger tapping speed[27]. In this earlier study, finger tapping was featured by instructing participants to repeatedly press a mechanical lever with an attached counter using the index finger of each hand over a fixed 10-second interval. It demonstrated that individuals who later converted to MCI exhibited a faster decline in tapping speed compared to non-converters. Similarly, in our study, reduced tapping speed was significantly associated with lower global and domain-specific cognitive performance, reinforcing the sensitivity of motor slowing as an early behavioral marker of cognitive decline.

Executive function emerged as the most consistently associated domain, showing strong relationships with thirteen finger tapping features. Given that executive function is a multidimensional construct encompassing key cognitive processes such as processing speed, planning, working memory, and inhibitory control[28], this finding provides important insight into the potential cognitive mechanisms underlying fine motor performance. Although the finger tapping task appears simple, its successful execution in a timed context requires the ability to sustain and update task goals (working memory)[29], initiate and maintain a consistent motor rhythm (planning and motor initiation)[30], and suppress irrelevant motor impulses (inhibitory control)[31]. The strong associations between temporal tapping features, particularly variability-based features, and executive function suggest that digital motor timing tasks may serve as sensitive proxies for detecting early executive dysfunction. Interestingly, language performance was most strongly associated with mean tap times for the right finger, suggesting that the dynamics of motor execution —beyond just timing or variability—may have a specific connection with language processing abilities. This finding is consistent with prior research indicating shared neural substrates for motor and language functions[32], and provides behavioral evidence for the functional interdependence between these domains.

Stratified analyses by hand and by handedness revealed generally consistent associations between finger tapping features and cognitive performance. Across both left- and right-hand administered tests, key temporal metrics—such as median ITI, SD of ITI, ITI range, and micro fluctuation index—remained associated with global cognitive function. However, subtle differences emerged in the number and strength of significant associations across hands and cognitive domains. For instance, visuospatial associations were more prominent in right-hand tests, while left-hand results showed fewer significant features overall. Analyses restricted to right-handed participants largely confirmed the main findings, with core tapping features such as mean ITI and ITI range consistently emerging as the informative predictors across domains. These results reinforce the generalizability of tapping-derived digital biomarkers, while also suggesting that motor laterality and hand-specific administration may modestly influence the association. While many tapping features showed associations with cognition, five features including skewness and kurtosis of ITI, alternating tap ratio, last-to-first ITI ratio, and finger dominance ratio, were not significantly related to any cognitive domain. These findings highlight the need to prioritize the most informative digital biomarkers when evaluating cognitive health. From a clinical standpoint, these findings also underscore the growing relevance of digital phenotyping as a complementary approach to traditional cognitive screening[33]. Early signs of executive dysfunction and cognitive decline are often subtle and can be overlooked, especially in high-functioning or highly educated individuals. The associations identified between fine motor irregularities and cognitive performance suggest that brief, app-based tapping tasks may serve as passive indicators of early neurocognitive vulnerability.

This study offers several notable strengths. First, it leverages a comprehensive battery of neuropsychological assessments covering four major cognitive domains, enabling robust evaluation of cognitive function. Second, the repeated administration of digital finger tapping tests at regular intervals provides a more detailed characterization of motor performance over time and its association with cognitive outcomes. While digital finger tapping tasks have been explored in prior studies, they have predominantly focused on targeted clinical populations, such as individuals with PD or other neurodegenerative disorders[10, 34, 35]. In contrast, our study is among the first to investigate smartphone-based finger tapping performance in a large, community-based sample of older adults, the majority of whom were subjectively healthy and free of diagnosed cognitive impairment. This distinction enhances the generalizability of our findings and supports the broader application of digital motor assessments for population-level cognitive monitoring. The use of a smartphone-based tapping task, coupled with the derivation of multiple temporal and variability-based digital metrics, represents a novel, non-invasive, and scalable approach for assessing fine motor control in real-world settings. Notably, a high proportion of older iPhone users successfully completed and returned the tapping assessments, with many participants completing multiple administrations. Given the well-documented challenges of adherence in digital health studies, this level of engagement suggests that the task was both accessible and acceptable to participants. Additionally, stratification of tapping performance by left and right hand allows for the exploration of potential lateralization effects, offering further insight into the relationship between motor function and cognitive domains.

Several limitations should also be acknowledged. Although finger tapping features were collected longitudinally, the cognitive assessments were not temporally aligned with each tapping session, limiting the ability to examine within-person changes over time. While the smartphone-based tapping task provides a standardized and practical assessment platform, performance may still be influenced by external factors such as participants' familiarity with digital devices or technical variability in smartphone hardware and software. Additionally, although this study controlled for key covariates such as age, sex, education, and handedness, clinicians should be aware of potential confounding effects from physical or psychological comorbidities. Conditions such as arthritis, motor fatigue, or depression may independently influence tapping speed, rhythm, or consistency, potentially mimicking cognitive dysfunction or obscuring true cognitive deficits. Accounting for these factors will be essential when interpreting tapping metrics in real-world clinical contexts, particularly in aging or multimorbid populations. Finally, the study sample was drawn from a single community-based cohort, with a relatively small number of left-handed participants. Participants were well educated and reported high levels of subjective health, which may affect the generalizability of the findings to more diverse populations with differing demographic or clinical characteristics.

In summary, this study identified several finger tapping features that were significantly associated with performance across multiple cognitive domains and highlighted the potential of digital finger tapping tasks as informative biomarkers for assessing cognitive function. These findings suggest that tapping tasks may serve as non-invasive, scalable tools for detecting cognitive decline. Further research in larger and more diverse populations is warranted to validate their utility for early detection and longitudinal monitoring of cognitive health in aging populations.

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Data Availability

The data used in this study can be accessed through the Framingham Heart Study upon reasonable request and in compliance with their data sharing guidelines[36].

Author Contributions

HD, JM, and HL conceptualized and designed the study. HD and HL performed the analysis. HD and HL draft the initial manuscript. TO, JR, HT, CL, ES, and CP critically reviewed the final draft. All authors reviewed and edited the manuscript and have read and agreed to the version for publication.

Conflicts of Interest Statement

ES is an employee of CareEvolution. The other authors have no conflicts of interest to report.

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Figure 1. Graphical abstract.

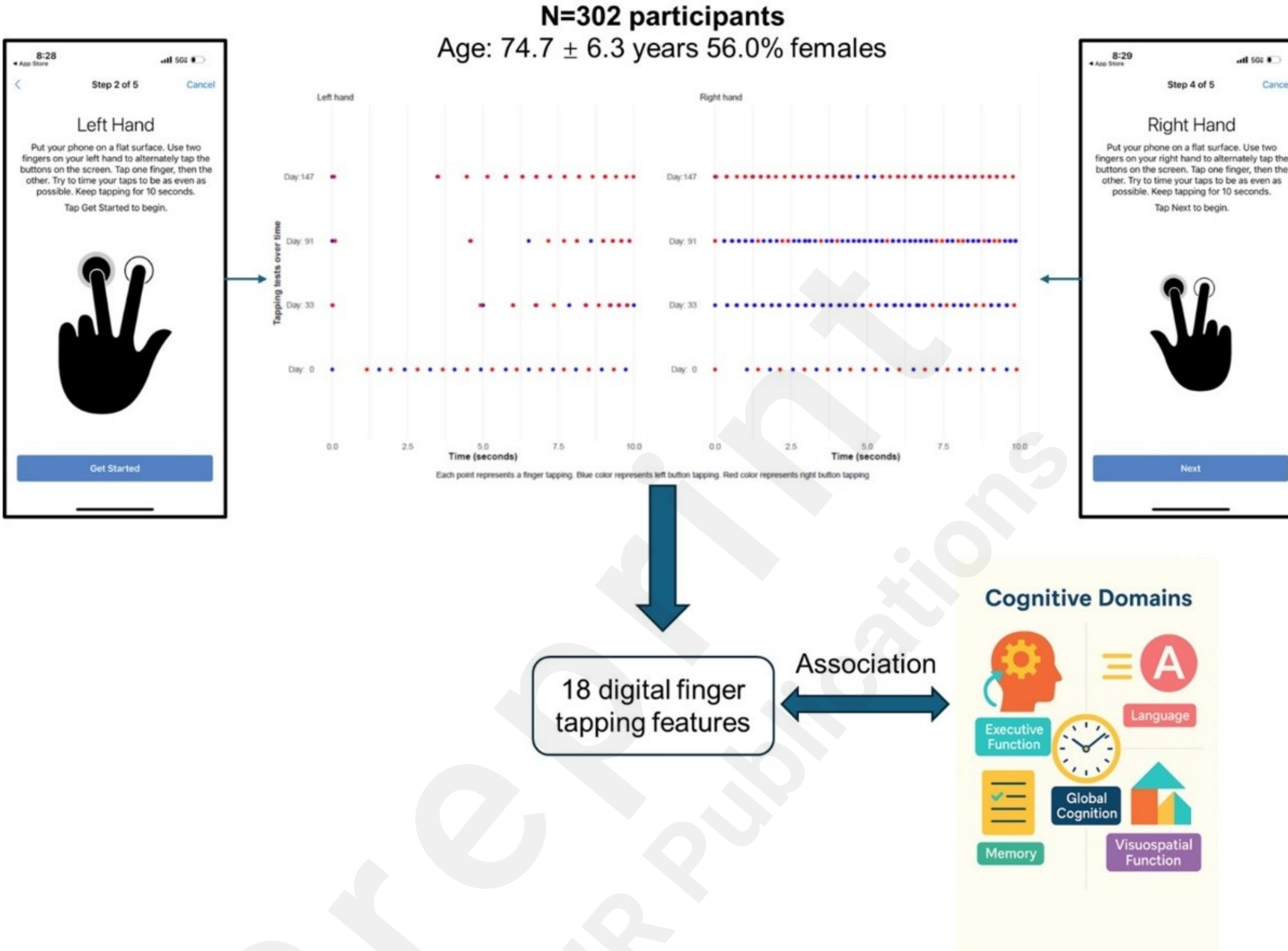
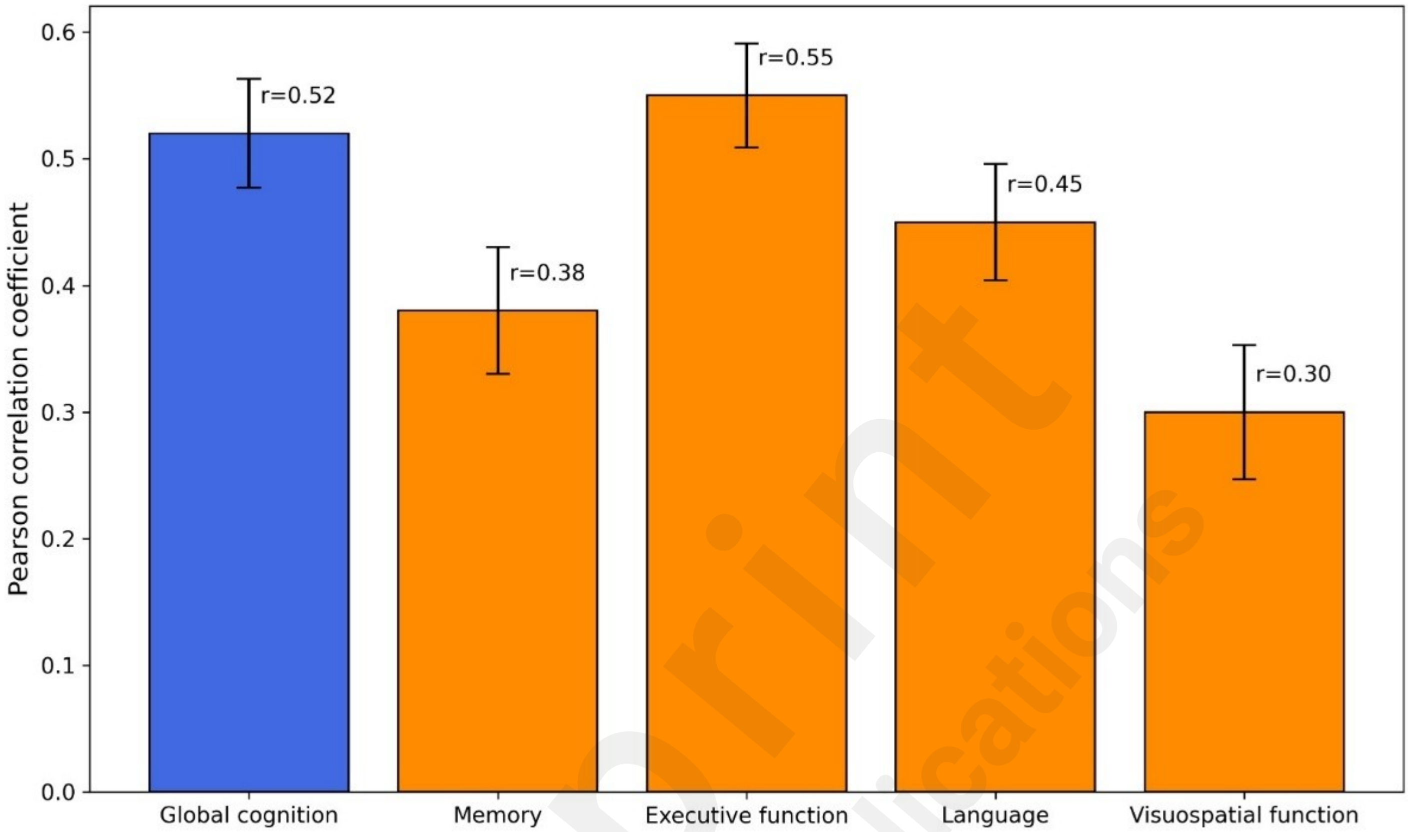


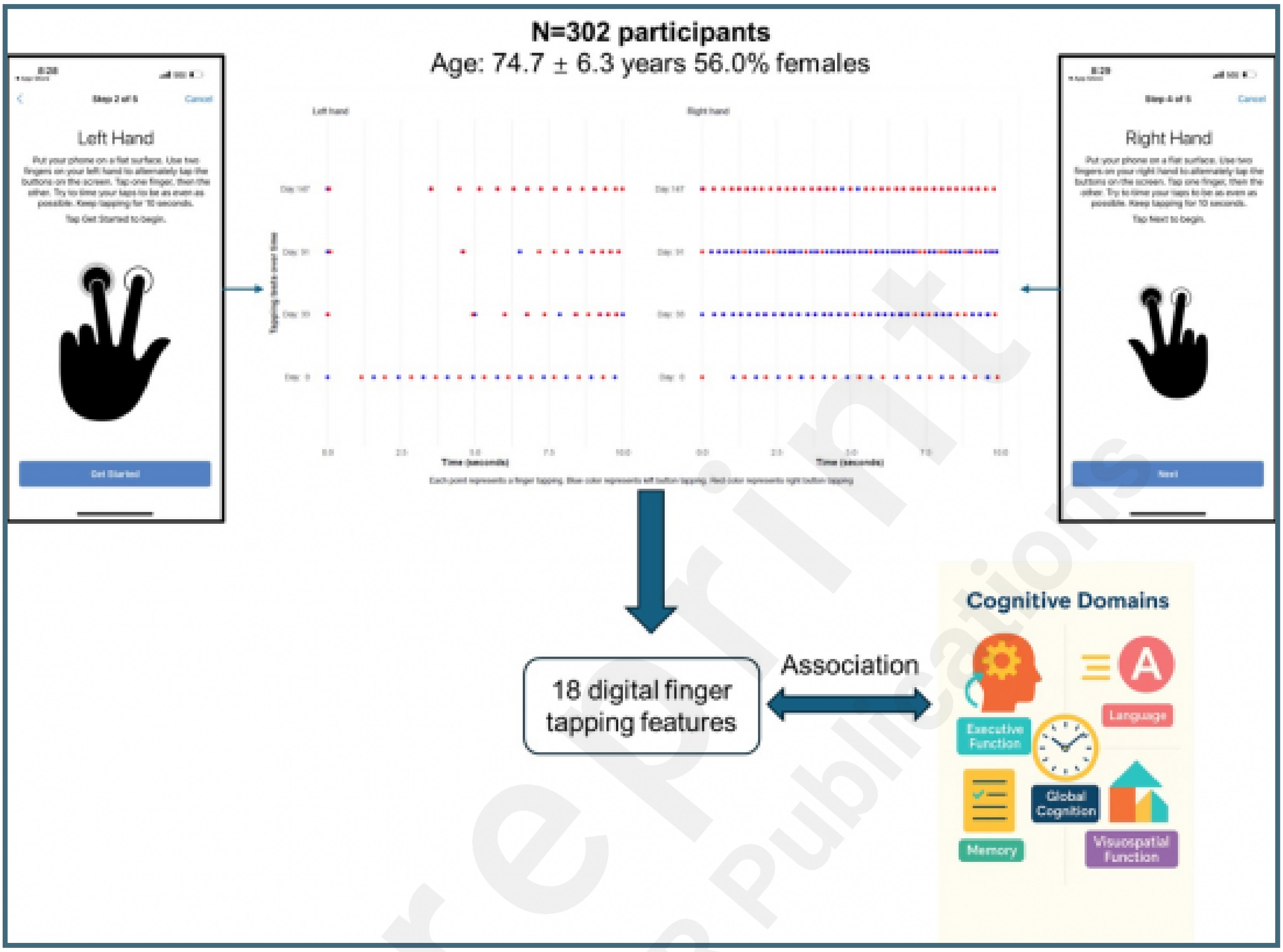
Figure 2. Correlation between finger tapping composite scores and cognitive performance.



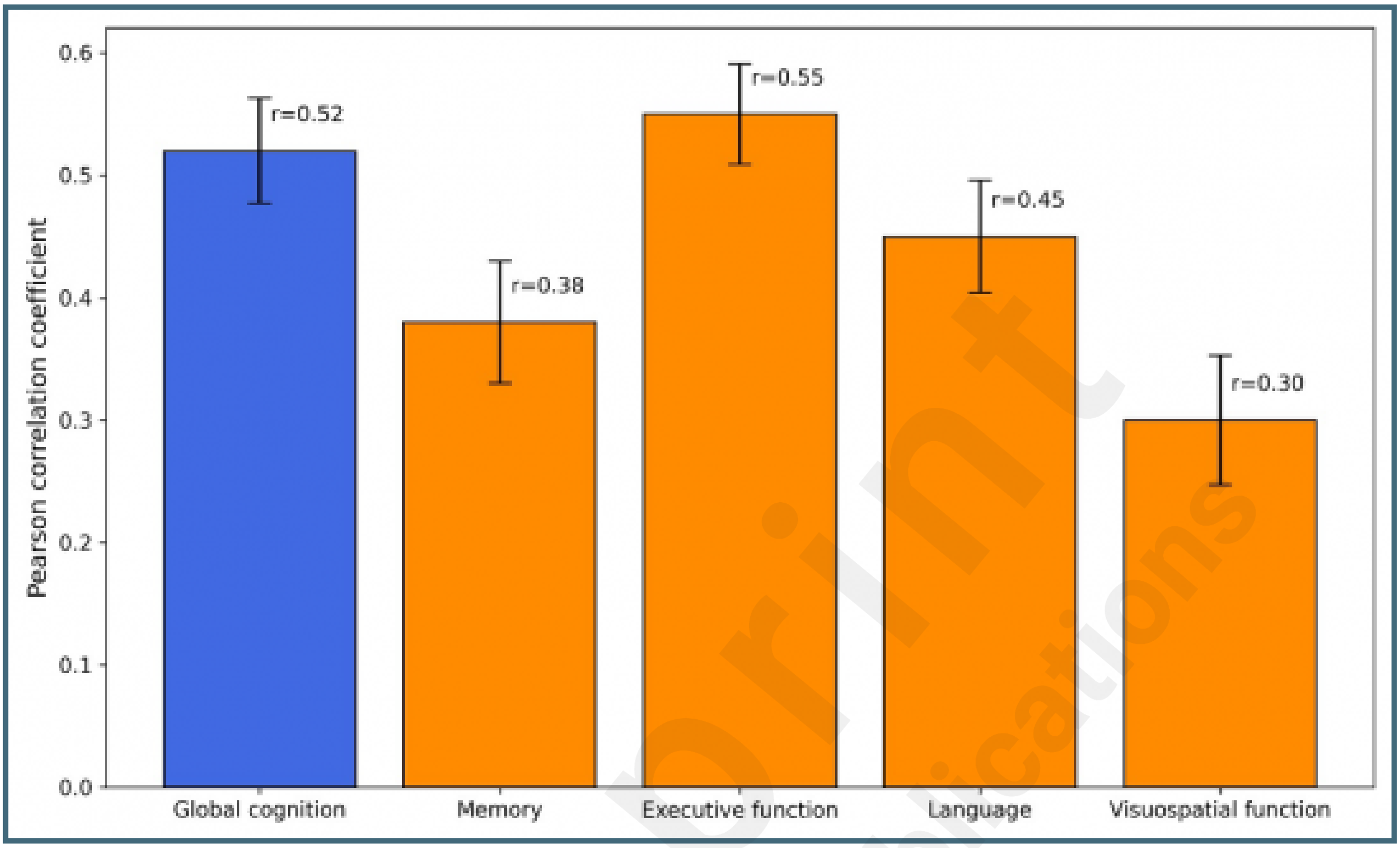
Supplementary Files

Figures

Graphical abstract.



Correlation between finger tapping composite scores and cognitive performance.



Multimedia Appendixes

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