# Visual–Motor Integration (VMI) Is Also Relevant for Computer, Smartphone, and Tablet Use by Adults: Introducing the Brief Box Clicking Test

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**Importance:** Visual–motor integration (VMI) is typically examined in children to promote handwriting, but it may also be relevant for adults' capacity for technology use.

**Objective:** To examine the reliability and validity of speed of completion of the box clicking test, a web-based test of VMI.

**Design:** Participants in the Understanding America Study completed online surveys on a regular basis, including a very brief (less than 30 s) self-administered box clicking test. For validity testing, we examined whether box clicking speed was associated with constructs relevant to visual–perceptual skills and motor coordination, the skills underlying VMI. Test–retest reliability was examined by computation of intraclass correlation coefficients.

**Participants:** A total of 11,114 adults.

**Measures:** Measures included the completion time for the box clicking task and measures relevant to visual perception (e.g., perceptual speed) and motor coordination (e.g., self-reported functional limitation).

**Results:** Results suggested that the box clicking test was a VMI task. Slower test performance was associated with lower visual–perceptual speed and a greater likelihood of reporting difficulties with dressing, a motor coordination relevant task. Box clicking tests taken within at least 2 yr of one another had moderate test–retest stability, but future studies are needed to examine test–retest reliabilities over brief (e.g., 2-wk) time intervals.

**Conclusions and Relevance:** The box clicking test may serve both as a tool for research and to clinically observe whether clients have VMI difficulties that interfere with computer, smartphone, or tablet use.

**Plain-Language Summary:** Use of devices such as smartphones and computers is increasingly becoming integral for daily functioning. Visual–motor integration (VMI) has often been addressed by occupational therapists to support handwriting of children, but it may also be important for technology use by adults. Prior literature supports the relevance of VMI to technology use, and adults with various chronic conditions have been found to have decrements in VMI. We tested the psychometric properties of a brief box clicking test of VMI that could be used to examine VMI underlying technology use among adults. Overall, results suggested that the box clicking test was a VMI task. Just as speed of gait has been used as an index of functional mobility, speed on the box clicking task seemed serviceable as an index of VMI ability. The box clicking test may also be used for clinical observation of whether VMI interferes with technology use.

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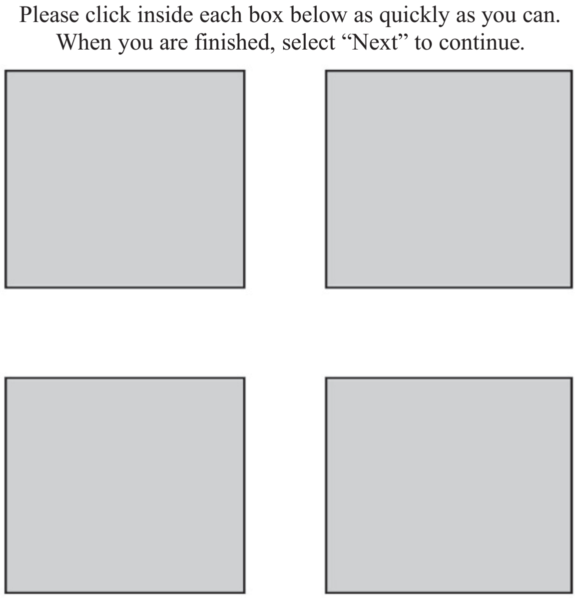
*Visual–motor integration* (VMI) is the ability to coordinate visual perception (the reception and interpretation of visual information; Bouska et al., 1990) and motor coordination (i.e., hand–eye coordination; Beery et al., 1997). For adults, VMI decrements can interfere with technology use, which is an increasingly important part of daily functioning (Muñoz-Neira et al., 2012) for tasks including health management (e.g., accessing personal medical records; Liu et al., 2019), making online purchases (Koch et al., 2020), and maintaining social connections (Williams, 2019). VMI is often addressed by occupational therapists in pediatric settings to support handwriting (Dankert et al., 2003; Kaiser et al., 2009), but it may also have importance for technology use among adult populations (Ahn, 2021; Perochon et al., 2023; Radovanovic, 2013).

Several formal VMI tests have been developed. They typically involve copying shapes (paper–pencil administration) with the assumption that the ability to copy more complicated shapes is indicative of greater VMI ability (Beery et al., 1997; Deitz et al., 2007). A more recently developed VMI test involved presenting people with multiple moving bubbles on a tablet screen and asking them to pop (tap) them (Perochon et al., 2023). Metrics such as the average amount of time needed to pop a bubble, number of screen touches, and tapping accuracy were used to infer VMI ability (Perochon et al., 2023).

We propose a box clicking test as a brief measure of VMI that can be administered online and completed on computers, tablets, and smartphones. A typical shape-copying task can be divided into the visual–perceptual step of looking at the shape to copy and the motor coordination step of moving the writing utensil to replicate the shape. The box clicking test can similarly be divided into visual–perceptual and motor coordination steps. In the visual–perceptual step, participants need to read instructions to click the four boxes underneath the text (Figure 1), after which they need to visually identify the boxes. Reading speed has been strongly associated with visual–perceptual skills (Çayir, 2017; Legge et al., 2007). Next, the motor coordination step involves moving a mouse or one's finger to all the perceived boxes.

**Figure 1. Box clicking task screen.**




Unlike other VMI tests that often emphasize *accuracy* of copying, we hypothesized that the *speed* of completing the box clicking test could serve as an indicator of VMI ability. That is, we anticipated that individuals with greater VMI ability would complete the box clicking task faster than those with lower VMI ability. Consistent with this, prior research has found an association between greater VMI ability and faster handwriting (Brown & Link, 2016; Tseng & Chow, 2000). Furthermore, there is precedence for inferring ability from speed. For instance, physical therapists often measure gait speed as an indicator of functional mobility (Kim et al., 2016).

## Present Study

The purpose of this study was to evaluate the reliability and validity of the box clicking test as an indicator of VMI ability. We administered the box clicking test to more than 10,000 adults ages 18 yr and older in a nationally representative internet-based longitudinal panel. A subset of the sample completed the box clicking test twice, allowing for examination of test–retest reliability. We took advantage of the breadth of other variables measured as part of the ongoing internet panel study to examine the validity of the box clicking test as an indicator of VMI ability.

We hypothesized that faster box clicking test speed would be associated with higher scores on cognitive performance measures, particularly those that are closely related to visual perception. Visual perception is a key underlying component of VMI, and prior research had found associations between the two (Bellocchi et al., 2017; Brown, 2012). We anticipated significant but smaller associations between box clicking speed and cognitive measures less directly related to visual perception, including tests of executive functioning, working memory, and fluid intelligence (Deary et al., 2010).

We expected that slower box clicking test speed would be associated with greater difficulties with activities of daily living (ADLs) and instrumental activities of daily living (IADLs). The motor coordination involved in clicking or tapping boxes has fine motor requirements, so we also hypothesized that box clicking speed would have a higher association with ADLs and IADLs that have a greater fine motor component, including dressing, preparing meals, and making phone calls.

We hypothesized that slower box clicking speed would be associated with a greater chance of reporting a medical diagnosis, particularly for diagnoses with presentations that likely affect VMI. Such diagnoses include stroke (Barrett & Muzaffar, 2014; i.e., through visual perception and motor coordination), diabetes (i.e., through visual perception; Yun et al., 2013), arthritis (i.e., through motor coordination; Kauranen et al., 2000), and dementia (through visual perception; Wood et al., 2013).

Finally, we expected slower box clicking speed to be significantly associated with older age, poorer eyesight, and less confidence in computer use. Poorer eyesight should lower VMI through decreased visual perception and so is associated with slower box clicking. Computer use confidence may serve as an approximate indicator of the amount of practice a person has with the visual–motor aspect of computer use. Greater practice would be expected to result in faster box clicking.

## Method

All data for the current study were collected in the Understanding America Study (UAS), a probability-based internet-based longitudinal survey panel of U.S. adult residents, instituted by the Center for Economic and Social Research at the University of Southern California, Los Angeles (Alattar et al., 2018). Invited respondents without prior internet access are provided with a tablet and broadband internet access. Panel members are 18 yr of age or older and complete one or two web-based assessments per month. Participants provide electronic informed consent to be part of the UAS and to be invited to complete surveys, including core surveys covering a wide variety of topics, which are administered every 2 yr. Because respondents join the UAS at different time points (the panel is still growing) and complete assessments at varying schedules, the timing and number of assessments available per person and measure differ across respondents. Only study measures completed within 1 yr of when a participant completed the box clicking test were included in our analyses. The study was approved by the institutional review board of the University of Southern California, Los Angeles. All active UAS members were invited to complete the survey that included the box clicking test, and no specific inclusion or exclusion criteria were applied.

### Measures

#### *Box Clicking Test*

The box clicking test was adapted from the Health and Retirement Study (2018) and programmed for web administration in the UAS. The test presented participants with the page shown in Figure 1. Boxes changed color when clicked to provide a visual confirmation that they were clicked. The box clicking test was offered to all UAS respondents once. A smaller subset of UAS participants ages 50 yr and older completed the box clicking test for a second time as part of a study comparing online assessment with telephone cognitive assessment (Gatz et al., 2023). A demo of the box clicking test can be accessed at the following link: https://uas.usc.edu/survey/playground/boxclick/test/index.php.

Our primary measure for VMI was the box clicking time from when the box clicking test page was loaded to when the final box was clicked, log-transformed to normalize its distribution. This box clicking time encompasses both visual perception (i.e., reading the instructions and perceiving the boxes) and motor coordination (i.e., clicking), consistent with VMI's operationalization as a construct encompassing both these components. For details on data cleaning steps followed, refer to the Supplemental Material (available online with this article at https://research.aota.org/ajot). We also examined subcomponents of the box clicking time; the corresponding results are presented in the Supplemental Material.

#### *Cognitive Performance*

Various cognitive domains were assessed in the UAS. One visual perception test that we anticipated would have a strong association with box clicking speed relative to other cognitive measures was the Figure Identification task (Liu et al., 2022). Another was the average response time to brief survey questions across all surveys that UAS participants completed within a year of the box clicking test. There is evidence that these response times can serve as approximate measures of perceptual speed (Hernandez et al., 2023; Junghaenel et al., 2022; Schneider et al., 2023). The choice reaction time subtest of the Stop and Go task (Liu et al., 2022) was one more assessment closely related to visual perception, because the score was dependent on the speed of reading single words (i.e., "stop" or "go") and then pushing the correct corresponding key. Cognitive measures less directly related to visual perception were other subtests of the Stop and Go task (i.e., response inhibition and task switching; Liu et al., 2022), Word Recall (episodic memory; Runge et al., 2015), Serial 7s (attention and working memory; Bristow et al., 2016), Number Series (fluid intelligence; Mather & Jaffe, 2016), Verbal Analogies (fluid intelligence; Mather & Jaffe, 2016), and Picture Vocabulary (word knowledge; Mather & Jaffe, 2016).

#### *Self-Reported Functional Limitations*

Questions regarding difficulties with ADLs or IADLs were taken from the Health and Retirement Study survey question, "Because of a health or memory problem, do you have any difficulty with (ADL/IADL)? Exclude any difficulties that you expect to last less than three months." The response options were *yes*, *no*, or *can't do*. If a participant responded with *yes* or *can't do*, it was coded as a 1 to indicate difficulty, whereas a *no* response was coded 0 to indicate no difficulty. ADLs assessed were dressing, eating, walking, getting in or out of bed, using the toilet, and bathing. IADLs assessed were preparing meals, making a phone call, shopping for groceries, taking medications, doing housework or yardwork, and money management.

#### *Self-Reported Diagnoses*

Questions regarding diagnoses had the following structure: "Has a doctor ever told you that you have (diagnosis)." Diagnoses asked about were diabetes, arthritis, stroke, dementia, heart condition, hypertension, cancer, lung disease, and emotional–psychiatric problems.

### Other Measures

We assessed eyesight with the question, "Is your eyesight excellent, very good, good, fair, or poor—using glasses or corrective lens as needed?" Response options were on a Likert scale from 1 (*excellent*) to 5 (*poor*). We tested computer use confidence with the question, "In general, how confident are you in using a computer for writing tasks that involve typing on the computer keyboard such as answering email?" Response options were on a Likert scale from 1 (*not confident*) to 4 (*completely confident*).

## Statistical Analyses

### Reliability

We examined test–retest reliability of the box clicking test for a smaller subset of the UAS sample that completed the box clicking test twice. The average time between tests was 1.3 yr (range = 0.2–3.3 yr), meaning that true change in VMI (e.g., from aging) could decrease reliability relative to a situation in which the tests were administered closer together. We examined reliability via computation of the intraclass correlation coefficient (ICC). ICCs may be interpreted according to the following cutoffs: poor (0–.19), fair (.20–.39), moderate (.40–.59), substantial (.60–.79), and almost perfect (.80–1.0; Bushnell et al., 2001). We examined how ICCs differed by the amount of time that elapsed between two completions of the box clicking test.

### Validity

We examined correlations between the box clicking speed metrics and other study measures. We also examined partial correlations between the study measures that were adjusted for age and device type. Correlations can be interpreted according to the following guidelines: .1 for small, .3 for medium, and .5 for large (Cohen, 1988). All analyses were conducted with M*plus* (Version 8.8; Muthén & Muthén, 1998) via the R package M*plusAutomation* (Hallquist & Wiley, 2018) in the statistical software R (R Core Team, 2020).

To compare the sizes of different correlations (e.g., testing whether the correlation between total box clicking time and visual–perceptual tests was higher than the correlation between box clicking time and other cognitive measures), we computed the full correlation matrix between all measures and conducted significance tests of differences between dependent correlations (Steiger, 1980). These tests of differences were conducted by first using Fisher's $z$ to transform each correlation to account for the nonnormal distribution of correlation coefficients (Asuero et al., 2006). Next, we jointly computed differences between Fisher's $z$-transformed correlations that were expected to differ, and for each difference we tested whether the value was statistically significantly different from zero using the δ method in M*plus* (Version 8.10; Muthén & Muthén, 1998).

# Results

Data from a total of 11,114 participants were included in the analyses. Table A.1 in the Supplemental Material shows the participants' demographic information. In brief, the average age of the sample was 49.7 yr ($SD$ = 16.3), and 61% ($n$ = 6,795) were female. In terms of race, the largest categories were White ($n$ = 8,072; 73%), Black ($n$ = 1,225; 11%), and Asian ($n$ = 783; 7%); 17% of the sample ($n$ = 1,847) identified as Spanish or Latino.

The box clicking time weighted quantiles were as follows: 25th percentile 8.88 s, median 12.27 s, and 75th percentile 17.73 s. Box clicking time differed significantly by device type ($p < .001$); 53% of participants completed the box clicking test on a computer ($n$ = 5,844), 44% on a mobile phone ($n$ = 4,912), and 3% on a tablet ($n$ = 356). The weighted median box clicking time was 12.21 s for computers, 12.15 s for mobile phones, and 16.77 s for tablets. Table A.2 shows the box clicking time quantiles by age group, by subcomponents of box clicking time, and for the smaller telephone cognitive assessment study.

## Reliability

Table 1 shows the different ICCs for box clicking time with various amounts of time between tests. We examined reliability for 1,563 participants who completed the box clicking test twice. The ICC for box clicking tests completed 6 mo or less apart was .48 (moderate reliability), and it decreased to .42 (still moderate) for tests completed within 1.5 to 2 yr of one another. The ICC dropped below .40 if there were more than 2 yr between tests, indicating fair reliability. Reliabilities for subcomponents of the box clicking time were similar to or lower than those shown in Table 1 (Table A.3 in the Supplemental Material).

## Validity

Correlations between the box clicking time and other measures of relevance to VMI are shown in Table 2.

**Table 1. Intraclass Correlation Coefficients (ICCs) for Test–Retest Correlations Between Box Clicking Tests**

| Measure | $n$ | ICC |
|---|---|---|
| All observations | 1,563 | .44 |
| 0 mo to ≤6 mo between tests | 156 | .48 |
| 6 mo to ≤1 yr between tests | 262 | .48 |
| 1 yr to ≤1.5 yr between tests | 519 | .46 |
| 1.5 yr to ≤2 yr between tests | 333 | .42 |
| 2 yr to ≤2.5 yr between tests | 435 | .39 |
| 2.5 yr to ≤3 yr between tests | 68 | .32 |

**Table 2. Correlations Without Adjustment for Age or Device Type ($N = 11{,}114$)**

| Variable | n | Total Box Clicking Time r | Total Box Clicking Time p |
|---|---|---|---|
| Cognition[a] | | | |
| **Figure ID (perceptual speed)** | 7,671 | −.40* | <.001 |
| **Average response time to brief questions across several surveys (perceptual speed)** | 10,459 | −.57* | <.001 |
| **Stop and Go test baseline (choice reaction time, baseline)** | 7,231 | −.26* | <.001 |
| Stop and Go reverse (response inhibition) | | −.28* | <.001 |
| Stop and Go nonswitch (task switching) | | −.33* | <.001 |
| Stop and Go switch (task switching) | | −.26* | <.001 |
| Serial 7s (attention and working memory) | 9,720 | −.07* | <.001 |
| Number Series (fluid intelligence) | 9,883 | −.11* | <.001 |
| Verbal Analogies (fluid intelligence) | 9,039 | −.17* | <.001 |
| Picture Vocabulary (word knowledge) | 9,473 | .04* | <.001 |
| Word Recall–immediate | 9,714 | −.12* | <.001 |
| Word Recall–delayed | 9,715 | −.13* | <.001 |
| ADLs (binary) | | | |
| **Difficulty dressing (422/10,283 = 4.1% yes)** | | .08* | <.001 |
| Difficulty eating (113/10,282 = 1.1% yes) | | .03* | <.003 |
| Difficulty walking (257/10,281 = 2.5% yes) | | .06* | <.001 |
| Difficulty getting in or out of bed (360/10,282 = 3.5% yes) | | .06* | <.001 |
| Difficulty using toilet (267/10,282 = 2.6% yes) | | .05* | <.001 |
| Difficulty bathing (350/10,281 = 3.4% yes) | | .07* | <.001 |
| At least 1 ADL difficulty reported (822/10,280 = 8% yes) | | .10* | <.001 |
| IADLs (binary) | | | |
| **Difficulty with meal preparation (226/10,281 = 2.2% yes)** | | .06* | <.001 |
| **Difficulty making phone calls (134/10,285 = 1.3% yes)** | | −.03* | .011 |
| Difficulty shopping for groceries (473/10,283 = 4.6% yes) | | .07* | <.001 |
| Difficulty taking medications (165/10,289 = 1.6% yes) | | .00 | .625 |
| Difficulty with housework–yardwork (1,035/10,244 = 10.1% yes) | | .11* | <.001 |
| Difficulty with money management (247/10,284 = 2.4% yes) | | .00 | .899 |
| At least 1 IADL difficulty reported (1,433/10,236 = 14% yes) | | .10* | <.001 |
| Self-reported diagnoses (binary) | | | |
| **Diabetes (1,816/11,074 = 16.4% yes)** | | .12* | <.001 |
| **Arthritis (2,912/11,074 = 26.3% yes)** | | .16* | <.001 |
| **Stroke (255/11,075 = 2.3% yes)** | | .06* | <.001 |
| **Dementia (79/11,074 = 0.7% yes)** | | .02 | .128 |
| Heart condition (1,008/11,077 = 9.1% yes) | | .10* | <.001 |
| Hypertension (3,976/11,075 = 35.9% yes) | | .17* | <.001 |
| Cancer (897/11,074 = 8.1% yes) | | .09* | <.001 |
| Lung disease (532/11,078 = 4.8% yes) | | .04* | <.001 |
| Emotional/psychiatric problem (2,403/11,075 = 21.7% yes) | | −.09* | <.001 |
| Other | | | |
| **Age** | 11,073 | .36* | <.001 |
| **Poor eyesight** | 11,080 | .11* | <.001 |
| **Computer use confidence** | 7,894 | −.24* | <.001 |

*Note.* Variables in bold are those for which associations of greater magnitude with the box clicking times were expected. ADLs = activities of daily living; IADLs = instrumental activities of daily living.
[a]For all cognitive tests, higher scores indicate better cognitive functioning.
*$p < .05$.

Table 2 also lists the prevalence rates for ADL and IADL difficulties and the various diagnoses. The correlations between subcomponents of the box clicking time and other measures were similar to those in Table 2 but lower in magnitude (Table A.4 in the Supplemental Material). Table A.5 shows correlations between box clicking time and other measures stratified by device type, and Table A.6 depicts box clicking time correlations with adjustment for age and device type. Table A.7 shows the results of testing of differences between correlations that were expected to differ.

### Cognition

Consistent with our hypotheses, except for the Picture Vocabulary test, higher time on the box clicking task was significantly associated with lower scores on all cognitive measures (*r*s range from –.07 to –.57). After adjustment for age and device type, the association between the Picture Vocabulary score and box clicking time was in the expected direction ($r = -.12$, $p < .001$). Also consistent with expectations, the correlation between box clicking time and the Figure Identification task ($r = -.40$, $p < .001$) and the correlation between box clicking time and survey item response time–based perceptual speed ($r = -.57$, $p < .001$) were significantly greater than the correlations between box clicking time and all other cognitive measures less directly related to visual perception. The correlation between choice reaction time and box clicking time ($r = -.26$, $p < .001$) was significantly greater than the correlations between box clicking time and all other cognitive measures less relevant to visual perception except for the other subtests of the Stop and Go task.

### ADLs

As anticipated, box clicking time was significantly associated with difficulties in all ADLs, although the correlations were small, ranging from .03 to .08. The correlation between box clicking time and dressing ($r = .08$, $p < .001$) was significantly greater than the correlations between box clicking time and four of five other ADLs anticipated to have lower fine motor demands. Contrary to our hypotheses, the correlation was not significantly larger than the correlation between box clicking time and difficulty bathing.

### IADLs

Box clicking time had small correlations with difficulties in all IADLs except taking medications and money management, although significant relationships with all IADLs were expected. The correlation between box clicking time and difficulty with meal preparation ($r = .06$, $p < .001$) was significantly greater than the correlations between box clicking time and difficulty with two of four other IADLs (taking medications and money management) anticipated to have lower fine motor demands. Contrary to expectations, the correlation between box clicking time and phone use was not significantly greater than the correlations between box clicking time and all other IADLs anticipated to have lower fine motor demands.

### Self-Reported Diagnoses

Box clicking time had small but significant positive correlations with all self-reported diagnoses (*r*s range from .04 to .17) except for psychiatric problems ($r = -.09$, $p < .001$) and dementia ($r = .02$, $p = .128$). The correlation between box clicking time and diabetes ($r = .12$, $p < .001$) was significantly greater than the correlations between box clicking time and two of five other diagnoses (lung disease and emotional problem) anticipated to have less of an impact on VMI. For arthritis, the correlation between box clicking time and arthritis ($r = .16$, $p < .001$) was significantly greater than the correlations between box clicking time and all other diagnoses expected to be less relevant to VMI, except hypertension. Finally, the correlations between box clicking time and stroke ($r = .06$, $p < .001$) and dementia ($r = .02$, $p = .128$) were not significantly greater than the correlations between box clicking time and any other diagnoses.

### Other Measures

Box clicking time was significantly correlated with age, eyesight, and computer use confidence. Specifically, consistent with our hypotheses, slower performance of the box clicking task was associated with older age, poorer eyesight, and lower confidence in computer use.

## Discussion

Even though the box clicking test requires only seconds to complete, our results support its validity as a VMI task. Box clicking time on box clicking tests taken within at least 2 yr of one another had moderate test–retest stability, but we were not able to assess test–retest reliabilities over brief (e.g., 2-wk) time intervals. Most of our validity hypotheses were confirmed, suggesting that scores on the box clicking task generally had expected relationships with relevant visual–perceptual and motor coordination variables.

The correlations of total box clicking time with ADL–IADL problems and self-reported diagnoses were all small to very small. Because participants were members of an internet panel study, our sample may have relatively high levels of functioning and technological experience. Thus, many participants may have found ways to use electronic devices despite difficulties associated with their ADL–IADL status and diagnoses, which may have attenuated the observed correlations. Future studies are needed to examine the relationship between box clicking time and other measures using samples with a broader range of functional ability. Nevertheless, the small magnitude of the correlations was aligned with expectation, given many possible presentations of difficulties with ADLs–IADLs and diagnoses. For instance, although fine motor skills may often underlie difficulties with dressing and therefore be anticipated to have an association with visual–motor skills (and box clicking time), numerous other factors can cause dressing difficulties, such as difficulties with standing–sitting balance and apraxia. The nonvisual–motor causes of dressing difficulties may have decreased the magnitude of the correlation between dressing difficulty and box clicking time.

### Reliability

The fact that reliability was moderate for speed on box clicking tests taken 2 yr or less apart implies some degree of temporal stability in VMI. Reliability lowered for tests taken more than 2 yr apart, likely because differences in VMI scores across assessment time points were due to true changes in VMI (e.g., aging effects) rather than measurement error. Future research is needed to examine test–retest reliabilities over brief (e.g., 2-wk) time intervals to assess reliability with less influence from change over time.

### Validity

The score on the Picture Vocabulary test may have had a positive association with box clicking time because older individuals may have greater word knowledge (Salthouse, 2014) but also worse VMI (Kim et al., 2014). Consistent with this, after adjustment for age, the association between the Picture Vocabulary test and box clicking time was negative. Furthermore, follow-up analyses indicated that older age was associated with a higher Picture Vocabulary test score ($r = .41$, $p < .001$).

All subtests of the Stop and Go task had similar associations with box clicking time, although the choice reaction time subtest was anticipated to have the largest correlation. This may have been because all subtests had scores that considered the speed of reading single words, and they differed primarily in the requested action after reading.

Bathing, shopping for groceries, and doing housework or yardwork had a larger than anticipated association with box clicking time on the box clicking test. When reporting difficulty in bathing, perhaps respondents had greater consideration of fine motor elements of the task (e.g., in-hand manipulation of soap bars) as opposed to other parts (e.g., transferring to the tub), thereby resulting in a higher association with box clicking task speed compared with what was expected. This argument had some support in follow-up analyses, which showed a high correlation between difficulty with dressing (a fine motor heavy activity) and difficulty with bathing ($r = .51$, $p < .001$). In terms of reporting difficulty in shopping for groceries, respondents may have put greater weight on the visual–perceptual component of the task (e.g., reading food labels) instead of other aspects (e.g., functional mobility), resulting in a higher association with box clicking time than anticipated. A correlation of $-.11$ ($p < .001$) was found between difficulty grocery shopping and visual perception as measured by the Figure Identification task. The association between box clicking time and housework–yardwork is difficult to decipher because of the wide range of activities (e.g., sweeping, gardening) that can constitute housework and yardwork. Finally, slower box clicking time was unexpectedly associated with less difficulty in making phone calls, and this may be because people with lower VMI took advantage of adaptations to make phone calls easier (e.g., voice dialing).

In terms of diagnoses, stroke had a lower correlation with box clicking time than expected. This may be because many participants who reported stroke did not have it recently (median of 4 yr between box clicking test data and stroke date), meaning they had time to regain motor function. Hypertension had an unexpectedly large association with box clicking time. A systematic review found that high blood pressure was associated with greater risk of cognitive decline in areas such as visuospatial abilities (Forte et al., 2019), meaning hypertension's association with VMI may be attributable to decreased visual–perceptual skills. Contrary to expectation, individuals who reported a psychiatric diagnosis had a faster box clicking time. This could in part have been due to an age effect, whereby younger individuals may be more likely to have psychiatric diagnoses compared with older individuals (Substance Abuse and Mental Health Services Administration, 2022), but are also more likely to have higher VMI compared with older individuals (Kim et al., 2014). Consistent with this, in our sample, for every 1 yr increase in age, the log odds of reporting an emotional or psychiatric problem decreased by 0.022 ($p < .001$). Finally, contrary to our hypothesis, dementia was not found to have an association with box clicking time. This may be because a very small percentage of the sample (0.7%) reported dementia.

Adjustment for age and device type decreased the magnitude of most of the correlations with box clicking time in Table 2. The decrease in magnitude was most pronounced, however, in the correlations with ADLs, IADLs, and diagnoses. Perhaps age was a large driver of the association between box clicking time and these variables.

## Limitations

Our study had several limitations. Box clicking time on the box clicking speed test was not compared with traditional VMI measures such as the Beery–Buktenica Developmental Test of Visual–Motor Integration (Beery et al., 1997). Future studies are needed to examine whether these measures are correlated, as would be expected even with the different types of tasks used (i.e., copying shapes vs. clicking on boxes).

Reliability within a day for speed-based tests such as the gait speed test and Timed Up and Go test has often been computed from two test trials, one after the other (Kim et al., 2016; Sebastião et al., 2016). Future research is needed to examine this within-day form of reliability for the box clicking test.

The reading requirement of the box clicking test may make it less relevant for young children but also a more naturalistic VMI task for adults The reading requirement of the test means it may not be feasible to implement with young children without adaptation.

## Implications for Occupational Therapy Practice and Research

The results of this study have several implications for occupational therapy research and practice:

- The box clicking test may be seen as the VMI counterpart to established assessments in other functioning domains such as the gait speed test and the Timed Up and Go test. All share the commonality of inferring ability from speed in conducting tasks of importance to daily functioning.
- Occupational therapists can potentially use the box clicking test to allow for clinical observation of whether VMI interferes with computer, smartphone, or tablet use.
- In its current form, the box clicking test can be used by researchers to study VMI at the population level, such as in large panel studies like the UAS.
- To capture more granular differences in VMI, researchers can develop other versions of the clicking test that include more trials and difficulty levels.

## Conclusion

The results of our study suggested that the brief box clicking test was a VMI task. Box clicking time on the box clicking test generally had expected associations with relevant measures of visual perception and motor coordination. A major strength of the test was that it took seconds to complete, making it easier to administer to clients as well as to participants in online studies. With technology (e.g., computers, smartphones, tablets) becoming increasingly integral to daily functioning, the box clicking test provides a form of VMI assessment of greater relevance to technology use in everyday life.

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