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The Rapid Naming Test: Development and Initial Validation in Typically Aging Adults

Jordan Stiver[1,2,*], **Adam M. Staffaroni**[1], **Samantha M. Walters**[1,3], **Michelle Y. You**[1], **Kaitlin B. Casaletto**[1], **Sabrina J. Erlhoff**[1], **Katherine L. Possin**[1], **Sladjana Lukic**[1], **Renaud La Joie**[1], **Gil D. Rabinovici**[1], **Molly E. Zimmerman**[2], **Maria Luisa Gorno-Tempini**[1], **Joel H. Kramer**[1]

[1]Memory and Aging Center, Department of Neurology, UCSF Weill Institute for Neurosciences, University of California, San Francisco, San Francisco, CA, USA

[2]Department of Psychology, Fordham University, New York, NY, USA

[3]Department of Psychology, University of California, Los Angeles, Los Angeles, CA, USA

Abstract

Objective: Progressive word-finding difficulty is a primary cognitive complaint among healthy older adults and a symptom of pathological aging. Classic measures of visual confrontation naming, however, show ceiling effects among healthy older adults. To address the need for a naming test that is sensitive to subtle, age-related word-finding decline, we developed the Rapid Naming Test (RNT), a computerized, one-minute, speeded visual naming test.

Method: Functionally intact older (n=145) and younger (n=69) adults completed the RNT. Subsets of older adults also completed neuropsychological tests, a self-report scale of functional decline, amyloid-β PET imaging, and repeat RNT administration to determine test-retest reliability.

Results: RNT scores were normally distributed and exhibited good test-retest reliability. Younger adults performed better than older adults. Within older adults, lower scores were associated with older age. Higher scores correlated with measures of language, processing speed, and episodic learning and memory. Scores were not correlated with visuospatial or working memory tests. Worse performance was related to subjective language decline, even after controlling for a classic naming test and speed. The RNT was also negatively associated with amyloid-β burden.

Conclusions: The RNT appears to be a reliable test that is sensitive to subtle, age-related word-finding decline. Convergent and divergent validity are supported by its specific associations with measures relying on visual naming processes. Ecological validity is supported by its relationship with subjective real-world language difficulties. Lastly, worse performance was related to amyloid-β deposition, an Alzheimer's disease biomarker. This study represents a key step toward validating a novel, sensitive naming test in typically aging adults.

Keywords

confrontation naming; word finding; tip-of-the-tongue; lexical retrieval; anomia

[*]**Corresponding author:** Jordan Stiver, MA, Fordham University, 441 East Fordham Road, DE 226, Bronx, NY 10458, jstiver@fordham.edu.

Introduction

Although aging is associated with an increasing vocabulary store (Hartshorne & Germine, 2015; Salthouse, 2019), progressive word-finding difficulty remains a widely prevalent cognitive complaint among healthy older adults (Martins et al., 2012; Ossher et al., 2013). This difficulty is primarily experienced as an increasing frequency of tip-of-the-tongue phenomena with advancing age (Heine et al., 1999; for review, see Shafto & Tyler, 2014). The tip-of-the-tongue state occurs when an individual is temporarily unable to produce a word despite knowing it due to a deficit in phonological information retrieval (Shafto et al., 2010). Word-finding difficulties can disrupt the quality of social interactions and cause a considerable degree of frustration and embarrassment (Cohen, 1994). In contexts of pathological aging, neurodegenerative diseases including Alzheimer's disease (AD; Weiner et al., 2008) and frontotemporal lobar degeneration (Seltman & Matthews, 2012) can also serve as strong underlying causes of word-retrieval failures (e.g., as observed in the semantic and logopenic variants of primary progressive aphasia; Gorno-Tempini et al., 2011; Lukic et al., 2021).

Clinical evaluation of word-finding difficulties typically involves the use of visual confrontation naming tests such as the Boston Naming Test (BNT; Kaplan et al., 1983, 2001; Rabin et al., 2016), the Neuropsychological Assessment Battery Naming Test (Rabin et al., 2016; Stern & White, 2003, 2009), or the Multilingual Naming Test (Gollan et al., 2012; Weintraub et al., 2018). These tests adhere to a classic paradigm requiring the examinee to verbally name a series of visually presented stimuli within 10 seconds per item or longer depending on the test, often leading to lengthy administration times. Item difficulties increase throughout testing as the word frequencies of stimuli decrease from high to very low. Of note, stimuli can become so infrequent that there is no way to determine whether an examinee's incorrect response to a difficult item reflects a genuine word-finding deficit or their complete unfamiliarity with the name of the stimulus (Killgore & Adams, 1999; Yochim et al., 2013). The classic naming paradigm was designed to reliably capture naming impairment in the context of stroke-induced and primary progressive aphasia (Harnish, 2018; Thompson et al., 2012) as well as other disorders affecting language (e.g., temporal lobe epilepsy; for review, see Hamberger, 2015). Traditional naming tests show a non-normal score distribution due to ceiling effects and a negative skew, making them useful for detecting the presence of a frank naming deficit as opposed to measuring the level of naming ability (Hamby et al., 1997; Mitrushina et al., 2005; Sachs et al., 2016; Tombaugh & Hubley, 1997). For this reason, healthy individuals who score slightly lower than the normative average on these tests run the risk of being overpathologized when clinicians rely on standard scores and associated percentiles for interpreting and reporting performance (Bortnik et al., 2013). Together, this classic naming paradigm is less ideally suited for efficiently detecting subtle word-finding decline in typical aging.

In the childhood reading disorder literature, rapid automatized naming (RAN) represents a test paradigm in which examinees name a series of highly familiar stimuli (e.g., letters, numbers, colors, shapes, common objects) as quickly as possible (Denckla & Rudel, 1976). Tests of RAN are useful for identifying reading difficulty in children with dyslexia due to

their shared dependence on the automaticity within and across individual components of the naming circuit (Decker et al., 2013; for review, see Norton & Wolf, 2012). RAN relies on the synchronized integration of visual naming processes, including lexical access and retrieval, which decline with advancing age among older adults. However, the application of the speeded nature of this paradigm for specifically developing a sensitive measure of word-finding ability in older adults has yet to be conducted.

To address the longstanding need for a more efficient, psychometrically sound visual confrontation naming test, we developed the Rapid Naming Test (RNT)—a computerized, one-minute, speeded naming test. To limit any confounding effects of education and vocabulary while maintaining adequate difficulty, we included items of high familiarity but with low to moderate word frequency (Killgore & Adams, 1999; Yochim et al., 2013). We hypothesized that performances on the RNT would approximate a normal distribution within older and younger adults. To assess the RNT's sensitivity to age-related decline in word-finding, we hypothesized that (a) older adults would perform worse compared to younger adults, and (b) within older adults, worse performance would be associated with older age. To establish support for convergent and divergent validity in older adults, we broadly expected the RNT to correlate most strongly with a classic naming test and other language measures. Due to the timed components of the RNT, we hypothesized it would also correlate with measures relying on processing speed. In light of documented links between visual confrontation naming and hippocampal structure and function (Arlt et al., 2013; Sawrie et al., 2000), we also hypothesized that it would be associated with measures of episodic learning and memory. We did not expect the RNT to relate to measures of visuospatial ability. With regard to ecological validity, we hypothesized that the RNT would contribute significant variance in subjective functional decline among older adults, particularly for language functioning. Furthermore, considering the presence of naming deficits in contexts of pathological aging, we hypothesized that worse RNT performance would relate to greater early AD pathology as measured by amyloid-β positron emission tomography (PET). Lastly, we aimed to investigate test-retest reliability and practice effects among older adults.

Method

Rapid Naming Test Development

An initial collection of possible stimuli was gathered from the International Picture-Naming Project (IPNP) database, an online repository containing 520 black-and-white line drawings (Székely et al., 2004). Target-name agreement for each stimulus is included in the IPNP database based on a normative sample of 50 U.S. college students (Székely et al., 2003). Target-name agreement is defined as the percentage of the sample that verbalized the target-name in response to the presented stimulus (i.e., the name used by the largest number of participants), a morphophonological variant of the target-name (e.g., "bike" for "bicycle"), or a synonym of the target-name (e.g., "couch" for "sofa"). Word frequencies for the majority of target-names were extracted from the SUBTLEXus database, an online corpus of more than 50 million words (Brysbaert & New, 2009), and are operationally defined as the frequency at which a word appeared in American English subtitles per million words.

Word frequencies per million for compound target-names were extracted from the News on the Web corpus, an online database of more than nine billion English words from web-based newspapers and magazines (English Corpora).

The next step was to identify stimuli with a high degree of target-name agreement in order to maximize item familiarity and minimize perceptual ambiguity across participants. To this end, an initial version of the test included only items with 100% target-name agreement and word frequencies of less than 100 per million to avoid items that would be too easy to name. However, pilot testing of this version showed ceiling effects, suggesting that greater item difficulty would be necessary to achieve a wider distribution of performances. To address ceiling effects, we established a more stringent set of item inclusion criteria, requiring an age-of-acquisition greater than five years old based on Kuperman et al.'s (2012) ratings, as well as a word frequency of less than five per million, while maintaining a high target-name agreement of 85% or greater.

In order to augment the pool of potential stimuli from the IPNP database, we utilized an additional visual stimulus repository, the Bank of Standardized Stimuli (BOSS; Brodeur et al., 2010, 2014). The BOSS contains target-name agreement rates for 1468 color pictures based on normative samples of native English-speaking adults. Black-and-white line-drawn versions are available for a subset of BOSS color picture stimuli, which were considered for inclusion in the RNT. For color pictures that met item inclusion criteria but did not have a corresponding line-drawing, we conducted a thorough internet search of publicly available line drawings to collect those with visual attributes closely resembling their original picture stimuli. The same procedure was conducted for all potential IPNP stimuli that met inclusion criteria but were protected by copyright law. A final set of 65 nonproprietary, black-and-white line drawings were compiled for presentation in the RNT, comprising 65 target-names with an age-of-acquisition greater than five years old and a word frequency of less than five per million. Stimuli include manipulable and nonmanipulable objects, spanning the categories of animals, foods, tools, and building infrastructure. Descriptive characteristics for stimulus target-names are presented in Table 1. Concreteness values of target-names are based on Brysbaert et al.'s (2014) ratings. Five additional stimuli with 100% target-name agreement and relatively high word frequencies (e.g., "car," "dress") were selected from the IPNP database for presentation as practice items.

The RNT was programmed in E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA) with stimuli arranged in a presentation order intended to minimize priming and/or interference from item to item, and to evenly distribute item difficulty throughout the test. Specifically, no target-name shares the same first or last phoneme as the preceding target-name's first or last phoneme. In addition, no more than two consecutive target-names share the same number of syllables, nor do any more than two consecutive target-names belong to the same semantic category. Lastly, target-name word frequencies were uniformly distributed across the order of stimuli to maintain a consistent level of difficulty throughout the test. To this end, a nonsignificant ($p > .05$) runs test of non-randomness confirmed that the sequence of word frequencies was randomly arranged.

Participants

Healthy older and younger adult samples were recruited for this study. Detailed demographic characteristics for the two groups are presented in Table 2. Recruitment and screening procedures for both samples are outlined below.

Older Adults—Neurologically and functionally intact older adults (n = 145) ages 65 and over (M_{age} = 76.0, SD = 5.7, range: 65.3–91.6) were included in this study as part of their participation in the Hillblom Brain Aging Network (PI: Joel H. Kramer), a larger longitudinal cohort study at the University of California, San Francisco (UCSF) Memory and Aging Center. Overall, the older adult sample had a slightly greater proportion of individuals identifying as female (60.0%) compared to male (40.0%), participants had a high level of educational attainment (M = 17.4 years, SD = 2.0), and the majority identified as non-Hispanic White (90.3%). All participants were reviewed at case conference with a board-certified clinical neuropsychologist (J.H.K.) and behavioral neurologist. Participants were considered neurologically and functionally intact based on their most recent neurologic and neuropsychological evaluations as well as an informant-based Clinical Dementia Rating (CDR; Morris, 1993) from the larger study. Exclusionary criteria included a global CDR score greater than 0, English as a second language, psychiatric illness and/or neurological disorder, significant medical illness, and active substance dependence. All older adult participants provided written informed consent and the UCSF Committee on Human Research approved the study protocol.

Younger Adults—Young adult college students (n = 69) ages 18 and over (M_{age} = 20.3, SD = 1.8, range: 18.1–29.4) from the Bronx, NY were recruited via campus flyers to participate in a parent study of sleep, light exposure, and cognitive functioning (PI: Molly E. Zimmerman). Participants reported no history of neurological disorder(s), no documented learning or intellectual disabilities, no history of head injury with a loss of consciousness lasting greater than five minutes, no vision and/or hearing impairment that would interfere with neuropsychological testing, and their first language was English. The younger adult sample also consisted of more females (68.1%) than males (31.9%) and the majority identified as non-Hispanic White (60.9%). All younger adult participants provided informed consent and the Fordham University Institutional Review Board approved the study protocol.

Rapid Naming Test Administration and Scoring

Participants were seated in front of a 15.6” Dell Latitude E6540 laptop and instructed to quickly name as many visually-presented objects as possible. Stimuli were presented individually on the screen throughout the test for 60 seconds total. The examiner advanced through individual items manually via mouse click immediately following each item response uttered by the participant. However, participants were only allowed a maximum of five seconds to name any given item before the subsequent item was automatically presented. As such, participants were presented with a new item either immediately after responding or after five seconds had lapsed with no response, depending on which occurred first. No cues or feedback were given during test trials. Prior to starting the test, participants were instructed to name five initial practice items as quickly as possible. However, the practice items did not have any time limit, as they were simply meant to familiarize

participants with the format of the test and allow them ample opportunity to clarify any questions before starting the test. A text screen appeared after the practice items that was read aloud by the examiner to remind participants of the instructions of the test. Item responses that were target-names, morphophonological variants of the target-name, and/or synonyms of the target-name were all scored as correct. The primary outcome variable for the RNT is the total number of correct responses made within 60 seconds, for a possible score range of 0–65.

Measures

In addition to the RNT, various subsets of the older adult sample completed additional measures and procedures through their participation in the larger study. Only data that were collected within 18 months of RNT administration were included in analyses.

Neuropsychological Test Battery—Older adult participants completed a neuropsychological evaluation to reliably capture a range of abilities. Individual tests are outlined below by domain.

Global: The Mini-Mental State Examination (MMSE; Folstein et al., 1975) is a short screener of global cognitive functioning.

Language: The first version of Mack et al.'s (1992) 15-item short forms of the Boston Naming Test (BNT-15; Kaplan et al., 1983) was used to measure visual confrontation naming according to the classic naming paradigm. Other language measures included the total raw score from the Wide Range Achievement Test, Fourth Edition Word Reading subtest (WRAT4-WR; Wilkinson & Robertson, 2006), a 5-item phrase repetition test, and the total number of words generated during 60-second phonemic (i.e., D-words) and semantic fluency (i.e., Animals) tests (Kramer et al., 2003).

Visuospatial: The Benson Figure copy test measures visuospatial construction, with possible scores ranging from 0–17 (Possin et al., 2011). Visuospatial perception was assessed with the 10-item Number Location subtest of the Visual Object and Space Perception battery (VOSP-NL; Warrington & James, 1991).

Learning and Memory: A Benson Figure delayed recall trial was administered following a 10-minute delay to assess visual episodic memory. With regard to verbal episodic memory, participants completed the California Verbal Learning Test—Second Edition (CVLT-II; Delis et al., 2000). The outcome variables in this study were the total number of words recalled across the five learning trials, short delay free recall, long delay free recall, and the long delay recognition discriminability index (d-prime).

Attention, Speed, Working Memory, and Executive Functioning: A modified version of the Trail-Making Test required participants to sequentially alternate between numbers and days of the week (Kramer et al., 2003). The outcome variable was the total time, in seconds, to complete the task. Design Fluency, Condition 1 from the Delis-Kaplan Executive Function System (Delis et al., 2001) required participants to draw as many different designs as possible within 60 seconds. Participants were also administered a digit span forward

and backward test to assess the longest span length for each condition. Lastly, the Stroop Interference Test assessed processing speed and response inhibition (Heflin et al., 2011; Stroop, 1935). Outcome variables included correct response totals for 60-second color naming and interference conditions. In addition, a Stroop interference/color naming score ratio was calculated with the goal of generating a metric of cognitive interference that is less confounded by processing speed, such that greater scores indicate better response inhibition ability.

Processing Speed—All but one of the older adult participants (n = 144) completed a brief computerized battery of five visual reaction-time based tasks described in detail by Kerchner et al. (2012). This battery has been validated as a sensitive marker of brain structure and function among cognitively normal older adults (Kerchner et al., 2012; Staffaroni et al., 2018). Response latency z-scores for all five tasks were averaged to create a composite z-score, with greater scores reflecting slower speed.

Subjective Functional Decline—Another subset of older adults (n = 118) also completed the self-report version of the Everyday Cognition Scale (ECog; Farias et al., 2008), a 39-item questionnaire on which they reported changes in their cognitively based functional abilities compared to 10 years prior across six domains: Memory, Language, Visuospatial, Planning, Organization, and Divided Attention. Individual item scores range from 1 (“No change”) – 4 (“Consistently much worse”). The self-report ECog has been shown to predict the development of mild cognitive impairment among cognitively normal older adults over the course of three years (Farias et al., 2017). Outcome variables of interest for this study were the average scores from each of the six ECog domains as well as the total average score. Greater scores reflect a higher degree of subjective decline over the last 10 years.

Amyloid-β PET—^{18}F-florbetapir (also known as AV-45 or Amyvid) PET was acquired to quantify amyloid-β plaque burden in the brain for a subset of older adult participants (n = 44). Scans were acquired on a GE Discovery VCT at the UCSF Imaging Center at China Basin and processed in accordance with the Alzheimer’s Disease Neuroimaging Initiative protocol (http://adni.loni.usc.edu/methods/pet-analysis-method/pet-analysis/). Briefly, participants were scanned from 50–70 minutes post-injection of 10 mCi of ^{18}F-florbetapir. A low-dose CT scan was acquired for attenuation correction. T1-weighted magnetization prepared rapid gradient echo (MPRAGE) MRI sequences were acquired at UCSF on a 3T Siemens Prisma Fit scanner (sagittal slice orientation; 1 × 1 × 1 mm resolution; slices per slab = 160; matrix = 240 × 256; repetition time = 2.3 ms; inversion time = 900 ms; flip angle = 9°; echo time = 2.9 ms). PET images were smoothed to achieve an effective 8 × 8 × 8 mm resolution and coregistered to their corresponding T1-MRI to extract values from regions of interest defined by FreeSurfer 5.3. The whole cerebellum was used as the reference region to create standard uptake value ratio (SUVR) images and a composite cortical SUVR value was calculated by combining six cortical regions (i.e., frontal, temporal, parietal, anterior cingulate, posterior cingulate, and precuneus; Landau et al., 2013). SUVR values were then converted to Centiloid (CL) values (^{18}F-florbetapir PET CL = (SUVR * 196.9) – 196.03). Values of 0 and 100 CLs correspond to the average PET

binding observed in groups of definitively amyloid-β PET negative individuals and patients with typical mild-to-moderate AD, respectively (Klunk et al., 2015; La Joie et al., 2019). We report amyloid-β positivity frequencies based on a processing pipeline- and tracer-specific threshold of ^{18}F-florbetapir PET SUVR > 1.11 (22.5 CLs)—a threshold that was derived from an independent dataset (Landau et al., 2013) with corresponding CL values that were validated against postmortem amyloid staging (La Joie et al., 2019).

Test-Retest Reliability and Practice Effects

A subset of older adult participants (n = 20; M_{age} = 74.5) completed a second administration of the RNT at a mean interval of 7.3 months (SD = 6.4, range: 1.2–18.7) between test administrations. This subset had an average education of 17.8 years, 55% identified as female, 95% identified as non-Hispanic White, and they obtained an average MMSE of 29.1.

Statistical Analyses

All data were analyzed using IBM SPSS Statistics for Macintosh, version 25.0 (IBM Corp., Armonk, NY). Independent-samples t-tests and chi-square tests compared the older and younger adult groups on demographic characteristics. A one-way analysis of covariance compared RNT performances between older and younger adults while controlling for race/ethnicity. Correlations were conducted within each group to assess the relationship between the RNT and demographic characteristics of age, sex, and education. Correlations corresponding to sex were point-biserial coefficients. Within the older adult sample, correlations between the BNT-15 and demographic variables were conducted to compare these relationships with those of the RNT. Fisher z-transformations were applied to test whether their magnitudes differed. Convergent and divergent validity were assessed by correlating the RNT with standardized neuropsychological measures while applying the Holm-Bonferroni method to p-values to control the familywise error rate (Holm, 1979). Spearman's ρ coefficients were conducted in all correlational analyses corresponding to measures with a high degree of skew (i.e., MMSE, BNT-15, Phrase Repetition, Benson Copy, VOSP-NL, and Modified Trails). All other correlations were Pearson's r coefficients. Ecological validity was assessed via a series of regression models predicting each of the six domain scores and the total score of the ECog. To determine the RNT's relationship with amyloid-β burden, we ran a series of regression models predicting ^{18}F-florbetapir PET CLs, adjusting for age, sex, and education. Finally, a Pearson's r coefficient was calculated to assess test-retest reliability and a paired-samples t-test was conducted to determine change in RNT performance from the first to second administrations of the test.

Results

Descriptive statistics for all study variables of interest are presented in Table 3. Frequency distributions for both the RNT and BNT-15 are presented in Figure 1. The total score on the RNT approximates a normal distribution among both the older and younger adult groups. This is in contrast to the BNT-15, which shows a marked negative skew among older adults, consistent with prior reports of non-normal distributions of classic naming tests. Associations with demographic characteristics are presented in Table 4. The older adult group scored significantly lower than the younger adult group after controlling for

race/ethnicity, $F(1, 211) = 11.98$, $p < .001$, $\eta_p^2 = 0.054$. Within the older adult group, the RNT showed a moderate negative correlation with age, and was not significantly related to sex or education. The BNT-15 was significantly related only to education, and not to age or sex. In younger adults, the RNT was not statistically significantly related to age, sex, or education.

Convergent and Divergent Validity

Correlations between the RNT and other neuropsychological outcome variables in the older adult group are presented in Table 5. Importantly, as hypothesized, the RNT was positively correlated with the BNT-15 and all other language measures. Generally, the RNT was significantly positively associated with tests relying on processing speed, with the exception of design fluency. RNT performance was also correlated with measures of episodic learning and memory. The RNT was not statistically significantly related to either test of visuospatial ability, or to either test of working memory.

Ecological Validity

The relationship between performance on the RNT and subjective functional decline in older adults is presented in Table 6. Linear regression models showed that the RNT was negatively associated with ECog Memory, Language, Visuospatial, Organization, and Total scores. The same models with the BNT-15 simultaneously entered as a predictor showed that the RNT remained a significant predictor, suggesting incremental validity of the RNT to associate with cognitive complaints over and above the BNT-15. Because the RNT was related to measures of processing speed, additional models also controlling for performance on a computerized test of processing speed (Kerchner et al., 2012) were conducted to determine whether the RNT was simply a proxy for speed. Results of the models showed that the RNT explained significant variance in ECog Memory, Language, Visuospatial, Organization, and Total scores over and above processing speed and the BNT-15. Of these models, the RNT accounted for the most variance in relation to the ECog Language score. The BNT-15 was significantly positively related to ECog Language, Organization, and Total scores in these models, such that better performance was related to greater cognitive complaints. Across all models, the RNT was not statistically significantly associated with either the ECog Planning or Divided Attention score.

Association with Amyloid-β PET

Evidence for a relationship between the RNT and amyloid-β PET in the older adult group is presented in Table 7. A linear regression model controlling for age, sex, and education showed that performance on the RNT was negatively associated with ^{18}F-florbetapir PET CLs, suggesting the RNT is sensitive to the presence of amyloid-β deposition even among neurologically and functionally intact older adults. Further supporting the test's incremental validity beyond the classic naming model, the RNT remained significantly associated with ^{18}F-florbetapir PET CLs in the same model controlling for the BNT-15, and in an additional model with processing speed subsequently added as a covariate. In contrast, the BNT-15 was significantly positively associated with ^{18}F-florbetapir PET CLs in these models, such that better performance was related to greater amyloid-β deposition.

Test-Retest Reliability and Practice Effects

A Pearson correlation indicated good test-retest reliability in the older adult sample, r = .86, p < .001, 95% CI [.68, .94]. A paired-samples t-test showed a significant positive improvement in mean RNT performance from the first administration (M = 35.8, SD = 6.2) to the second administration (M = 37.5, SD = 5.3), $t(19) = 2.56$, p = .019, d = 0.57, 95% CI [0.33, 3.27]. A Pearson correlation indicated that within-subject change in RNT score from the first to second administration was not statistically significantly related to length of the retest interval, r = −.06, p = .786, 95% CI [−.49, .39].

Discussion

We developed the Rapid Naming Test (RNT) to meet the clinical and research needs for a brief, sensitive, normally distributed, and reliable measure of the word-finding difficulties so prevalent in aging. The RNT is a one-minute, speeded, visual confrontation naming test that is administered electronically.

Results of the present study provide initial validation of the RNT as a useful tool for measuring visual naming ability in functionally intact older adults. Scores obtained on the RNT approximated a normal distribution. A test-retest correlation on a subset of older individuals indicated good reliability. Younger adults performed significantly better than older adults after controlling for race/ethnicity. Within older adults, lower scores were moderately associated with older age, suggesting the RNT captures age-related changes in word-finding ability. The RNT was not related to age or education within the younger adult group, likely due to their restricted range of educational attainment as undergraduate students as well as their young and limited age range (i.e., 18.1–29.4 years)—an interval of the lifespan in which adults are broadly expected to demonstrate optimal lexical retrieval and processing speed (Salthouse, 2019; for review, see Shafto & Tyler, 2014). Importantly, RNT performance was not related to sex or education in either age group, suggesting performance was not confounded by these factors, though additional work is needed to replicate these nonsignificant associations in individuals from a greater range of educational backgrounds. A medium practice effect (Cohen's d = 0.57) was demonstrated in older adults, suggesting that individuals show an improvement in performance at repeat assessment, likely resulting from familiarity with the test format and stimuli.

Evidence supporting the convergent and divergent validity of the RNT is based on its relationships with standard neuropsychological tests. Specifically, the RNT showed significant associations with the BNT-15 and all other language-domain measures, as would be expected given shared reliance on semantic and phonological processes (for review, see Wulff et al., 2019). Also consistent with our hypotheses, RNT performance correlated with measures relying heavily on processing speed, as well as with episodic learning and memory measures. While the RNT does not specifically tap episodic learning and memory ability, its relatively strong relationship with such tests may be attributable to shared medial temporal structures underlying both visual confrontation naming facility and episodic learning and memory (Arlt et al., 2013; Sawrie et al., 2000). Finally, as expected, the RNT was not related to measures of visuospatial ability, likely due to their reliance on brain regions within the

nondominant hemisphere that are largely unrelated to naming ability (Possin et al., 2011; Putcha et al., 2019).

With regard to ecological validity, worse RNT performance was associated with greater overall subjective real-world functional decline (i.e., ECog Total) among older adults, an important finding given the role of cognitive complaints in predicting later conversion to mild cognitive impairment and dementia (Farias et al., 2017; for review, see Rabin et al., 2017). Of the six ECog domains, in models controlling for the BNT-15 and a robust computerized measure of processing speed, the RNT showed the largest association with ECog Language, supporting its sensitivity to subtle word-finding decline beyond the classic model of naming assessment. Results also suggest that RNT performance was not simply a proxy for speed. This is consistent with prior work showing that age-related decline in word-finding can only partially be explained by generalized slowing of processing speed (Facal et al., 2012; Soble et al., 2016; Verhaegen & Poncelet, 2013). Analogous to its correlations with verbal and visuospatial episodic memory tests, the RNT was also associated with ECog Memory and ECog Visuospatial—a domain in which the majority of items reflect spatial/navigational memory function (e.g., finding my car in a parking lot, finding my way back to a meeting spot, etc.). Surprisingly, the RNT was also related to ECog Organization—a domain characterized by items reflecting exactness in one's work and daily activities (e.g., keeping financial records organized, prioritizing tasks by importance, etc.). However, one study of the informant-report ECog showed that ECog Organization correlated with a range of neuropsychological test domains, including semantic memory, in a sample of older adults with and without cognitive impairment (Farias et al., 2013). As such, subjective measures of functional ability domains cannot always be expected to uniquely relate to their corresponding neuropsychological test domains.

Worse RNT performance was also related to a pathological PET marker (i.e., amyloid-β) associated with AD after controlling for demographic covariates. A recent meta-analysis by Han et al. (2017) showed that cognitively intact older adults who were amyloid-β positive exhibited worse language test scores compared to those who were amyloid-β negative. However, this group difference was fully explained by differences in age. Because we accounted for demographic covariates, our findings suggest the RNT contributes unique variance to amyloid-β retention independently of age, perhaps reflecting its sensitivity to subtle, early neuropathologic change associated with preclinical AD. Importantly, this relationship held even after controlling for the BNT-15, which was not related to amyloid-β burden in the expected direction. This is in line with a recent longitudinal study of cognitively intact older adults showing no differences at baseline, or in rates of decline, on the BNT based on amyloid-β and phosphorylated tau statuses (Ho & Nation, 2018). Lastly, RNT performance remained a significant predictor of amyloid-β after adding processing speed to the model, further highlighting that the RNT is not just a proxy for speed.

While this initial validation study of the RNT shows promise for a novel visual confrontation naming paradigm, it was not without limitations. First, the older and younger adult samples were recruited in two different geographic regions of the United States as part of different study protocols. Also, because multiple research assistants were involved in data collection, one potential source of variance in RNT performance is the speed at which different

examiners advanced through the stimuli following participant responses, which we were unable to test. In addition, within the older adult sample, not all participants completed all study procedures (i.e., ECog, amyloid-β PET, RNT retest, etc.), highlighting the potential for selection bias in our data. Importantly, our study used a 15-item short form of the BNT (Mack et al., 1992), potentially limiting its representation as a classic naming test in our analyses due to its highly restricted range of scores and ceiling effect. The full 60-item version of the BNT, while also negatively skewed and prone to ceiling effects (Hamby et al., 1997), would likely have provided a greater range of scores, perhaps making it more suitable for statistical inferences. However, it is worth noting that Mack et al.'s (1992) 15-item short forms have demonstrated high correlations with the full 60-item BNT in older adults with and without cognitive impairment (Spearman's ρ range = .73 to .96; Katsumata et al., 2015), suggesting they both sample the same underlying construct. Finally, the subset of older adults who were retested on the RNT was limited in size, and the retest interval was variable, which likely affected the stability of the test-retest correlation. Thus, our estimates of test-retest reliability and practice effects should be considered preliminary.

Additional work is needed to further assess the RNT's psychometric properties and to generate normative data across a broader range of participant groups before its utility in clinical settings can be fully realized. Specifically, the participants in this study were primarily non-Hispanic White, highly educated, native English-speakers. Studies including more diverse individuals with regard to race/ethnicity, education, acculturation, language, and age are a key next step for validating the RNT's use in broader populations. Given that RNT performance appears to reflect lexical access and processing speed abilities, future studies will be important to clarify the clinical interpretation of RNT scores. Such questions to address include whether or not the RNT discriminates patients with neurodegenerative disease and other neurological disorders (e.g., stroke, temporal lobe epilepsy, infectious disease, traumatic brain injury) from controls, and within those clinical populations, whether it discriminates those with anomia from those without it. While a close examination of error rates was beyond the scope of the present study, analysis of naming errors and error types could also prove useful in precisely differentiating patient groups (for review, see Harry & Crowe, 2014). Given the RNT's relationship to amyloid-β, longitudinal studies will be valuable in determining its ability to predict conversion to mild cognitive impairment and/or dementia due to AD. Similarly, associations between the RNT and a measure of tau deposition will better elucidate the association between AD and RNT performance. Neuroimaging studies will also be essential for identifying neuroanatomical correlates of performance. Lastly, a more rigorous approach to assessing reliability is needed to expand upon the present findings and examine the internal consistency, test-retest reliability, and inter-examiner reliability of the RNT. Nevertheless, the present study represents a fundamental step toward validating a novel, efficient measure of visual naming ability in typically aging adults.

Availability of Materials

A tablet-based version of the RNT is programmed in the Tablet-based Cognitive Assessment Tool (TabCAT) software platform (UCSF, San Francisco, CA). The RNT and associated materials are available to qualified users upon request at https://memory.ucsf.edu/

research-trials/professional/tabcat. The tablet-based RNT adheres to identical administration procedures as the laptop-based version used in the present study, with the exception of the examiner using screen tapping instead of mouse clicking to advance through items. In transition from the laptop- to the tablet-based RNT, we sent out a UCSF Memory and Aging Center-wide email to elicit feedback from colleagues of culturally and linguistically diverse backgrounds on whether any of the stimuli would be considered unfamiliar and/or nominally ambiguous in their culture of origin. Nine of our UCSF colleagues who were born and raised in countries across North and South America, Africa, Europe, Asia, and Australia identified a total of 13 items that would be unfamiliar and/or ambiguous in their respective cultures of origin. These items were removed to reduce the cultural bias of the test. Eight new items that were deemed more culturally neutral by the same nine individuals were subsequently added, resulting in a possible score range of 0–60. Descriptive characteristics of target-names for the tablet-based RNT and statistical comparisons with the laptop-based RNT target-names are presented in Table S1 of the Supplemental Material. Briefly, independent-samples *t*-tests showed no significant differences for any target-name characteristics between the laptop- and tablet-based RNT (all *p*s > .05). All effect sizes were trivial (Cohen's *d* range = 0.00 to 0.11). In addition to English, there are Spanish and Portuguese versions of the test for which stimuli were selected and arranged according to the same procedures described above. Validation studies for these versions are ongoing. An examiner's manual provides detailed instructions for administration and scoring. Technical support is available through the TabCAT website.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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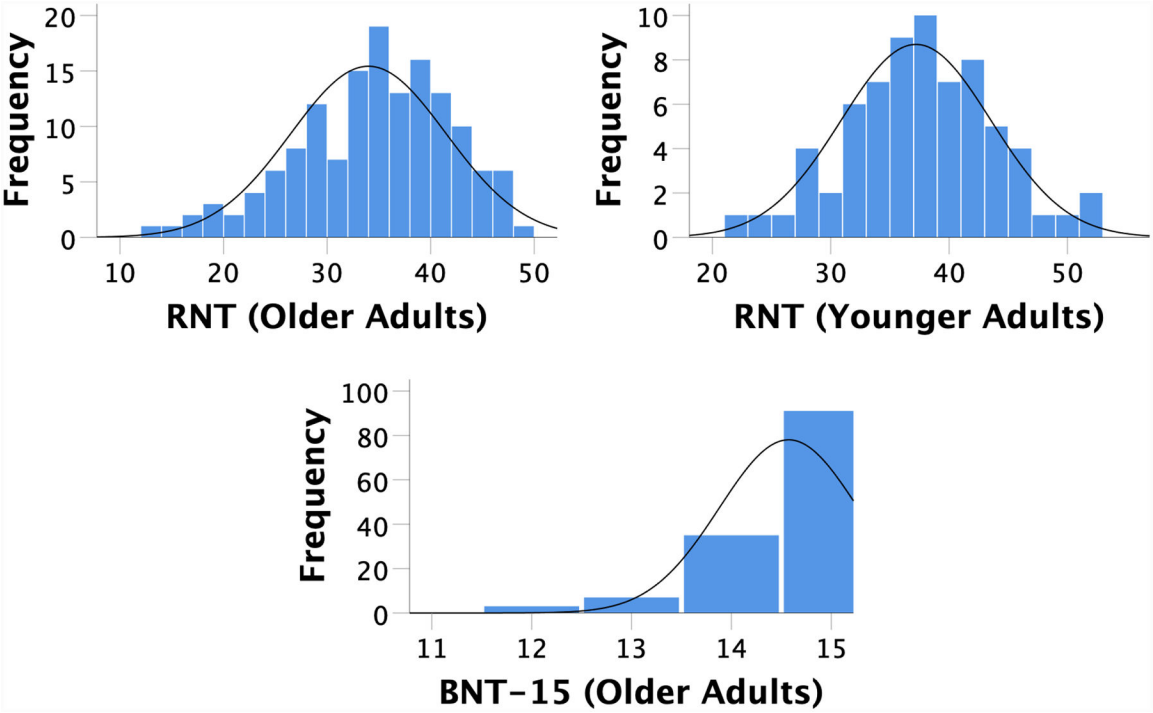

Figure 1.

Frequency distributions of Rapid Naming Test (RNT) and Boston Naming Test—15-Item (BNT-15) total scores

Note. RNT = Rapid Naming Test; BNT-15 = Boston Naming Test—15-Item. Sample sizes: RNT (older adults; $n = 145$), RNT (younger adults; $n = 69$), BNT-15 (older adults; $n = 136$).

Table 1

Characteristics of Rapid Naming Test (RNT) target-names (N = 65)

	Mean	*SD*	Range
No. of letters	7.65	2.18	2—12
No. of phonemes	6.23	1.83	2—10
No. of syllables	2.29	0.76	1—4
Word Frequency	1.98	1.40	0.03—4.84
Word Frequency (LN)	0.22	1.25	−3.52—1.58
Age of Acquisition	6.48	0.93	5.00—9.32
Concreteness	4.83	0.19	4.03—5.00

Note. LN = natural logarithm.

Table 2

Demographic characteristics of older and younger adult groups

	Older Adults (*n* = 145)	Younger Adults (*n* = 69)	*t* or χ^2	*p*
Age, mean (*SD*)	76.0 (5.7)	20.3 (1.8)	78.9	<.001***
Education, mean (*SD*)	17.4 (2.0)	13.4 (1.3)	15.1	<.001***
Sex			1.3	.251
Male, *n* (%)	58 (40.0%)	22 (31.9%)		
Female, *n* (%)	87 (60.0%)	47 (68.1%)		
Race/Ethnicity			26.2[a]	<.001***
Non-Hispanic White, *n* (%)	131 (90.3%)	42 (60.9%)		
Black/African American, *n* (%)	1 (0.7%)	4 (5.8%)		
Asian American, *n* (%)	11 (7.6%)	11 (15.9%)		
Hispanic/Latinx, *n* (%)	2 (1.4%)	12 (17.4%)		
Handedness			1.0[b]	.593
Right, *n* (%)	131 (90.3%)	64 (92.8%)		
Left, *n* (%)	11 (7.6%)	5 (7.3%)		
Ambidextrous, *n* (%)	1 (0.7%)	—		
Spoken Language			—	—
Monolingual English, *n* (%)	122 (84.1%)	—		
Bilingual, *n* (%)	18 (12.4%)	—		
Multilingual, *n* (%)	5 (3.5%)	—		

[a] Non-Hispanic White = 0, any other race/ethnicity = 1.

[b] Right = 0, left or ambidextrous = 1.

*** $p < .001$.

Table 3

Descriptive statistics for study variables

	n	Mean	*SD*	Range
Younger Adults				
Rapid Naming Test	69	37.2	6.3	22—52
Older Adults				
Rapid Naming Test	145	34.0	7.5	13—49
Global				
Mini-Mental State Examination	135	29.1	1.3	25—30
Language				
Boston Naming Test—15-Item	136	14.6	0.7	12—15
WRAT4-Word Reading	135	65.2	2.8	54—70
Phrase Repetition	135	4.7	0.7	2—5
D-Words	136	15.9	4.9	6—30
Animals	139	22.5	4.7	12—38
Visuospatial				
Benson Copy	135	15.4	0.8	12—16
VOSP-Number Location	136	9.0	1.3	3—10
Learning and Memory				
Benson Recall	136	11.7	2.4	5—16
CVLT-II Trials 1–5	140	50.1	10.5	21—80
CVLT-II Short Delay Free Recall	140	11.2	3.1	2—16
CVLT-II Long Delay Free Recall	140	11.5	3.3	0—16
CVLT-II Recognition, d-prime	140	3.2	0.8	1.1—4.0
Attention, Speed, WM, and EF				
Modified Trails, seconds	132	30.2	14.2	10—99
Design Fluency	136	11.6	3.0	4—21
Longest Digit Span Forward	136	6.8	1.3	4—9
Longest Digit Span Backward	136	5.4	1.4	2—8
Stroop Color Naming	135	85.1	14.7	55—139
Stroop Interference	133	50.6	11.2	26—92
Stroop Interference/Color Naming	133	0.60	0.10	0.31—0.88
Processing Speed, z-score[a]	144	2.55	1.42	−0.27—7.65
Subjective Functional Decline				
ECog Memory	118	1.44	0.39	1.00—2.91
ECog Language	118	1.33	0.35	1.00—2.56
ECog Visuospatial	118	1.11	0.21	1.00—2.00
ECog Planning	118	1.08	0.20	1.00—2.00
ECog Organization	118	1.20	0.33	1.00—2.57
ECog Divided Attention	118	1.41	0.48	1.00—3.00
ECog Total	118	1.28	0.25	1.00—2.18
Amyloid-β Burden				

	n	Mean	*SD*	Range
^{18}F-florbetapir PET CL	44	16.7	29.5	−21.1—129.7
Amyloid-β Positive, *n* (%)	13 (29.5%)	—	—	—

Note. WM = working memory; EF = executive functioning; CVLT-II = California Verbal Learning Test—Second Edition; WRAT4 = Wide Range Achievement Test—Fourth Edition; VOSP = Visual Object and Space Perception; ECog = Everyday Cognition Scale; PET = positron emission tomography; CL = Centiloid value.

[a]Higher = worse performance.

Table 4

Demographic correlates of the Rapid Naming Test (RNT) and Boston Naming Test—15-Item (BNT-15)

	Older Adults			Younger Adults		
	Age	Sex[a]	Education	Age	Sex[a]	Education
RNT	−.45***	.10	−.04	.08	.17	.04
BNT-15	−.13	.02	.22*	—	—	—
z[b]	−2.97**	0.63	−2.16*	—	—	—

Note. RNT = Rapid Naming Test; BNT-15 = Boston Naming Test—15-Item. Sample sizes: RNT (older adults; n = 145), BNT-15 (older adults; n = 136), RNT (younger adults; n = 69). Correlations corresponding to sex are point-biserial coefficients. All other correlations corresponding to RNT are Pearson's r coefficients and to BNT-15 are Spearman's ρ coefficients due to skew.

[a] Male = 0, female = 1.

[b] Formula for comparing correlations with different sample sizes from Cohen et al. (2013).

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 5

Rapid Naming Test (RNT) correlations with neuropsychological test variables in older adults

	Global	Language					Visuospatial			Learning / Memory				Attention / Speed / WM / EF						
										CVLT-II								Stroop		
	MMSE	BNT-15	WRAT4-WR	Rep	D-Words	Animals	Benson Copy	VOSP-NL	Benson Recall	Trials 1–5	SDFR	LDFR	Recog	MT[a]	DF	LDSF	LDSB	CN	Int	Int/CN
RNT	.35***	.38***	.28*	.25*	.31**	.37***	.01	.06	.25*	.33**	.27*	.29**	.31**	−.26*	.17	.20	.18	.39***	.34***	.08

Note. RNT = Rapid Naming Test; WM = working memory; EF = executive functioning; CVLT-II = California Verbal Learning Test—Second Edition; MMSE = Mini-Mental State Examination; BNT-15 = Boston Naming Test—15-Item; WRAT4-WR = Wide Range Achievement Test—Fourth Edition Word Reading; Rep = phrase repetition; VOSP-NL = Visual Object and Space Perception—Number Location; SDFR = short delay free recall; LDFR = long delay free recall; Recog = recognition discriminability index; MT = modified trails; DF = design fluency; LDSF = longest digit span forward; LDSB = longest digit span backward; CN = color naming; Int = interference. Sample sizes: MMSE (n = 135), BNT-15 (n = 136), WRAT4-WR (n = 135), Rep (n = 135), D-Words (n = 136), Animals (n = 139), Benson Copy (n = 135), VOSP-NL (n = 136), Benson Recall, (n = 136), CVLT-II (n = 140), MT (n = 132), DF (n = 136), LDSF (n = 136), LDSB (n = 136), CN (n = 135), Int (n = 133), Int/CN (n = 133). Correlations corresponding to MMSE, BNT-15, Rep, Benson Copy, VOSP-NL, and MT are Spearman's ρ coefficients due to skew. All other correlations are Pearson's r coefficients. The Holm-Bonferroni method was applied to p-values to correct for multiple comparisons.

[a]Seconds, higher = worse performance.

*$p < .05$.

**$p < .01$.

***$p < .001$.

Table 6

Rapid Naming Test (RNT) and Boston Naming Test—15-Item (BNT-15) contributions to subjective functional decline scores (Everyday Cognition Scale; n = 118)

	Everyday Cognition Scale													
	Memory		Language		Visuospatial		Planning		Organization		Divided Attention		Total Score	
	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*
Model predictor														
RNT	−.20	.032 *	−.21	.026 *	−.22	.018 *	−.14	.128	−.24	.010 *	−.11	.223	−.25	.007 **
Model predictor														
BNT-15	.03	.789	.08	.375	.04	.695	.03	.742	.09	.320	.09	.356	.08	.403
Model predictors														
BNT-15	.14	.183	.22	.029 *	.16	.112	.11	.274	.24	.017 *	.17	.109	.23	.022 *
RNT	−.26	.013 *	−.32	.002 **	−.29	.005 **	−.19	.068	−.34	<.001 ***	−.18	.078	−.35	<.001 ***
Model predictors														
Processing Speed[a]	.03	.788	−.14	.134	.06	.548	.00	.994	.12	.201	.12	.219	.03	.765
BNT-15	.14	.184	.22	.029 *	.16	.112	.11	.276	.24	.016 *	.17	.106	.23	.022 *
RNT	−.25	.018 *	−.35	<.001 ***	−.28	.009 **	−.19	.075	−.31	.002 **	−.16	.138	−.34	<.001 ***

Note. RNT = Rapid Naming Test; BNT-15 = Boston Naming Test—15-Item.

[a]Z-score, higher = worse performance.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 7

Rapid Naming Test (RNT) and Boston Naming Test—15-Item (BNT-15) contributions to amyloid-β burden (^{18}F-florbetapir PET Centiloids; n = 44)

	^{18}F-florbetapir PET Centiloids		
	β	***t***	***p***
Model predictor			
RNT	−.37	−2.24	.031 *
Model predictor			
BNT-15	.34	2.32	.025 *
Model predictors			
BNT-15	.54	3.36	.002 **
RNT	−.48	−2.94	.006 **
Model predictors			
Processing Speed[a]	.25	1.71	.095
BNT-15	.57	3.66	<.001 ***
RNT	−.44	−2.72	.009 **

Note. Models are adjusted for age, sex, and education. RNT = Rapid Naming Test; BNT-15 = Boston Naming Test—15-Item; PET = positron emission tomography.

[a]Z-score, higher = worse performance.

*$p < .05$.

**$p < .01$.

***$p < .001$.