Published in final edited form as:

Heart Lung. 2015 ; 44(5): 387–394. doi:10.1016/j.hrtlng.2015.07.002.

Performance of the Automated Neuropsychological Assessment Metrics (ANAM) in Detecting Cognitive Impairment in Heart Failure Patients

Susan S. Xie^a, Carly M. Goldstein, M.A.^{a,c}, Emily C. Gathright, M.A.^b, John Gunstad, Ph.D.^b, Mary A. Dolansky, RN, Ph.D.^e, Joseph Redle, M.D.^d, and Joel W. Hughes, Ph.D.^{b,d}

^aBaylor College of Medicine, Houston, TX 77030, United States

^bKent State University, Kent, OH 44242, United States

^cWarren Alpert Medical School of Brown University, Providence, RI 02903, United States

^dSumma Health System, Akron, OH 44304, United States

^eFrances Payne Bolton School of Nursing, Case Western Reserve University, Cleveland, OH 44106, United States

Abstract

Objective—Evaluate capacity of the Automated Neuropsychological Assessment Metrics (ANAM) to detect cognitive impairment (CI) in heart failure (HF) patients.

Background—CI is a key prognostic marker in HF. Though the most widely used cognitive screen in HF, the Mini-Mental State Examination (MMSE) is insufficiently sensitive. The ANAM has demonstrated sensitivity to cognitive domains affected by HF, but has not been assessed in this population.

Methods—Investigators administered the ANAM and MMSE to 57 HF patients, compared against a composite model of cognitive function.

Results—ANAM efficiency ($p < .05$) and accuracy scores ($p < .001$) successfully differentiated CI and non-CI. ANAM efficiency and accuracy scores classified 97.7% and 93.0% of non-CI patients, and 14.3% and 21.4% with CI, respectively.

Conclusions—The ANAM is more effective than the MMSE for detecting CI, but further research is needed to develop a more optimal cognitive screen for routine use in HF patients.

Corresponding Author: Susan S. Xie, **Phone:** +1 330-205-7139, **Fax:** +1 330-672-3786, **susan.xie@bcm.edu**, **Address:** Baylor College of Medicine, One Baylor Plaza, Houston, TX 77030, U.S.A..

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Declaration of Conflicting Interests:
None declared.

Keywords

Mild cognitive impairment; Heart failure; Mass screening; Cognition

Introduction

Over five million Americans suffer from congestive heart failure (HF), and an additional three million are projected to have HF by 2030.^{1, 2} HF results in reduced cerebral blood perfusion leading to gray matter loss, and is associated with mild cognitive impairment (CI) and difficulties with processing and executing demanding self-care regimens.³ HF patients show two to four times the risk of CI compared to the general population and approximately a quarter of HF patients exhibit deficits in at least three cognitive domains.⁴⁻⁶ Approximately 25-80% of patients experience cognitive deficits in at least a single domain.^{7,8}

The most common domains of CI in HF are memory, attention, learning, psychomotor speed, language, and executive function; deficits in these domains impede self-care such as adherence to dietary and medication regimens.⁶⁻⁹ Patients' decreased ability to carry out appropriate self-care due to CI leads to unsuccessful HF management, which is associated with increased mortality and disability, impaired quality of life, greater need for hospitalization, and higher healthcare costs.^{7,10,11} Thus, CI is an essential prognostic marker in elderly HF patients.¹²

Although the prevalence and effects of CI have implications for HF management and outcomes, cognitive screening is not routinely performed in this population, and no sufficiently sensitive neuropsychological test is currently accepted for widespread use to screen for CI in HF.^{4,13} Previous studies of HF and cognition commonly utilize the 30-point Mini-Mental State Examination (MMSE)¹⁴—which assesses orientation, registration, attention, language and comprehension, calculation, and immediate recall. Classification of CI in these studies is commonly based on a total MMSE score <24.¹⁵⁻¹⁹ According to a review of screening instruments that are currently used to evaluate for CI in patients with HF, the MMSE has been the most frequently used neuropsychological test in this population, surpassing use of the Montreal Cognitive Assessment (MoCA), Six Item Screener, Abbreviated Mental Test (AMT), Clock Drawing Test (CDT), Short Portal Mental Status Questionnaire (SPMSQ), and Blessed Test of Orientation, Memory, and Concentration (BTOMC) in the clinical setting.¹³

However, despite its widespread usage in clinical contexts, the MMSE is inadequate for detecting CI in HF patients. The MMSE may not detect the subtler levels of cognitive deficits that HF patients experience, as this test was originally designed to assess for dementia and is insensitive to less severe impairments in executive function and memory.²⁰⁻²² Furthermore, there is no consensus on an appropriate MMSE cutoff score for determining CI in this population. The standard MMSE cutoff of <24 may be insensitive to milder forms of CI—especially among patients with higher educational levels or pre-morbid intelligence, who show a ceiling effect of higher MMSE scores and thus more false-negative results.²³ Although higher MMSE cutoffs have been suggested for detecting CI in various

populations (e.g., 29 for individuals with nine or more years of schooling, 27 or 28 for HF patients, or 25 for individuals aged 80 or older),²⁴⁻²⁶ the applicability of these various cutoff scores remains unclear for wider clinical applications. Although the MMSE may be quick to administer and therefore attractive as a screening measure, its insufficiency for detecting cognitive deficits in HF patients may create clinical obstacles for observing and treating cognitive problems in this population, making this issue important to care providers and patients alike.

The Research Committee of the American Neuropsychiatric Association has recommended that clinicians should use the MMSE only as a minimum screening measure, that scores should be corrected for age and education, and that when used, the MMSE should be supplemented with specific measures of memory, executive function, and visuospatial ability.²⁷ Despite recommendations against utilizing the MMSE for purposes beyond dementia screening, the MMSE is still regularly used to detect the milder types of CI in HF patients. It has even served as the sole test of cognitive function in a substantial number of recent studies evaluating HF patients, in both hospitals and outpatient settings.²⁸⁻³⁵ Given that the MMSE is the most commonly used cognitive test for this population in the clinical setting, evaluation of other screening tools is needed to establish a more appropriately sensitive test for CI in patients with HF.

The Automated Neuropsychological Assessment Metrics (ANAM)³⁶ is a computerized battery that has previously demonstrated capacity in testing the cognitive domains that are adversely affected by HF, but has not yet been evaluated specifically for the purpose of detecting CI in HF patients. The ANAM has already shown a wide range of utility in studies assessing the cognitive effects of concussions,^{37,38} environmental stressors and exposures,³⁹⁻⁴² and medications and drugs of abuse.^{43,44} It has served as an efficient tool for monitoring cognitive deficits in a range of patients, from screening military personnel for minor traumatic brain injuries and neuropsychological deficits,⁴⁵⁻⁴⁹ to managing chronic medical conditions, including systemic lupus erythematosus^{50,51} and multiple sclerosis.⁵² Recently, in a mixed clinical sample, the ANAM significantly predicted CI status with a sensitivity of 81% and specificity of 89.1%.⁵³ The ANAM has also demonstrated high sensitivity to CI among patients with Alzheimer's disease—correctly classifying 100% of the participants in a pilot study based on a discriminant function analysis of throughput scores—as well as the potential capacity to detect earlier, more subtle cognitive changes in the disease process.⁵⁴

In particular, the ANAM consists of subtests that evaluate cognitive domains including attention, processing speed, learning, memory, and visuospatial ability—in which deficits often impede self-care in HF patients, leading to poor prognosis. Unlike most computerized cognitive batteries, the ANAM calculates a throughput score for each subtest (a corrected response rate ratio of accurate responses per minute), which measures cognitive efficiency. The throughput score is uniquely useful in increasing sensitivity to changes in a patient's cognitive performance over time, and facilitating comparisons across different tasks that measure accuracy and speed.⁵⁵ Another advantage of the ANAM is its configurability, as clinicians can select combinations of over 20 ANAM subtests to tailor a cognitive screening battery for specific populations and testing purposes.^{56,57} Examinations of the construct

validity of ANAM subtests compared to more traditional neuropsychological measures have already shown that ANAM scores can successfully measure processing efficiency, working memory, and recall.⁵⁸

Despite its applications to various clinical populations and, importantly, demonstrations of its sensitivity to subtle cognitive changes, the ANAM has not been assessed as a screening tool for CI in patients with HF. Considering the insufficiency of the MMSE and lack of routine cognitive screening, evaluation of newer approaches is crucial to developing a sensitive, standardized measure to recognize CI and, in turn, improve HF patient care. The investigators aim to evaluate the extent to which the ANAM can better detect cognitive deficits in HF patients, compared to the widely used MMSE. The performance of the ANAM and MMSE in discerning CI among HF patients will be compared against a composite model of CI comprising a battery of neuropsychological tests—a more comprehensive reflection of the cognitive domains affected by HF, including attention, processing speed, learning, working memory, and delayed memory.

Method

Participants

The current study is a cross-sectional analysis of 57 systolic and diastolic HF outpatients recruited from Akron City Hospital (Summa Health System, Akron, OH). The investigators confirmed HF diagnosis by a review of the patients' medical charts. All participants were in an ongoing study examining HF self-management and completed a comprehensive battery of neuropsychological tests—including the ANAM and the individual tests comprising the composite model—to assess overall cognitive function. This investigation conformed to the principles outlined in the Declaration of Helsinki. A graduate student trained in neuropsychology tested participants at the Summa Center for Clinical Trials or in their respective homes between June 2011 and June 2012. The present analyses represent a sub-study of a trial aimed at examining medication adherence in heart failure patients using technology interventions. The sample size of that intervention was limited due to availability of the novel technologies; the investigators made all efforts to include participants' data from the parent study into this sub-study to maximize the sample size.

Inclusion criteria were: aged 45-90; English speaking; New York Heart Association class II or III for three or more months; history of HF managed by the patient for at least three months; systolic HF with LVEF $\geq$ 40% documented using left ventricular angiography, nuclear wall motion study, echocardiography within 12 months of study enrollment, or diastolic HF confirmed by chart diagnosis; willing to allow a device attached to their telephone to be installed for the duration of the study; and reside within 30 miles of the performance site (Summa Health System in Akron, Ohio).

Exclusion criteria were: history of a neurological disorder or injury; moderate or severe head injury defined as >10 minutes of loss of consciousness; history of a learning disorder or developmental disability that could interfere with functions of daily living as defined by Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition Test Revision (DSM-IV) criteria; renal failure requiring dialysis; sleep apnea not managed by continuous positive

airway pressure (CPAP) therapy; past or current history of psychotic disorders or bipolar disorder; five-year past or current history of alcohol or drug abuse defined by DSM-IV criteria; history of coronary artery bypass grafting within three months prior to enrollment; and terminal illness (e.g., less than six-month life expectancy). Finally, individuals with severe cognitive impairment (e.g., advanced Alzheimer's dementia) were not included in this study because they likely would not have been able to complete the study.

Materials and procedure

Participants were enrolled from an outpatient hospital-affiliated cardiology clinic through meeting the researchers during their clinic appointment or through mailings sent to their homes. The investigators first administered the Modified MMSE (3MS) to participants to screen for severe dementia, followed by the Rey Auditory Verbal Learning Test (RAVLT), Rey-Osterrieth Complex Figure (ROCF), Trail Making Test (TMT) Parts A and B, Letter-Number Sequencing (LNS), Frontal Assessment Battery (FAB), and Stroop Color-Word Test (SCWT), with the cognitive domains, instructions, scoring, and norms used for each test detailed in Table 1. The aforementioned tests were chosen together to tap into multiple dimensions of cognitive functioning, such as executive functioning, memory, attention, and visuospatial reasoning. These domains are all tested in the ANAM in service of providing a comprehensive view of cognitive functioning. Rather than testing one specific cognitive domain, the investigators chose the aim of the present study to reflect the likely aim of a practitioner performing cognitive screening in a clinic setting: to assess for broad levels of functioning and potentially strengths and weaknesses, especially in the cognitive domains adversely impacted by HF. The 3MS was used to screen for dementia, as it was expanded from the MMSE and designed to probe a greater variety of cognitive functions.⁵⁹ MMSE scores were then derived from administration of the 3MS. Participants completed all tests in pen-and-paper format. Correcting for age, gender, and educational level, raw neuropsychological test scores were converted to T-scores on cited norms; test scores were converted to T-scores. The normed test scores are meant to provide a context for how an individual performed in relationship to their peers' performances as documented in previous studies (see Table 1 for scoring and norms used for each test). The investigators then determined the composite comparison variable for CI by calculating the mean T-scores for the RAVLT delayed recall score, ROCF delayed recall score, TMT Trails B completion time, and FAB total score, LNS total score, and SCWT color-word score.

Following the paper-and-pen neuropsychological test components of the composite comparison variable for CI, participants then completed a 20-minute computerized ANAM battery. Using a computer, keyboard, and mouse, participants completed six tests from the ANAM library: simple reaction time (SRT), two-choice reaction time (2CRT), code substitution-learning (CS-L), matching to sample (MTS), running memory continuous performance task (CPT), and code substitution-delayed (CS-D). These measured attention and reaction time, processing speed, learning, visuospatial working memory, working memory, and delayed memory, respectively. Participants followed the preprogrammed ANAM instructions and practice trials preceding each task independently, with minimal examiner interference aside from ensuring that each participant had sufficient computer knowledge to complete the tests.

The SRT test measured response speed to appearances of a stimulus (a series of * symbols) on the display, upon which participants pressed a button as quickly as possible. The 2CRT test presented participants with either a * or o symbol with designated buttons corresponding to each of the two stimuli. The MTS test presented spatial patterns of eight shaded cells on a 16-cell square grid; the sample pattern was then removed, and participants selected which of two subsequent patterns matched the original sample. In the CPT test, a series of single numbers continuously appeared on the display, one after the other, and participants pressed designated buttons to indicate whether or not the current number matched the preceding number. The code substitution test prompted participants to compare a number-symbol pair with a set of correct number-symbol pairs, collectively defined as the “key,” and to decide if the current pair matched the pair in the key. In the learning phase of the code substitution test (CS-L), participants were presented number-symbol pairs alongside the key for reference at the top of the screen, while the later delayed memory phase (CS-D) presented number-symbol pairs without the key.

Statistical analyses

Means, standard deviations, and frequencies were used to describe the sample. The data were examined to ensure the assumptions of discriminant function analyses were met. No violations of assumptions were present and data were normally distributed (skewness < 3 and kurtosis < 10).

Discriminant function analyses were conducted to determine whether ANAM scores could correctly predict group membership of cognitively impaired and non-impaired (CI and non-CI) patients. As assumptions were met, discriminant function analysis was used to increase power and accuracy of prediction. Additionally, as the outcome variable was artificially dichotomized and the focus of our research question was group prediction, discriminant function analysis was preferable to logistic regression.

Separate discriminant function analyses were conducted for ANAM efficiency scores (number of correct responses per minute) and ANAM accuracy scores (percentage of correct responses). For the discriminant function analysis of efficiency scores, the independent variable was the sum of the ANAM efficiency scores for all the subtests. For the analysis of accuracy scores, the independent variable was the sum of ANAM accuracy scores with the exception of the SRT. The SRT subtest was excluded from the ANAM accuracy composite due to the nature of the subtest (i.e., all participants demonstrated 100% “accuracy” because this task assessed response time rather than true accuracy of response). In addition to the primary analyses, a supplemental discriminant function analysis was conducted to compare the ability of the MMSE to correctly classify individuals as CI or non-CI in our sample. Data analyses were conducted using IBM SPSS version 20.0 statistical software.

Results

Participants consisted of 38 males and 19 females with primarily NYHA Class I (24.6%), II (19.0 %), or III (43.1%) systolic or diastolic HF, with an age range of 48-89 years ($M = 68.86$, $SD = 10.95$). The sample was predominately Caucasian (79.3%). A variety of educational levels was represented, with participants having completed 9th-11th grade (4),

high school (17), technical or trade school (6), some college (19), a bachelor's degree (8), or a master's degree (3). The mean 3MS score was 95.07 ($SD = 4.7$), with scores ranging from 83 to 100. The mean MMSE score was 28.6 ($SD = 1.6$), with scores ranging from 23 to 30. Participants reported an average of 4.6 ($SD = 2.7$) comorbid conditions. As a 3MS score below 78 is a standard cutoff for dementia, no participants in our sample demonstrated pre-existing dementia.

Mean scores and standard deviations, as well as the respective converted scores, for the individual tests used in the global measure of cognitive performance are presented in Table 2. The mean composite CI score was 41.48 ($SD = 8.35$). Using a cutoff of <35 (1.5 S.D. below mean performance), 14 HF patients were considered cognitively impaired and 43 were considered non-impaired. Mean ANAM accuracy and efficiency scores (and standard deviations) for each subtest are presented in Table 3. Three of the six ANAM efficiency scores were significantly correlated with CI: the CSL subtest of learning ($p < .01$), the MTS subtest of visuospatial working memory ($p < .05$), and the CPT subtest of working memory ($p < .01$). For ANAM accuracy scores, the CPT subtest of working memory correlated with CI ($p < .01$).

The Intra-Class Correlation Coefficient (ICC) between the sum of ANAM accuracy scores and neuropsychological battery performance was .007, and the ICC between the sum of ANAM efficiency scores and neuropsychological battery performance was .002. The sum ANAM accuracy and efficiency scores were not correlated with education ($p > .05$). However, age was modestly associated with the sum ANAM accuracy ($r = -.36, p < .01$) and efficiency scores ($r = -.27, p < .05$). In determining whether differential validity was present in the prediction of CI (i.e., in better understanding whether ANAM scores systematically incorrectly predicted CI as a function of demographic factors such as age), moderated multiple regression analysis is a standard means of testing prediction bias.⁶⁰ Step-down hierarchical multiple regression⁶¹ was used to test for age bias. Log-likelihood ratio tests were used to compare the full model (age, ANAM score, and the interaction of the two in predicting CI) vs. the prediction model (ANAM score in predicting CI). Across all model comparisons, there was no evidence for prediction bias. Given the lack of normative data and the absence of evidence of prediction bias, corrected scores for the ANAM were not used in the current analyses. Sensitivity and specificity were examined using Receiver Operating Characteristic (ROC) curve analysis. ANAM accuracy, ANAM efficiency, and MMSE scores demonstrated failing accuracy prediction (area under the curve: accuracy = .22; efficiency = .33, MMSE = .33). ROC curves are presented in Figures 1-3. Discriminant function analyses were conducted to determine whether ANAM performance scores could classify cognitively impaired and non-impaired HF patients on the basis of global cognitive performance (Table 4).

ANAM efficiency scores

A discriminant analysis for ANAM efficiency (throughput) scores was conducted using the <35 cutoff of the composite CI variable to classify HF patients into CI and non-CI groups. ANAM efficiency scores successfully differentiated CI and non-CI patients to a significant degree, Wilk's lambda = .92, $\chi^2(1) = 4.45, p < .05$. Individual correlations between

efficiency scores of each ANAM subtest and T-scores of the cognitive tests incorporated into the composite variable for CI are presented in Table 5.

Overall, the ANAM efficiency measure demonstrated correct classification of 77.2% of HF patients according to the CI and non-CI groups determined by the composite measure of cognitive function. While the ANAM efficiency measure correctly classified 42 out of 43 HF patients as non-impaired (97.7% accuracy for non-CI), this model only classified 2 out of 14 impaired patients as impaired (14.3% accuracy for CI).

ANAM accuracy scores

Another discriminant analysis using the <35 cutoff of the composite CI variable was conducted for ANAM accuracy scores. The SRT test was removed from the analysis of ANAM accuracy due to the universally high accuracy scores resulting from the subtest's goal of assessing reaction time to a single stimulus. ANAM accuracy scores differentiated CI and non-CI patients, Wilk's lambda = .80, $\chi^2(1) = 12.53$, $p < .001$. Individual correlations between accuracy scores of each ANAM subtest (excluding the SRT) and T-scores of the cognitive tests incorporated into the composite variable for CI are presented in Table 6.

The ANAM accuracy measure demonstrated correct classification of 75.4% of HF patients according to the CI and non-CI groups determined by the composite measure of cognitive function. While the ANAM accuracy measure correctly classified 40 out of 43 HF patients as non-impaired (93.0% accuracy for non-CI), this model only classified 3 out of 14 impaired patients as impaired (21.4% accuracy for CI).

In comparison, a discriminant function analysis conducted using the <35 cutoff of the composite CI variable for MMSE scores was non-significant; the MMSE correctly classified 0 HF patients as impaired and 1 patient as non-impaired. The ANAM appeared to more successfully classify CI and non-CI patients than the <35 cutoff of the composite CI variable for MMSE scores. Furthermore, using the standard MMSE <24 cutoff to determine CI, only 1 HF patient was classified as impaired (with a score of 23), whereas the composite CI variable indicated 14 individuals with CI. Using <24 as a MMSE cutoff to determine CI, the ANAM continued to have better predictive success. However, a discriminant function analysis for 3MS scores indicated that 3MS performance successfully differentiated 75.4% of patients as cognitively impaired or non-impaired, Wilk's lambda = .90, $\chi^2(1) = 5.98$, $p < .05$. Similar to ANAM accuracy scores, 3MS scores correctly classified 40 out of 43 HF patients as non-impaired (93.0% accuracy for non-CI) and classified only 3 out of 14 impaired patients as impaired (21.4% accuracy for CI). Using <90 as a 3MS cutoff to determine CI, a more conservative cutoff than <78 used to screen for dementia, only 7 HF patients were considered cognitively impaired.

Discussion

The ANAM was examined as a potential screening tool for detecting CI in HF patients—a population that suffers a high prevalence of CI, yet for which routine cognitive screening is not performed, contributing to undetected CI, compromised self-care, and poor health outcomes.¹⁰ With current measures of CI rates among HF patients being based on screening

tools that vary widely in length, scoring, cutoff points, comprehensiveness of cognitive domains, and the “gold standards” used as comparisons, it is imperative that a standard, sensitive neuropsychological screening tool specific to CI in HF be established. Because the ANAM has already demonstrated utility and sensitivity in monitoring neurocognitive changes in other clinical populations, the present study evaluated the ANAM against a composite model of global cognitive function in detecting CI among HF patients. Performance of the ANAM in correctly classifying CI and non-CI patients was compared to the MMSE, as the MMSE remains the most widely used cognitive test for HF patients in clinical settings.¹³

The present findings indicate that the ANAM may have greater utility in discerning HF patients without CI (97.7% accuracy with ANAM efficiency scores; 93.0% accuracy with ANAM accuracy scores) than patients with CI (14.3% accuracy with ANAM efficiency scores; 21.4% accuracy with ANAM accuracy scores), compared against the composite variable of cognitive domains measured by the RAVLT, ROCF, TMT, LNS, FAB, and SCWT. Both the ANAM efficiency scores ($p < .05$) and accuracy scores ($p < .001$) successfully classified CI and non-CI patients, with the ANAM being markedly more effective than the MMSE, which failed to differentiate CI and non-CI patient groups. ANAM efficiency scores that measured learning and visuospatial working memory correlated with CI, and both ANAM efficiency and accuracy scores for working memory correlated with CI—reflecting a portion of the cognitive domains affected by HF. Having correctly classified approximately three-quarters of HF patients (77.2% with ANAM efficiency scores; 75.4% with ANAM accuracy scores) into CI and non-CI groups, the ANAM may not be a sufficiently sensitive tool for determining CI in patients with HF because similar to the 3MS (which was administered to screen for dementia), the ANAM failed to detect one-quarter of HF patients with CI. In addition, the ANAM, MMSE, and CI composite model demonstrated poor diagnostic accuracy according to ROC analysis.

This study contributes to the issue in the existing literature of developing an ideal method of screening for CI in this population. While the ANAM was more successful than the MMSE in differentiating CI and non-CI patients, particularly for the non-CI group, the ANAM only detected CI among the impaired HF patients to a limited extent in this sample. The composite model, by comparison, was used in this study as a representation of global cognitive function, but its length precludes the efficient, brief administration necessary for practical use in clinical settings. Further research is needed, potentially using differently configured batteries of ANAM subtests or other tailored neuropsychological tools with adequate sensitivity for this population.

While usage of the MMSE continues to surpass that of other cognitive screens in many clinical settings—contributing to the rationale of using the MMSE as comparison against the ANAM in the present study—other cognitive tests have also shown promise as effective screening tools. Of note, the MoCA has shown sensitivity in detecting cognitive deficits among HF patients with greater frequency and at subtler levels of CI than the MMSE, particularly in the domains of executive function, visuospatial ability, and memory.^{26,62} As a brief pen-and-paper test, the MoCA would be as clinically practical to administer as the MMSE in this population. However, recent findings have also shown the MoCA and MMSE

to be comparable in differentiating CI and non-CI patients, with both tests incorrectly classifying approximately one-third of HF patients.²⁴ As the MoCA continues to become more widely utilized among clinicians, it would be useful for future research to include the MoCA in other comparison studies of neuropsychological tests for HF patients, and to evaluate the utility of the MoCA more fully in this population.

The present study was limited by a relatively small sample size; further studies examining the performance of the ANAM in larger samples of HF patients are needed in order to achieve sufficient statistical power to confirm the present findings. Furthermore, no population-based normative data matched to the HF patients' demographics—especially with regards to age—currently exist for the ANAM, which evaluates CI based on the number of standard deviations that an individual's scores fall below the mean ANAM efficiency scores of an appropriate control population.⁶³ Until adequate norms are established or further studies are conducted with appropriate age-matched control groups in comparison to HF patients, the present study may need to be replicated in a larger sample to determine whether age significantly impacts the utility of the ANAM. In addition, although patients were informally monitored for fatigue, anxiety, and any difficulty with computer usage, these factors were not formally controlled for or assessed as covariates in the analyses and may impact performance. In this study, all participants received clear verbal and written instructions until they stated that they fully understood and were comfortable using the computer to complete the ANAM, which should be an important component of administering this neuropsychological test. Overall, further research is necessary to evaluate or develop a brief, sensitive screening instrument specifically designed to monitor CI in HF.

Although routine screening for CI in HF patients is a crucial goal to improve patient outcomes, there is no consensus to date on an optimal neuropsychological test with an established CI cutoff threshold that is sensitive and specific to distinguishing the levels and domains of CI typically found in HF patients.⁶⁴ Based on the present findings, additional investigation of cognitive testing for HF patients or alternative ANAM subtest configurations in this clinical population are warranted. This study has direct relevance to clinicians and healthcare providers by highlighting the need for a neuropsychological instrument designed for routine, practical implementation in patients with HF. A standard screening tool would be essential not only for comparing CI in HF patients across different clinical studies, but also for tailoring HF management and self-care regimens to improve the quality of life and healthcare costs associated with comorbid CI and HF.

Acknowledgements

This research was supported by from the National Heart Lung and Blood Institute, National Institutes of Health [1 R01 HL096710-01A1], the Kent State University Initiative for Clinical and Translational Research, and Case Western Reserve University School of Nursing.

References

1. Roger VL, Go AS, Lloyd-Jones DM, et al. Heart disease and stroke statistics--2012 update: A report from the American Heart Association. *Circulation*. 2012; 125(1):e2–e220. [PubMed: 22179539]
2. Roger VL, Weston SA, Redfield MM, et al. Trends in heart failure incidence and survival in a community-based population. *JAMA*. 2004; 292(3):344–350. [PubMed: 15265849]

3. Almeida OP, Garrido GJ, Beer C, Lautenschlager NT, Arnolda L, Flicker L. Cognitive and brain changes associated with ischaemic heart disease and heart failure. *Eur Heart J*. 2012; 33(14):1769–1776. [PubMed: 22296945]
4. Athilingam P, King KB. Heart and brain matters in heart failure: A literature review. *J N Y State Nurses Assoc*. 2007; 38(2):13–19. [PubMed: 18683451]
5. Sauve MJ, Lewis WR, Blankenbiller M, Rickabaugh B, Pressler SJ. Cognitive impairments in chronic heart failure: A case controlled study. *J Card Fail*. 2009; 15(1):1–10. [PubMed: 19181287]
6. Pressler SJ, Subramanian U, Kareken D, et al. Cognitive deficits in chronic heart failure. *Nurs Res*. 2010; 59(2):127–139. [PubMed: 20216015]
7. Bennett SJ, Sauve MJ. Cognitive deficits in patients with heart failure: A review of the literature. *J Cardiovasc Nurs*. 2003; 18(3):219–242. [PubMed: 12837012]
8. Pressler SJ. Cognitive functioning and chronic heart failure: A review of the literature (2002-july 2007). *J Cardiovasc Nurs*. 2008; 23(3):239–249. [PubMed: 18437066]
9. Vogels RL, Oosterman JM, van Harten B, et al. Profile of cognitive impairment in chronic heart failure. *J Am Geriatr Soc*. 2007; 55(11):1764–1770. [PubMed: 17727641]
10. Cameron J, Worrall-Carter L, Page K, Riegel B, Lo SK, Stewart S. Does cognitive impairment predict poor self-care in patients with heart failure? *Eur J Heart Fail*. 2010; 12(5):508–515. [PubMed: 20354031]
11. Zuccala G, Onder G, Pedone C, et al. Cognitive dysfunction as a major determinant of disability in patients with heart failure: Results from a multicentre survey. *J Neurol Neurosurg Psychiatry*. 2001; 70(1):109–112. [PubMed: 11118258]
12. Zuccala G, Pedone C, Cesari M, et al. The effects of cognitive impairment on mortality among hospitalized patients with heart failure. *Am J Med*. 2003; 115(2):97–103. [PubMed: 12893394]
13. Davis KK, Allen JK. Identifying cognitive impairment in heart failure: A review of screening measures. *Heart Lung* [– 2]. 2013; 42(2):92–97.
14. Folstein MF, Folstein SE, McHugh PR. “Mini-mental state”. A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975; 12(3):189–198. [PubMed: 1202204]
15. Zuccala G, Cattel C, Manes-Gravina E, Di Niro MG, Cocchi A, Bernabei R. Left ventricular dysfunction: A clue to cognitive impairment in older patients with heart failure. *J Neurol Neurosurg Psychiatry*. 1997; 63(4):509–512. [PubMed: 9343133]
16. Cacciatore F, Abete P, Ferrara N, et al. Congestive heart failure and cognitive impairment in an older population. *osservatorio geriatrico campano study group*. *J Am Geriatr Soc*. 1998; 46(11):1343–1348. [PubMed: 9809754]
17. Almeida OP, Tamai S. Congestive heart failure and cognitive functioning amongst older adults. *Arq Neuropsiquiatr*. 2001; 59(2-B):324–329. [PubMed: 11460173]
18. Ekman I, Fagerberg B, Skoog I. The clinical implications of cognitive impairment in elderly patients with chronic heart failure. *J Cardiovasc Nurs*. 2001; 16(1):47–55. [PubMed: 11587240]
19. Haworth JE, Moniz-Cook E, Clark AL, Wang M, Waddington R, Cleland JG. Prevalence and predictors of anxiety and depression in a sample of chronic heart failure patients with left ventricular systolic dysfunction. *Eur J Heart Fail*. 2005; 7(5):803–808. [PubMed: 16054436]
20. Lancu I, Olmer A. The minimental state examination--an up-to-date review. *Harefuah*. 2006; 145(9):687–90, 701. [PubMed: 17078433]
21. Antonelli Incalzi R, Cesari M, Pedone C, Carosella L, Carbonin PU. Gruppo Italiano di Farmacovigilanza nell'Anziano. Construct validity of the abbreviated mental test in older medical inpatients. *Dement Geriatr Cogn Disord*. 2003; 15(4):199–206. [PubMed: 12626852]
22. Nys GM, van Zandvoort MJ, de Kort PL, Jansen BP, Kappelle LJ, de Haan EH. Restrictions of the mini-mental state examination in acute stroke. *Arch Clin Neuropsychol*. 2005; 20(5):623–629. [PubMed: 15939186]
23. Ismail Z, Rajji TK, Shulman KI. Brief cognitive screening instruments: An update. *Int J Geriatr Psychiatry*. 2010; 25(2):111–120. [PubMed: 19582756]
24. Hawkins MA, Gathright EC, Gunstad J, et al. The MoCA and MMSE as screeners for cognitive impairment in a heart failure population: A study with comprehensive neuropsychological testing. *Heart Lung*. 2014; 43(5):462–468. [PubMed: 25035250]

25. Crum RM, Anthony JC, Bassett SS, Folstein MF. Population-based norms for the mini-mental state examination by age and educational level. *JAMA*. 1993; 269(18):2386–2391. [PubMed: 8479064]
26. Cameron J, Worrall-Carter L, Page K, Stewart S, Ski CF. Screening for mild cognitive impairment in patients with heart failure: Montreal cognitive assessment versus mini mental state exam. *Eur J Cardiovasc Nurs*. 2012; 12(3):252–260. [PubMed: 22514141]
27. Malloy PF, Cummings JL, Coffey CE, et al. Cognitive screening instruments in neuropsychiatry: A report of the committee on research of the american neuropsychiatric association. *J Neuropsychiatry Clin Neurosci*. 1997; 9(2):189–197. [PubMed: 9144098]
28. Alosco ML, Brickman AM, Spitznagel MB, et al. Cerebral perfusion is associated with white matter hyperintensities in older adults with heart failure. *Congest Heart Fail*. 2013; 19(4):E29–34. [PubMed: 23517434]
29. Casas-Vara A, Santolaria F, Fernandez-Bereciartua A, Gonzalez-Reimers E, Garcia-Ochoa A, Martinez-Riera A. The obesity paradox in elderly patients with heart failure: Analysis of nutritional status. *Nutrition*. 2012; 28(6):616–622. [PubMed: 22261572]
30. Dodson JA, Truong TT, Towle VR, Kerins G, Chaudhry SI. Cognitive impairment in older adults with heart failure: Prevalence, documentation, and impact on outcomes. *Am J Med*. 2013; 126(2):120–126. [PubMed: 23331439]
31. Gonzalez MJ, Sanchez Benavides G, Verdu Rotellar JM, et al. Cognitive impairment in heart failure: Clinical and functional markers and vital status at 12 months follow-up. *Eur Heart J*. 2013; 34(suppl 1):294–295.
32. O'Donnell M, Teo K, Gao P, et al. Cognitive impairment and risk of cardiovascular events and mortality. *Eur Heart J*. 2012; 33(14):1777–1786. [PubMed: 22551598]
33. Vellone E, Alvaro R, Fida R, et al. Self-care confidence mediates the relationship between cognition and self-care behaviors in adults with heart failure. *Circulation*. 2013; 128:A16531.
34. Yano Y, Bakris GL, Inokuchi T, et al. Association of cognitive dysfunction with cardiovascular disease events in elderly hypertensive patients. *J Hypertens*. 2014; 32(2):423–431. [PubMed: 24351802]
35. Ye S, Graham S, Qian M, et al. Cognitive function in ambulatory patients with systolic heart failure: Insights from the warfarin versus aspirin in reduced cardiac ejection fraction (WARCEF) trial. *J Am Coll Cardiol*. 2014; 63(12_S)
36. Reeves D, Kane R, Winter K. Automated neuropsychological assessment metrics (ANAM): Test administrator's guide version 3.11. 1995:NCRF-95-01.
37. Daniel JC, Olesniewicz MH, Reeves DL, et al. Repeated measures of cognitive processing efficiency in adolescent athletes: Implications for monitoring recovery from concussion. *Neuropsychiatry Neuropsychol Behav Neurol*. 1999; 12(3):167–169. [PubMed: 10456800]
38. Segalowitz SJ, Mahaney P, Santesso DL, MacGregor L, Dywan J, Willer B. Retest reliability in adolescents of a computerized neuropsychological battery used to assess recovery from concussion. *NeuroRehabilitation*. 2007; 22(3):243–251. [PubMed: 17917174]
39. Patel AV, Mihalik JP, Notebaert AJ, Guskiewicz KM, Prentice WE. Neuropsychological performance, postural stability, and symptoms after dehydration. *J Athl Train*. 2007; 42(1):66–75. [PubMed: 17597946]
40. Lowe M, Harris W, Kane RL, Banderet L, Levinson D, Reeves D. Neuropsychological assessment in extreme environments. *Arch Clin Neuropsychol*. 2007; 22(Suppl 1):S89–99. [PubMed: 17147982]
41. Gamache GL, Levinson DM, Reeves DL, Bidyuk PI, Brantley KK. Longitudinal neurocognitive assessments of ukrainians exposed to ionizing radiation after the chernobyl nuclear accident. *Arch Clin Neuropsychol*. 2005; 20(1):81–93. [PubMed: 15620815]
42. McDiarmid MA, Engelhardt S, Oliver M, et al. Health effects of depleted uranium on exposed gulf war veterans: A 10-year follow-up. *J Toxicol Environ Health A*. 2004; 67(4):277–296. [PubMed: 14713562]
43. Gottschalk LA, Bechtel RJ, Maguire GA, et al. Computer detection of cognitive impairment and associated neuropsychiatric dimensions from the content analysis of verbal samples. *Am J Drug Alcohol Abuse*. 2002; 28(4):653–670. [PubMed: 12492262]

44. Wilken JA, Sullivan CL, Lewandowski A, Kane RL. The use of ANAM to assess the side-effect profiles and efficacy of medication. *Arch Clin Neuropsychol*. 2007; 22(Suppl 1):S127–33. [PubMed: 17116387]
45. Vasterling JJ, Proctor SP, Amoroso P, Kane R, Heeren T, White RF. Neuropsychological outcomes of army personnel following deployment to the Iraq war. *JAMA*. 2006; 296(5):519–529. [PubMed: 16882958]
46. Ivins BJ, Kane R, Schwab KA. Performance on the automated neuropsychological assessment metrics in a nonclinical sample of soldiers screened for mild TBI after returning from Iraq and Afghanistan: A descriptive analysis. *J Head Trauma Rehabil*. 2009; 24(1):24–31. [PubMed: 19158593]
47. Girard P. Military and VA telemedicine systems for patients with traumatic brain injury. *J Rehabil Res Dev*. 2007; 44(7):1017–1026. [PubMed: 18075958]
48. Luethcke CA, Bryan CJ, Morrow CE, Isler WC. Comparison of concussive symptoms, cognitive performance, and psychological symptoms between acute blast-versus nonblast-induced mild traumatic brain injury. *J Int Neuropsychol Soc*. 2011; 17(1):36–45. [PubMed: 21083963]
49. Wright JK, Zant E, Groom K, Schlegel RE, Gilliland K. Case report: Treatment of mild traumatic brain injury with hyperbaric oxygen. *Undersea Hyperb Med*. 2009; 36(6):391–399. [PubMed: 20112530]
50. Brunner HI, Ruth NM, German A, et al. Initial validation of the pediatric automated neuropsychological assessment metrics for childhood-onset systemic lupus erythematosus. *Arthritis Rheum*. 2007; 57(7):1174–1182. [PubMed: 17907235]
51. Roebuck-Spencer TM, Yarburo C, Nowak M, et al. Use of computerized assessment to predict neuropsychological functioning and emotional distress in patients with systemic lupus erythematosus. *Arthritis Rheum*. 2006; 55(3):434–441. [PubMed: 16739211]
52. Wilken JA, Kane R, Sullivan CL, et al. The utility of computerized neuropsychological assessment of cognitive dysfunction in patients with relapsing-remitting multiple sclerosis. *Mult Scler*. 2003; 9(2):119–127. [PubMed: 12708806]
53. Woodhouse J, Heyanka DJ, Scott J, et al. Efficacy of the ANAM general neuropsychological screening battery (ANAM GNS) for detecting neurocognitive impairment in a mixed clinical sample. *Clin Neuropsychol*. 2013; 27(3):376–385. [PubMed: 23368639]
54. Levinson D, Reeves D, Watson J, Harrison M. Automated neuropsychological assessment metrics (ANAM) measures of cognitive effects of Alzheimer's disease. *Arch Clin Neuropsychol*. 2005; 20(3):403–408. [PubMed: 15797175]
55. Thorne DR. Throughput: A simple performance index with desirable characteristics. *Behav Res Methods*. 2006; 38(4):569–573. [PubMed: 17393825]
56. Jones WP, Loe SA, Krach SK, Rager RY, Jones HM. Automated neuropsychological assessment metrics (ANAM) and Woodcock-Johnson III tests of cognitive ability: A concurrent validity study. *Clin Neuropsychol*. 2008; 22(2):305–320. [PubMed: 17853133]
57. Snyder PJ, Jackson CE, Petersen RC, et al. Assessment of cognition in mild cognitive impairment: A comparative study. *Alzheimers Dement*. 2011; 7(3):338–355. [PubMed: 21575877]
58. Kabat MH, Kane RL, Jefferson AL, DiPino RK. Construct validity of selected automated neuropsychological assessment metrics (ANAM) battery measures. *Clin Neuropsychol*. 2001; 15(4):498–507. [PubMed: 11935451]
59. Teng EL, Chui HC. The modified mini-mental state (3MS) examination. *J Clin Psychiatry*. 1987; 48(8):314–318. [PubMed: 3611032]
60. Nunnally, JC.; Bernstein, IH. *Psychometric theory*. 3rd ed.. McGraw-Hill; New York: 1994.
61. Lautenschlager GJ, Mendoza JL. A step-down hierarchical multiple regression analysis for examining hypotheses about test bias in prediction. *Appl Psychol Meas*. 1986; 10:133–139.
62. Athilingam P, King KB, Burgin SW, Ackerman M, Cushman LA, Chen L. Montreal cognitive assessment and mini-mental status examination compared as cognitive screening tools in heart failure. *Heart Lung*. 2011
63. Antonchak MA, Saoudian M, Khan AR, Brunner HI, Luggen ME. Cognitive dysfunction in patients with systemic lupus erythematosus: A controlled study. *J Rheumatol*. 2011; 38(6):1020–1025. [PubMed: 21459946]

64. Cameron J, Ski CF, Thompson DR. Cognitive impairment in chronic heart failure and the need for screening. *Am J Cardiol*. 2011; 107(10):1547–1548. [PubMed: 21539950]
65. Rey, A. L'examen clinique en psychologie. Presses Universitaires de France; Paris: 1964.
66. Ivnik RJ, Malec JF, Smith GE, et al. Mayo's older americans normative studies: WAIS-R norms for ages 56 to 97. *Clin Neuropsychol*. 1992; 6(S1):1–30.
67. Osterrieth PA. Le test de copie d'une figure complexe; contribution à l'étude de la perception et de la mémoire. *Ar de Ps*. 1944; 30:206–353.
68. Rey A. L'examen psychologique dans les cas d'encéphalopathie traumatique. *Ar de Ps*. 1941; 28:286–340.
69. Spreen, O.; Strauss, E. A compendium of neuropsychological tests: Administration, norms, and commentary: Administration, norms, and commentary. Oxford University Press; USA: 1998.
70. Reitan, RM. Trail making manual for administration, scoring, and interpretation. Department of Neurology, Section of Neuropsychology, Indiana University Medical Center; Indianapolis: 1958.
71. Tombaugh TN. Trail making test A and B: Normative data stratified by age and education. *Arch Clin Neuropsychol*. 2004; 19(2):203–214. [PubMed: 15010086]
72. Wechsler, D. WAIS-III: Administration and scoring manual: Wechsler adult intelligence scale. Psychological Corporation; 1997.
73. Dubois B, Slachevsky A, Litvan I, Pillon B. The FAB: A frontal assessment battery at bedside. *Neurology*. 2000; 55(11):1621–1626. [PubMed: 11113214]
74. Appollonio I, Leone M, Isella V, et al. The frontal assessment battery (FAB): Normative values in an italian population sample. *Neurol Sci*. 2005; 26(2):108–116. [PubMed: 15995827]
75. Golden CJ. Stroop color and word test: Cat. no. 30150M; a manual for clinical and experimental uses. Stoelting. 1978
76. Ivnik RJ, Malec JF, Smith GE, Tangalos EG, Petersen RC. Neuropsychological tests' norms above age 55: COWAT, BNT, MAE token, WRAT-R reading, AMNART, STROOP, TMT, and JLO. *Clin Neuropsychol*. 1996; 10(3):262–278.

Figure 1. ROC curve showing discrimination between individuals with vs. without CI by ANAM efficiency scores.

Figure 2.
ROC curve showing discrimination between individuals with vs. without CI by ANAM accuracy scores.

Figure 3. ROC curve showing discrimination between individuals with vs. without CI by MMSE scores.

Table 1

Cognitive domains, instructions, scoring, and norms used for each component of the composite measure of cognitive performance.

Cognitive test	Cognitive domains	Instructions	Scoring	Norms
RAVLT ⁶⁵	Auditory-verbal learning and memory through a list-learning paradigm	Participants heard a list of 15 nouns, read aloud by an examiner, and were asked to recall verbally as many words as possible. After four more rounds of auditory presentation and free recall of the same list, participants were then presented an unrelated, 15-word distractor list in the same manner and were asked to recall as many items from the second list as they could. Immediately following the distractor list, participants were then prompted to freely recall words from the initial list. After a 20-minute delay, during which other cognitive tests were administered, participants were again instructed to recall items from the initial list.	The number of correctly recalled words out of 15 constituted the RAVLT delayed recall score.	[⁶⁶]
ROCF ^{67,68}	Visuospatial functions, attention, planning, and working memory	Participants were asked to draw a complex line figure on a blank sheet of paper, first using a copy of the figure for reference, then relying on immediate recall to draw the figure from memory. Following a 20-minute delay—after the RAVLT delay period has ended—participants were again instructed to draw the complex figure from memory.	The delayed recall drawing was scored according to the correct reproduction and location of 18 elements.	[⁶⁹]
TMT Trails B ⁷⁰	Visual attention, task switching, processing speed, and executive functions	Participants were prompted to connect 25 dots on a sheet of paper in a consecutive manner. Participants were first given a sample sheet (Trails A), in which the dots were numbered 1 to 25 and must be connected in sequential order (i.e., 1-2-3). In Trails B, the dots were either numbered (1 to 13) or lettered (A to L), and participants were instructed to connect the dots sequentially according to an ascending, alternating pattern of numbers and letters (i.e., 1-A-2-B-3-C) as quickly as possible, without lifting the pen from the sheet.	The completion time for each part was recorded, and the time for TMT Trails B was used.	[⁷¹]
LNS ⁷²	Attention, auditory working memory, and processing speed	The examiner verbally presented strings of numbers and letters, which lengthened by one digit after three trials of one length, beginning at two digits and increasing up to eight digits. After each string, participants were asked to recall the numbers in ascending order, followed by the letters in alphabetical order (e.g., A-3 would be reordered to 3-A; C-2-S-6-F-9 would be reordered to 2-6-9-C-F-S). The LNS was discontinued if participants failed to correctly reorder three consecutive strings of the same length.	The final score was the number of correct responses out of a total possible of 21.	[⁷²]
FAB ⁷³	Abstract reasoning, lexical fluency, motor skills, behavioral self-regulation, inhibitory control, and autonomy from environmental stimuli	These markers of executive function were measured using subtests asking participants to identify the categorical link between two items (e.g., an apple and a banana: fruit), to say as many words as possible beginning with a given letter within 60 seconds, to correctly execute a series of hand movements, to provide a response conflicting with the examiner's cues (e.g., tapping twice when the examiner taps once), to withhold a previous response (e.g., not tapping when the examiner taps), and to inhibit prehension behaviors when the examiner touches the palms of participants' hands, respectively.	Each of the six subtests was scored from 0-3 for a final score out of a total possible of 18.	[⁷⁴]
SCWT ⁷⁵	Selective attention, processing speed, response inhibition, and executive functions	Participants were timed on trials requiring them to read aloud the names of colors printed in black ink, to name colors (red, green, or blue) printed as XXXX, and to name colors printed as incongruent color words.	Color-word scores were calculated according to Golden's method. ⁷⁵	[⁷⁶]

Table 2

Mean scores (S.D.) and converted T-scores (S.D.) for the tests used in the composite measure of cognitive performance.

Cognitive test	Mean (S.D.)	Converted score (S.D.)
RAVLT: <i>delayed recall score</i>	42.68 (10.90)	51.88 (14.02)
ROCF: <i>delayed recall score</i>	15.10 (7.07)	50.93 (15.03)
TMT Trails B: <i>completion time</i>	132.67 (85.63)	34.57 (23.37)
LNS: <i>total score</i>	8.77 (2.38)	50.70 (6.80)
FAB: <i>total score</i>	16.60 (1.87)	48.67 (17.64)
SCWT: <i>color-word score</i>	30.98 (9.60)	49.42 (10.46)

Table 3

Mean (S.D.) measures of accuracy and efficiency on each ANAM subtest.

ANAM subtest	Accuracy	Efficiency (Throughput)
Simple reaction time (SRT)	—	138.02 (59.70)
Attention/Processing speed (2CRT)	90.57 (20.57)	89.63 (27.79)
Learning (CS-L)	94.04 (11.81)	26.71 (6.88)
Spatial working memory (MTS)	75.74 (21.95)	14.73 (7.06)
Working memory (CPT)	65.83 (15.79)	41.29 (22.93)
Delayed memory (CS-D)	57.61 (24.87)	17.92 (6.72)

Table 4

Results of discriminant function analyses conducted for ANAM accuracy and efficiency scores.

ANAM measure	Eigenvalue	Canonical correlation	Wilk's lambda	χ^2	<i>p</i>
Efficiency	.09	.28	.92	4.46	.035
Accuracy	.26	.45	.80	12.53	.000

Table 5

Pearson correlations between the efficiency scores of each ANAM subtest and T-scores of each cognitive test used in the composite CI variable.

Component of the composite CI measure	<i>ANAM subtest</i>					
	SRT	2CRT	CS-L	MTS	CPT	CS-D
RAVLT	.245	.133	.454 **	.356 **	.324 *	.332 *
ROCF	.361 **	.297 *	.133	.186	.201	.133
TMT Trails B	.022	.142	.283 *	.156	.265 *	.151
LNS	.271 *	.241	.320 *	.316 *	.283 *	.063
FAB	.251	.048	.319 *	.255	.285 *	.153
SCWT	-.033	.059	.252	-.019	.140	-.022

*** $p < .001$.

*
 $p < .05$

**
 $p < .01$

Table 6

Pearson correlations between the accuracy scores of each ANAM subtest and T-scores of each cognitive test used in the composite CI variable.

Component of the composite CI measure	<i>ANAM subtest</i>					
	SRT	2CRT	CS-L	MTS	CPT	CS-D
RAVLT	—	.015	.060	.282 *	.351 **	.225
ROCF	—	.134	.132	.148	.238	.263 *
TMT Trails B	—	.108	.262 *	.167	.220	.106
LNS	—	.066	-.027	.198	.286 *	.217
FAB	—	-.092	.042	.218	.305 *	.208
SCWT	—	-.038	-.080	-.126	.101	-.060

*** $p < .001$.

*
 $p < .05$

**
 $p < .01$