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Cognitive Assessment CODEBOOK

Knight Alzheimer's Disease Research Center
Saint Louis, Missouri
2026

Introduction

This document was painstakingly developed by Lisa Schoolcraft and based on prior versions developed by Denise Maue Dreyfus. This serves as a comprehensive codebook for all cognitive assessments collected at the Joanne F. and Charles Knight Alzheimer Disease Research Center (Knight ADRC) at Washington University in St. Louis. All Knight ADRC participants undergo cognitive testing as a part of their research participation. Since the inception of the Knight ADRC in 1979, the tests used have naturally evolved as the scientific understanding of Alzheimer disease has advanced and has focused increasingly on earlier detection. There are a handful of measures that have been consistently collected for decades, but other measures were introduced and then dropped for various reasons. Investigators using this codebook are encouraged to refer to the Cognitive Assessment Timeline in section 7 of this document that gives an overview of the time periods and availability of cognitive assessments over the years. For example, the Associate Learning test from the Wechsler Memory Scale has been continuously collected since 1979 and will be widely available for most Knight ADRC participants. In contrast, the Reading Span task was administered only from 2009-2014 and will have much less available data.

Which cognitive tests should I use?

In general, if you are interested in cognitive tests that have been administered to participants with biomarker data, it is strongly suggested that you use the Knight ADRC Preclinical Alzheimer's Cognitive Composite (Knight PACC) and/or the domain- specific cognitive composite measures described in section 8 of this document. These measures have been equated across test versions and have excellent psychometric characteristics in terms of reliability and have proven to be sensitive to biomarker load and genetic risk. They will also be the most broadly available for use across the various Memory and Aging Project (MAP) and Knight ADRC cohorts.

Full details of each cognitive assessment test can be viewed in Section 3. Cognitive Tests A-Z. Test details include the date the tests were added, dropped, references for standard tests, test descriptions, subtests (if applicable), variable names, shorthand labels, the range of scores on the specified variable, and the direction of quantitative scales (e.g., high score = good).

Template:

NAME OF TEST				
Date added				
Date dropped (if applicable)				
References				
Description				
VARIABLE NAME	*Shorthand label*			
	Range:	*# - ##*	Score:	*(e.g., good, poor, etc.)*

- Jason Hassenstab, PhD
Knight ADRC Cognitive Assessment Unit Leader

Knight ADRC Cognitive Batteries

OFFICE

Designed to be administered to MAP participants. The office battery consists of the NACC Uniform Data Set (UDS) version 4 plus Washington University specific tests. This battery is the primary and preferred method for MAP cognitive assessments
~2 hours

REMOTE

Designed to be administered to MAP participants. The remote battery was instated in April of 2020. Administered via video call, phone call, or combination of both. The remote battery remains an option for participants who cannot otherwise complete testing at the MAP office
~1.5 hours

COMPASS

Designed to be administered to participants enrolled in the COMPASS study. Abbreviated version of the MAP cognitive assessment battery. Administered in person at participating offsite facilities
~45 minutes

ACS (2012 - 2020)

Designed to be administered to participants enrolled in the Adult Children Study before age 65; participants who were enrolled at 65 years or older received the standard Knight ADRC battery.

Current Knight ADRC Cognitive Batteries

Click on battery names for more information→	OFFICE	REMOTE	COMPASS
Ambulatory Research in Cognition (ARC)	X	X	
Benson Complex Figure Copy	X		
Category Fluency – Animals and Vegetables	X	X	X
Craft Story 21 Recall	X	X	X
Free and Cued Selective Reminding Test (FCSRT)	X	X	X
Geriatric Depression Scale	X	X	
Handedness	X	X	X
Mini-Mental State Examination (MMSE)	X		X
Montreal Cognitive Assessment (MoCA)			X
Multilingual Naming Test (MINT)	X	X	X
Number Span Test	X	X	
Number Symbol Test – Web-based	X	X	X
Psychomotor Vigilance Task (PVT)	X	X	
Rey Auditory Verbal Learning Test (RAVLT)	X	X	
Slosson Oral Reading Test (SORT-R)	X	X	X
Stroop Color Only – Web-based	X	X	
Sustained Attention To Response Task (SART)	X	X	
Switching Task (CVOE)	X	X	
Trail Making Test A and B	X		X
Verbal Fluency: Phonemic Test	X	X	
WMS: Associate Learning	X	X	

Identification/Additional Information

INFO NAME	DESCRIPTION	ALLOWABLE CODES
ID	Participant identification number	
PSY_DATE	Date of cognitive assessment	
PLACE	Location of test	1=MAP office or remote, 2=Home, 3=Nursing home, 4=Hospital, 5=Daycare
MODCOMM	Modality of Communication used for remote assessments	1=Telephone, 2=Zoom/video, 3=Combination
TESTER	Identification of tester. Coded by number	
TIME	Visit number	

Missing Data Codes

MISSING DATA CODE	DESCRIPTION
I	INJURY/ILLNESS refers to missing data due to broken finger, amputated digit, or an illness like polyneuropathy, arthritis, stroke, Parkinson's disease, deafness, or severe loss of vision. This code is related to motor tasks such as writing or other movements. This should not be confused with the next code, C.
C	COULDN'T DO because of memory loss or cognitive confusion. The tester must attempt to administer the task to use this code.
M	MISSING is coded when the tester chose not to give a measure because the participant was uncooperative, agitated, hostile, had already demonstrated severe language disturbance, or the test
R	REFUSED is the code used when the tester tried to administer the task, but the participant refused to do it (e.g., "I don't want to do that").
.	Originally a DOT was used to indicate missing data for any reason. Therefore, data from earlier times of testing will have this generic code.
T	TREMOR is observed by the tester as the reason measure are not completed, specifically in the case of individuals in the Parkinson's disease sample but may be used with any tremor.
D	No computerized test due to technical difficulties.
95/995	Missing data code from National Alzheimer's Coordinating Center (NACC) for Physical problem. Equivalent to letter codes 'I' and 'T'
96/996	Missing data code from National Alzheimer's Coordinating Center (NACC) for Cognitive/behavior problem. Equivalent to letter code 'C'
97/997	Missing data code from National Alzheimer's Coordinating Center (NACC) for Other problem. Equivalent to letter codes 'M', '.', and 'D'
98/998	Missing data code from National Alzheimer's Coordinating Center (NACC) for Verbal refusal. Equivalent to letter code 'R'

Please note: The single letter codes are SAS special missing values.

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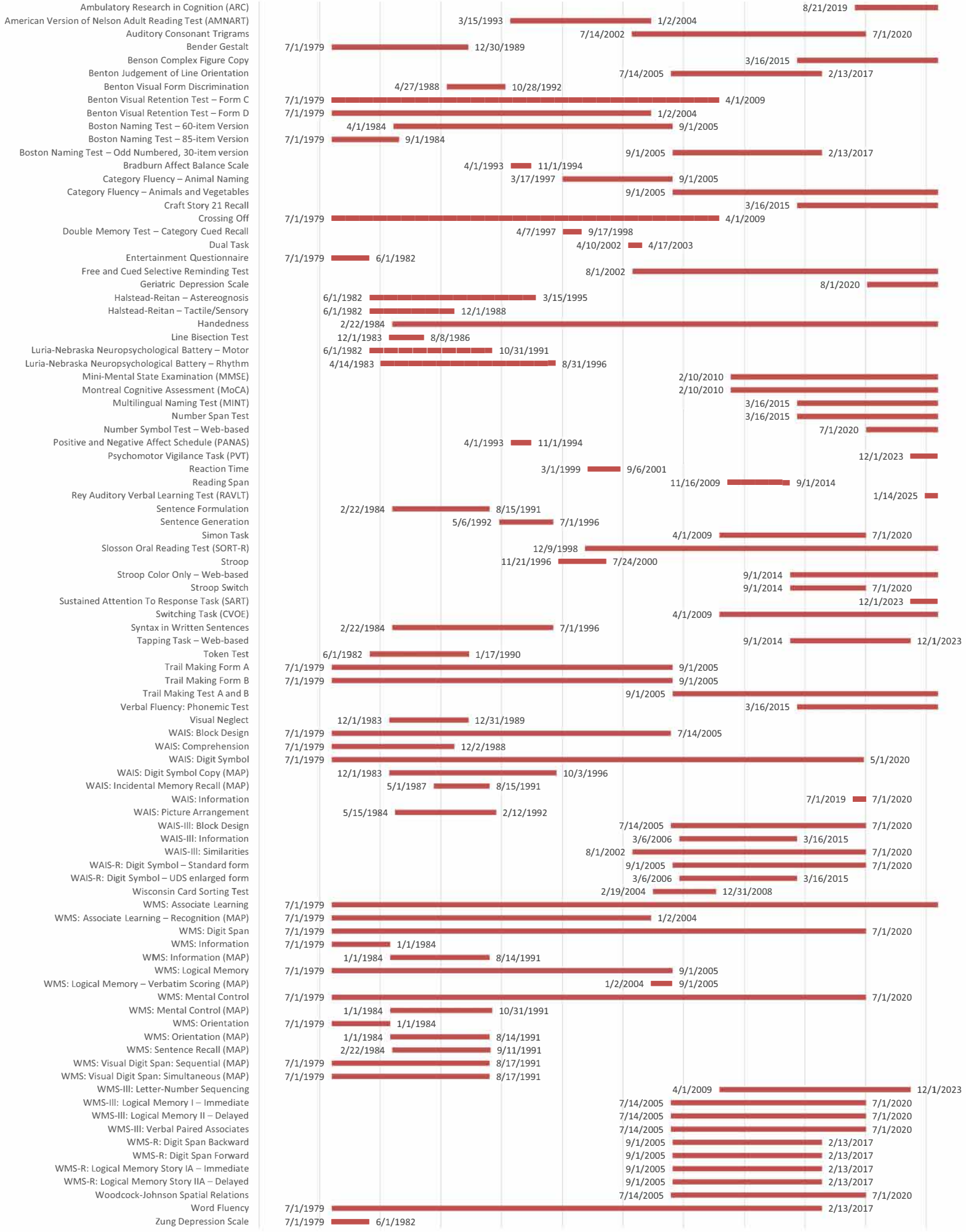
Knight ADRC Cognitive Assessment Timeline



Knight ADRC Cognitive Tests A-Z

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American Version of Nelson Adult Reading Test (AMNART)

DATE ADDED	3/15/1993
DATE DROPPED	1/2/2004
DESCRIPTION	Beginning 9/12/1994 the test items were reduced from 50 to 45. The tests prior to that time were rescored retrospectively so that the items and scores in the database are the same.
REFERENCE	Grober, E. & Sliwinski, M. (1991). Development and Validation of a Model for Estimating Premorbid Verbal Intelligence in the Elderly. Journal of Clinical and Experimental Neuropsychology, 13, 933-949.

PSY254 Total number of errors

RANGE 0 - 45 **HIGH SCORE** good

Auditory Consonant Trigrams

DATE ADDED	7/14/2002
DATE DROPPED	7/1/2020
DESCRIPTION	Three consonants are read to the participant followed immediately by a random number. The participant is asked to count out loud backwards from that number by threes for either 9, 18, or 36 seconds determined randomly. The participant then recalls the consonant trigram. The score is the sum of the number of consonants recalled correctly over 20 trials.
REFERENCE	Brown, J. (1958). Some tests of the decay theory of immediate memory. Quarterly Journal of Experimental Psychology, 10, 12-21. Peterson, L., & Peterson, M. J. (1959). Short-term retention of individual verbal items. Journal of Experimental Psychology, 58, 193-198.

TRIGRAMS Auditory Consonant Trigrams

RANGE 0 - 60 **HIGH SCORE** good

Bender Gestalt

DATE ADDED	7/1/1979
DATE DROPPED	12/30/1989
DESCRIPTION	The test consists of nine index cards picturing different geometric designs. The cards are presented individually, and participants are asked to copy the design before the next card is shown. Test results are scored based on the accuracy and organization of the reproductions.Score is the total of PSY118+...PSY129. Each of these variables is scored 1 if the participant made that type of error or 0 if not. Scoring is according to a modified Hutt-Briskin system (Lacks, 1984).
REFERENCE	Bender, L. (1963). Bender Visual Motor Gestalt Test. New York: American Orthopsychiatric Corporation. Lacks, P. (1984). Bender Gestalt Screening for Brain Dysfunction. New York: John Wiley & Sons.

PSY037 Total error score

RANGE 0 - 12 **HIGH SCORE** poor

PSY118 Rotation

RANGE 0 - 1 **HIGH SCORE** poor

PSY119 Overlapping difficulty

RANGE 0 - 1 **HIGH SCORE** poor

PSY120 Simplification

RANGE 0 - 1 **HIGH SCORE** poor

PSY121 Fragmentation

RANGE 0 - 1 **HIGH SCORE** poor

PSY122 Retrogression

RANGE 0 - 1 **HIGH SCORE** poor

PSY123 Perseveration

RANGE 0 - 1 **HIGH SCORE** poor

PSY124 Collision

RANGE 0 - 1 **HIGH SCORE** poor

PSY125 Impotence

RANGE 0 - 1 **HIGH SCORE** poor

PSY126 Closure difficulty

RANGE 0 - 1 **HIGH SCORE** poor

PSY127 Motor incoordination

RANGE 0 - 1 **HIGH SCORE** poor

PSY128 Angulation difficulty

RANGE 0 - 1 **HIGH SCORE** poor

PSY129 Cohesion

RANGE 0 - 1 **HIGH SCORE** poor

Benson Complex Figure Copy

DATE ADDED	3/16/2015
DATE DROPPED	
DESCRIPTION	There are two phases to this task. In the copy phase, the participant is presented with a figure composed of geometric shapes and asked to reproduce the figure on the same page. In the second phase, the participant is asked to recall from memory each figure. The purpose of this test is to assess the participant's visuoconstructional and visual memory functions. The accuracy of each shape and its placement is recorded. Scored according to NACC UDS 3 scoring rules.
REFERENCE	Possin, KL, Laluz VR, Alcantar OZ, Miller BL, Kramer JH. Distinct neuroanatomical substrates and cognitive mechanisms of figure copy performance in Alzheimer's disease and behavioral variant frontotemporal dementia. Neuropsychologia. 2011 Jan; 49(1):43-8.

UDSBENRS Recognition of original stimulus among four options

RANGE 0 - 1 **HIGH SCORE** good

UDSBENTC Total score for copying the Benson figure

RANGE 0 - 17 **HIGH SCORE** good

UDSBENTD Total score for drawing the Benson figure from memory following delay

RANGE 0 - 17 **HIGH SCORE** good

Benton Judgement of Line Orientation

DATE ADDED	7/14/2005
DATE DROPPED	2/13/2017
DESCRIPTION	Participant judges which two lines drawn at different angles on a response card correspond to the placement of two lines drawn at different angles on a stimulus card.
REFERENCE	Benton, A.L., Hamsher, K. deS., Varney, N.R., & Spreen, O. (1983). Contributions to neuropsychological assessment: A clinical manual. New York: Oxford University Press.

LINE Line orientation

RANGE 0 - 30 **HIGH SCORE** good

Benton Visual Form Discrimination

DATE ADDED	4/27/1988
DATE DROPPED	10/28/1992
DESCRIPTION	This gauges visual perception and the ability to recall objects that have been seen. The subject looks at 16 different images and then tries to draw them faithfully from memory.
REFERENCE	Benton, A.L., Hamsher, K. deS., Varney, N.R., & Spreen, O. (1983). Contributions to neuropsychological assessment: A clinical manual. New York: Oxford University Press.

PSY247 Visual form discrimination # correct

RANGE 0 - 16 **HIGH SCORE** good

PSY248 Visual form discrimination peripheral error

RANGE 0 - 16 **HIGH SCORE** poor

PSY249 Visual form discrimination major rotation

RANGE 0 - 16 **HIGH SCORE** poor

PSY250 Visual form discrimination major distortion

RANGE 0 - 16 **HIGH SCORE** poor

Benton Visual Retention Test – Form C

DATE ADDED	7/1/1979
DATE DROPPED	4/1/2009
DESCRIPTION	Form C of the Benton Visual Retention Test administered with a 10-second viewing time.
REFERENCE	Benton, A. L. (1963). The Revised Visual Retention Test: Clinical and experimental applications. New York: Psychological Corp.

PSY023 Benton Form C Delay # Correct

RANGE 0 - 10 **HIGH SCORE** good

PSY090 Benton Form C Errors: Omissions

RANGE 0 - 26 **HIGH SCORE** poor

PSY090 + PSY091 + PSY092 + PSY093 + PSY094 + PSY095 Summary score: Errors

RANGE 0 - 65 **HIGH SCORE** poor

PSY091 Benton Form C Errors: Distortions

RANGE 0 - 26 **HIGH SCORE** good

PSY092 Benton Form C Errors: Perseverations

RANGE 0 - 26 **HIGH SCORE** poor

PSY093 Benton Form C Errors: Rotations

RANGE 0 - 26 **HIGH SCORE** poor

PSY094 Benton Form C Errors: Misplacements

RANGE 0 - 26 **HIGH SCORE** poor

PSY095 Benton Form C Errors: Size

RANGE 0 - 26 **HIGH SCORE** poor

PSY235 Benton Form C Errors Right: Number of errors on right side of figure

RANGE 0 - 26 **HIGH SCORE** poor

PSY236 Benton Form C Errors Left: Number of errors on left side of figure

RANGE 0 - 26 **HIGH SCORE** poor

Benton Visual Retention Test – Form D

DATE ADDED	7/1/1979
DATE DROPPED	1/2/2004
DESCRIPTION	Form D of the Benton Visual Retention Test is administered with no delay; stimulus present when copied. Score is number correct.
REFERENCE	Benton, A. L. (1963). The Revised Visual Retention Test: Clinical and experimental applications. New York: Psychological Corp.

PSY025 Benton Form D Delay # Correct

RANGE 0 - 10 **HIGH SCORE** good

PSY096 Benton Form D Errors: Omissions

RANGE 0 - 26 **HIGH SCORE** poor

PSY096 + PSY097 + PSY098 + PSY099 + PSY100 + PSY101 Summary score: Errors

RANGE 0 - 65 **HIGH SCORE** poor

PSY097 Benton Form D Errors: Distortions

RANGE 0 - 26 **HIGH SCORE** poor

PSY098 Benton Form D Errors: Perseverations

RANGE 0 - 26 **HIGH SCORE** poor

PSY099 Benton Form D Errors: Rotations

RANGE 0 - 26 **HIGH SCORE** poor

PSY100 Benton Form D Errors: Misplacements

RANGE 0 - 26 **HIGH SCORE** poor

PSY101 Benton Form D Errors: Size

RANGE 0 - 26 **HIGH SCORE** poor

PSY237 Benton Form D Errors Right: Number of errors on right side of figure

RANGE 0 - 26 **HIGH SCORE** poor

PSY238 Benton Form D Errors Left: Number of errors on left side of figure

RANGE 0 - 26 **HIGH SCORE** poor

Boston Naming Test – 60-item Version

DATE ADDED 4/1/1984

DATE DROPPED 9/1/2005

DESCRIPTION This test consists of 60-line drawings of objects of graded difficulty, ranging from very common objects (e.g., a tree) to less familiar objects such as an abacus. See PSY27, Boston Naming Test 85-item version. Data from rescored tests from 7/1979 to 4/1/1984 included here.

REFERENCE

Goodglass, H., & Kaplan, E. (1983). The assessment of aphasia and related disorders (2nd ed.). Philadelphia: Lea & Febiger.

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). Boston Naming Test scoring booklet. Philadelphia: Lea & Febiger.

PSY027 Boston Naming Test; 60-Item version

RANGE 0 - 60 **HIGH SCORE** good

NOTES PSY027 was recoded as variable BNT as of 9/1/2005 to conform to NACC field. Administration altered to begin with the first item (effective 4/1/1984 to 8/1/2004). Effective August 1, 2004, administration changed back to standard procedure (i.e., begin with

PSY105 Boston Naming Test: # Correct printed cue

RANGE 0 - 60 **HIGH SCORE** good or poor, depends on PSY027 score

NOTES Reference: Devised for this project. Date added: 5/1984. Date dropped: 11/20/1991.If no response is given within 20 seconds, a card containing the stimulus drawing with four printed words arranged horizontally below it is presented. One printed word is

PSY109 Boston Naming Test: # Correct object cue

RANGE 0 - 60 **HIGH SCORE** good or poor, depends on PSY027 score

NOTES Reference: Devised for this project.Date added: 2/22/1984. Date dropped: 9/18/1986.If the stimulus is not named after administration of the printed cue, the real object or a miniature is presented.

BNT Boston Naming Test (60 item version)

RANGE 0 - 60 **HIGH SCORE** good

NOTES This variable replaced PSY027 to conform to NACC field as of 9/1/2005

Boston Naming Test – 85-item Version

DATE ADDED 7/1/1979

DATE DROPPED 9/1/1984

DESCRIPTION This experimental version included 85 line drawings in black and white drawings of objects, ranging in difficultly from the commonly encountered (e.g., tree, bed) to the rarely encountered (e.g., sphinx, abacus) – are presented, and the participant provides the name of each object. According to the 1976 experimental scoring booklet, administration was begun with item 39. If any of the next 8 items failed, proceed backward from item failed until a total of 8 consecutive preceding items are passed. Then resume in a forward direction until 6 consecutive errors; stop.

REFERENCE

Kaplan, E., Goodglass, H., & Weintraub, S. (1976). Boston Naming Test Scoring Booklet, Experimental Edition. Boston: Veterans Administration Hospital.

PSY028 Boston Naming Test: # Correct without cue at T1

RANGE 0 - 85 **HIGH SCORE** good

PSY029 Boston Naming Test: # Correct with cue at T1

RANGE 0 - 85 **HIGH SCORE** good or poor, depending on number correct without cue

PSY030 Boston Naming Test: # Total correct at T1

RANGE 0 - 85 **HIGH SCORE** good

PSY031 Boston Naming Test: Last correct response at T1

RANGE 0 - 85 **HIGH SCORE** good

PSY27 Boston Naming Test; 85-item version. Score is number correct

RANGE 0 - 85 **HIGH SCORE** good

NOTES All tests were rescored to conform to revised 60-item version; rescored data available in PSY027.Note: PSY27 is the correct variable name, not to be confused with PSY027; it is not a typographical error.

Boston Naming Test – Odd Numbered, 30-item version

DATE ADDED	9/1/2005
DATE DROPPED	2/13/2017
DESCRIPTION	Begin at item 1 and present all 30 (odd numbered) items in order. Allow 20 seconds for each response. If participant gives a response that indicates a misperception of the picture, administer the printed stimulus cue. Allow 20 seconds for response. Total score is the number of items named correctly including those named following given stimulus cues and then multiplied by 2 so as to be consistent with previous 60-item version.

REFERENCE

Fisher, N. J., Tierney, M. C., Snow, W. G., & Szalai, J. P. (1999). Odd/even short forms of the Boston Naming Test: Preliminary geriatric norms. Clinical Neuropsychologist, 13, 359-364.

Goodglass, H., & Kaplan, E. (1983). The assessment of aphasia and related disorders (2nd ed.). Philadelphia: Lea & Febiger.

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). Boston Naming Test scoring booklet. Philadelphia: Lea & Febiger.

Mack, W. J., Freed, D. M., Williams, B. W., & Henderson, V. W. (1992). Boston Naming Test: Shortened versions for use in Alzheimer's disease. Journal of Gerontology: Psychological Sciences, 45, 154-158.

BOSTON Total correct

RANGE 0 - 30 **HIGH SCORE** good

Bradburn Affect Balance Scale

DATE ADDED	4/1/1993
DATE DROPPED	11/1/1994
DESCRIPTION	Begin at item 1 and present all 30 (odd numbered) items in order. Allow 20 seconds for each response. If participant gives a response that indicates a misperception of the picture, administer the printed stimulus cue. Allow 20 seconds for response. Total score is the number of items named correctly including those named following given stimulus cues and then multiplied by 2 so as to be consistent with previous 60-item version.
REFERENCE	Bradburn, N. (1969). The Structure of Psychological Well-Being. Chicago, IL: Aldine.

BRAD1-BRAD10 Response to each question. 0 = No, 1 = Yes

RANGE 0 - 1 **HIGH SCORE** n/a

BRADBAL Affect balance: The difference between BRADP and BRADN

RANGE 0 - 5 **HIGH SCORE** n/a

BRADN Negative affect: Score is # of "Yes" answers to items 2, 4, 6, 8 and 10

RANGE 0 - 5 **HIGH SCORE** n/a

BRADP Positive affect: Score is # of "Yes" answers to items 1, 3, 5, 7 and 9

RANGE 0 - 5 **HIGH SCORE** n/a

Category Fluency – Animal Naming

DATE ADDED	3/17/1997
DATE DROPPED	9/1/2005
DESCRIPTION	Participants are asked to name as many different animals as they can for about a minute. Total score is based on the most productive consecutive 60 seconds. They are actually allowed 90 seconds.
REFERENCE	Goodglass, H. & Kaplan, E., (1983). Boston Diagnostic Aphasia Examination Booklet, III, ORAL EXPRESSION, J. Animal Naming (Fluency in Controlled Association). Philadelphia: Lea & Febiger.

ANIMAL Total of animal 1 through animal 4

RANGE UNLIMITED **HIGH SCORE** good

ANIMAL 1 Number of animal names recorded verbatim in first 15 seconds

RANGE UNLIMITED **HIGH SCORE** good

ANIMAL 2 Number of animal names recorded verbatim in 15 - 30 second interval

RANGE UNLIMITED **HIGH SCORE** good

ANIMAL 3 Number of animal names recorded verbatim in 30 – 45 second interval

RANGE UNLIMITED **HIGH SCORE** good

ANIMAL 4 Number of animal names recorded verbatim in 45 – 60 second interval

RANGE UNLIMITED **HIGH SCORE** good

ANIMAL 5 Number of animal names recorded verbatim in 60 – 75 second interval

RANGE UNLIMITED **HIGH SCORE** good

ANIMAL 6 Number of animal names recorded verbatim in 75 – 90 second interval

RANGE UNLIMITED **HIGH SCORE** good

Category Fluency – Animals and Vegetables

DATE ADDED	9/1/2005
DATE DROPPED	
DESCRIPTION	This is a widely used measure of semantic memory (verbal fluency, language). The subject is asked to name different exemplars of a given semantic category, and the number of unique exemplars named is scored.
REFERENCE	Goodglass, H. & Kaplan, E., (1983). Boston Diagnostic Aphasia Examination Booklet, III, ORAL EXPRESSION, J. Animal Naming (Fluency in Controlled Association). Philadelphia: Lea & Febiger.

ANIMALS Number of animal names recorded in one minute

RANGE UNLIMITED **HIGH SCORE** good

VEG Number of vegetable names recorded in one minute

RANGE UNLIMITED **HIGH SCORE** good

Craft Story 21 Recall

DATE ADDED	3/16/2015
DATE DROPPED	
DESCRIPTION	A brief story is read to the participant, who is then asked to retell it from memory immediately. The primary measure of performance is the number of story units recalled both immediately after story is presented and after a delay.
REFERENCE	Craft S, Newcomer J, Kanne S, Dagogo-Jack S, Cryer P, Sheline Y, Luby J, Dagogo-Jack A, Alderson A. Memory improvement following induced hyperinsulinemia in Alzheimer's disease. Neurobiology of Aging. 1996 Jan-Feb; 17(1):123-30.

CRAFTCUE Cue (boy) needed

RANGE 0 - 1 **HIGH SCORE** n/a

CRAFTDRE Total story units recalled after delay, paraphrase scoring

RANGE 0 - 25 **HIGH SCORE** good

CRAFTDTI Delayed time

RANGE Unknown **HIGH SCORE** n/a

CRAFTDVR Total story units recalled after delay, verbatim scoring

RANGE 0 - 44 **HIGH SCORE** good

CRAFTURS Total story units recalled immediately after story presented, paraphrase scoring

RANGE 0 - 25 **HIGH SCORE** good

CRAFTVRS Total Story units recalled immediately after story presented, verbatim scoring

RANGE 0 - 44 **HIGH SCORE** good

Crossing Off

DATE ADDED	7/1/1979
DATE DROPPED	4/1/2009
DESCRIPTION	The score is the number of lines crossed off divided by the number of seconds taken to complete the page. This quotient is then multiplied by 100. A maximum of 180 seconds is allowed.
REFERENCE	Botwinick, J., & Storandt, M. (1973). Speed functions, vocabulary ability, and age. Perceptual and Motor Skills, 36, 1123-1128.

PSY017 Summary score = (PSY017L ÷ PSY017S) x 100

RANGE 0 and above **HIGH SCORE** good

PSY017L Crossing off # lines

RANGE 0 - 96 **HIGH SCORE** good

PSY017S Crossing off # seconds

RANGE 1 - 180 **HIGH SCORE** poor

Double Memory Test – Category Cued Recall

DATE ADDED	4/7/1997
DATE DROPPED	9/17/1998
DESCRIPTION	During the acquisition phase, participant is shown 4 words, each from a different category on a screen. Appropriate category cues are shown one at a time in the center of the screen. There are 16 different categories with a total of 64 screens. Immediately after participant is asked to name the four items from each category in any order.
REFERENCE	Buschke, H., Sliwinski, M.J., Kuslansky, G., Lipton, R.B. (1997). Diagnosis of early dementia by the Double Memory Test: encoding specificity improves diagnostic sensitivity and specificity. Neurology 48(4), 989-97.

BUSCH01-BUSCH64 During the acquisition phase, participant is shown 4 words, each from a different category on a screen. Appropriate category cues are shown one at a time in the center of the screen. There are 16 different categories with a total of 64 screens. Immedia

RANGE 0 - 64 **HIGH SCORE** good

Dual Task

DATE ADDED	4/10/2002
DATE DROPPED	4/17/2003
DESCRIPTION	This task measures the effects of divided attention that can be done by very mildly and mildly demented participants as well as healthy older participants. Participants first complete a letter trails task similar to Trailmaking A in which they draw a line through a sequence of letters from A to Z on an 8.5- x 11-inch sheet of paper. The letters are placed so that it is possible to connect the entire 26-letter sequence without crossing any previously drawn line. The length of time it takes to finish this task is noted. Then the participant is asked to count backward by 1s from 100. This continues for the length of time the participant required to mark the alphabet trail. For both these single tasks the participant is instructed to work as quickly and as accurately as possible. Finally, the participant is asked to perform the two tasks simultaneously.
REFERENCE	Devised for MAP.

DUAL Time and errors are scored according to manual

RANGE _____ **HIGH SCORE** _____

Entertainment Questionnaire

DATE ADDED	7/1/1979
DATE DROPPED	6/1/1982
DESCRIPTION	
REFERENCE	Botwinick, J., & Storandt, M. (1980). Recall and recognition of old information in relation to age and sex. Journal of Gerontology, 35, 70-76.
	Storandt, M., Grant, E.A., & Gordon, B.C. (1978). Remote memory as a function of age and sex. Experimental Aging Research, 4, 365-375.

PSY034 ENTERTAINMENT QUESTIONNAIRE: RECALL T1

RANGE 0 - 12 **HIGH SCORE** good

PSY035 ENTERTAINMENT QUESTIONNAIRE: RECALL &/OR RECOG T1

RANGE 0 - 12 **HIGH SCORE** good

Free and Cued Selective Reminding Test (FCSRT)

DATE ADDED	8/1/2002
DATE DROPPED	
DESCRIPTION	During learning the participant is required to provide the name of a pictured item (e.g., grapes) when given the category cue (e.g., fruit). This 16-item list learning test includes immediate category-cued recall (four items at a time) to confirm initial correct encoding and provide retrieval practice before the test phase. For scoring purposes there are three recall trials, each trial preceded by 20 seconds of interference by counting backwards from 97 by 3s. On each recall the participant is allowed up to 90 seconds to recall items. Then the participant is given the category cue for items that were not recalled. If the item is not retrieved in 10 seconds, the examiner tells the participant what it is. The scores are the number of items recalled on each of 3 trials under free and then cued recall.
REFERENCE	Grober, E., Buschke, H., Crystal, H., Bang, S., & Dresner, R. (1988). Screening for dementia by memory testing. Neurology, 3, 900-903.

SRT1C Free & Cued SRT: Trial 1 Cued Recall

RANGE 0 - 16 **HIGH SCORE** good

SRT1F Free & Cued SRT: Trial 1 Free Recall

RANGE 0 - 16 **HIGH SCORE** good

SRT2C Free & Cued SRT: Trial 2 Cued Recall

RANGE 0 - 16 **HIGH SCORE** good

SRT2F Free & Cued SRT: Trial 2 Free Recall

RANGE 0 - 16 **HIGH SCORE** good

SRT3C Free & Cued SRT: Trial 3 Cued Recall

RANGE 0 - 16 **HIGH SCORE** good

SRT3F Free & Cued SRT: Trial 3 Free Recall

RANGE 0 - 16 **HIGH SCORE** good

SRTFREE SRT1F + SRT2F + SRT3F

RANGE 0 - 48 **HIGH SCORE** good

SRTTOTAL SRTfree + SRT1C + SRT2C + SRT3C

RANGE 0 - 48 **HIGH SCORE** good

Geriatric Depression Scale

DATE ADDED	8/1/2020
DATE DROPPED	
DESCRIPTION	The GDS is collected by the clinical core at the time of the CA, if administered in person. If the CA is conducted by telephone, the GDS is collected at the cognitive assessment visit. The participant is asked to say yes or no to 15 questions about their feelings, depending on how they "…have been feeling the past week, including today."
REFERENCE	Sheikh, J.I. and Yesavage, J.A. (1986) Geriatric Depression Scale (GDS): Recent evidence and development of a shorter version. Clinical Gerontology: A Guide to Assessment and Intervention 165-173, NY: The Haworth Press, 1986. Reproduced by permission of the publisher.

AFRAID Geriatric Depression Scale Q6

RANGE 0 - 1 **HIGH SCORE** poor

BETTER Geriatric Depression Scale Q15

RANGE 0 - 1 **HIGH SCORE** poor

BORED Geriatric Depression Scale Q4

RANGE 0 - 1 **HIGH SCORE** poor

DROPACT Geriatric Depression Scale Q2

RANGE 0 - 1 **HIGH SCORE** poor

EMPTY Geriatric Depression Scale Q3

RANGE 0 - 1 **HIGH SCORE** poor

ENERGY Geriatric Depression Scale Q13

RANGE 0 - 1 **HIGH SCORE** poor

GDS Geriatric Depression Scale SUM (88 if NC)

RANGE 0 - 15 **HIGH SCORE** poor

HAPPY Geriatric Depression Scale Q7

RANGE 0 - 1 **HIGH SCORE** poor

HELPLESS Geriatric Depression Scale Q8

RANGE 0 - 1 **HIGH SCORE** poor

HOPELESS Geriatric Depression Scale Q14

RANGE 0 - 1 **HIGH SCORE** poor

MEMPROB Geriatric Depression Scale Q10

RANGE 0 - 1 **HIGH SCORE** poor

NOGDS	Geriatric Depression Scale: Not able to complete = 1		
	RANGE 0 - 1	**HIGH SCORE**	n/a
SATIS	Geriatric Depression Scale Q1		
	RANGE 0 - 1	**HIGH SCORE**	poor
SPIRITS	Geriatric Depression Scale Q5		
	RANGE 0 - 1	**HIGH SCORE**	poor
STAYHOME	Geriatric Depression Scale Q9		
	RANGE 0 - 1	**HIGH SCORE**	poor
WONDRFUL	Geriatric Depression Scale Q11		
	RANGE 0 - 1	**HIGH SCORE**	poor
WRTHLESS	Geriatric Depression Scale Q12		
	RANGE 0 - 1	**HIGH SCORE**	poor

Halstead-Reitan – Astereognosis

DATE ADDED	6/1/1982
DATE DROPPED	3/15/1995
DESCRIPTION	Item 26, Halstead Battery
REFERENCE	Reitan, R., & Davison, L. A. (1974). Clinical Neuropsychology: Current Status and Applications. New York: Winston/Wiley.

PSY055 REITAN # ERRORS COINS SINGLY RIGHT

RANGE 0 - 3 **HIGH SCORE** poor

PSY055 + PSY056 + PSY057 + PSY058 Summary score

RANGE 0 - 12 **HIGH SCORE** poor

PSY056 REITAN # ERRORS COINS SINGLY LEFT

RANGE 0 - 3 **HIGH SCORE** poor

PSY057 REITAN # ERRORS COINS BOTH RIGHT

RANGE 0 - 3 **HIGH SCORE** poor

PSY058 REITAN # ERRORS COINS BOTH LEFT

RANGE 0 - 3 **HIGH SCORE** poor

Halstead-Reitan – Tactile/Sensory

DATE ADDED	6/1/1982
DATE DROPPED	12/1/1988
DESCRIPTION	Items 17a (Finger agnosia) and 25 (Finger number writing) of the Halstead Battery
REFERENCE	Reitan, R., & Davison, L. A. (1974). Clinical Neuropsychology: Current Status and Applications. New York: Winston/Wiley.

PSY051 REITAN # ERRORS FINGER AGNOSIA RIGHT

RANGE 0 - 20 **HIGH SCORE** poor

PSY052 REITAN # ERRORS FINGER AGNOSIA LEFT

RANGE 0 - 20 **HIGH SCORE** poor

PSY053 REITAN # ERRORS FINGER NUMBER WRITING RIGHT

RANGE 0 - 20 **HIGH SCORE** poor

PSY054 REITAN # ERRORS FINGER NUMBER WRITING LEFT

RANGE 0 - 20 **HIGH SCORE** poor

PSY051 + PSY052 + PSY053 + PSY054 Summary score

RANGE 0 - 80 **HIGH SCORE** poor

Handedness

DATE ADDED 2/22/1984

DATE DROPPED

DESCRIPTION Administered only at entry to study. The participant is asked to demonstrate 8 actions using objects (e.g., comb one's hair). The objects are placed in the center of the table prior to the request. The hand used to demonstrate the action is noted. When the object has 2 parts (e.g., the box with a lid, the hand used to demonstrate the action is still noted. In this case, the hand used to take off the lid) The normal rule for determining handedness is 6 out of 8 actions. Testers also make a note when most or all the actions on the handedness task are performed with a different hand used for writing during the testing session. Modified 11/4/1988.

REFERENCE Kimura, D., & Vanderwolf, C. H. (1970). The relation between hand preference and the performance of individual finger movements by left and right hands. Brain, 93, 769-774.

PSY113 HANDEDNESS RIGHT

RANGE 0 - 8 **HIGH SCORE** right-handed

PSY114 GESTURAL IRREGULARITIES

RANGE 0 - 16 **HIGH SCORE** poor

PSY232 HANDEDNESS LEFT

RANGE 0 - 8 **HIGH SCORE** left-handed

PSY233 HANDEDNESS BOTH

RANGE 0 - 8 **HIGH SCORE** handedness unresolved

PSY234 HANDEDNESS NO RESPONSE

RANGE 0 - 8 **HIGH SCORE** unresponsive

Line Bisection Test

DATE ADDED	12/1/1983
DATE DROPPED	8/8/1986
DESCRIPTION	Details of administration and scoring are provided in the reference. The participant chooses the first hand (right or left) to use.
REFERENCE	Schenkenberg, T., Bradford, D. C., & Ajax, E. T. (1980). Line bisection and unilateral visual neglect in patients with neurologic impairment. Neurology, 30, 509-517.

PSY138 LINE BISECT, R HAND OMISSIONS RT

RANGE _____ **HIGH SCORE** _____

PSY139 LINE BISECT, R HAND OMISSIONS LFT

RANGE _____ **HIGH SCORE** _____

PSY140 LINE BISECT, R HAND TIME

RANGE _____ **HIGH SCORE** _____

PSY142 LINE BISECT, R HAND RT., NO. LINES RT

RANGE _____ **HIGH SCORE** _____

PSY143 LINE BISECT, R HAND RT., % LINES RT

RANGE _____ **HIGH SCORE** _____

PSY144 LINE BISECT, R HAND RT., NO. LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY145 LINE BISECT, R HAND RT., % LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY146 LINE BISECT, R HAND RT., NO. LINE CTR

RANGE _____ **HIGH SCORE** _____

PSY149 LINE BISECT, R HAND LFT., NO. LINES RT

RANGE _____ **HIGH SCORE** _____

PSY150 LINE BISECT, R HAND LFT., % LINES RT

RANGE _____ **HIGH SCORE** _____

PSY151 LINE BISECT, R HAND LFT., NO. LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY152 LINE BISECT, R HAND LFT., % LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY153 LINE BISECT, R HAND LFT., NO LINES CTR

RANGE _____ **HIGH SCORE** _____

PSY156 LINE BISECT, R HAND CTR., NO LINES RT

RANGE _____ **HIGH SCORE** _____

PSY157 LINE BISECT, R HAND CTR., % LINES RT

RANGE _____ **HIGH SCORE** _____

PSY158 LINE BISECT, R HAND CTR., NO LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY159 LINE BISECT, R HAND CTR., % LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY160 LINE BISECT, R HAND CTR., NO. LINES CTR

RANGE _____ **HIGH SCORE** _____

PSY163 LINE BISECT, R HAND TIME

RANGE _____ **HIGH SCORE** _____

PSY167 LINE BISECT, L HAND OMISSIONS RT

RANGE _____ **HIGH SCORE** _____

PSY168 LINE BISECT, L HAND OMISSIONS LFT

RANGE _____ **HIGH SCORE** _____

PSY169 LINE BISECT, L HAND OMISSIONS CTR

RANGE _____ **HIGH SCORE** _____

PSY171 LINE BISECT, L HAND RT., NO. LINES RT

RANGE _____ **HIGH SCORE** _____

PSY172 LINE BISECT, L HAND RT., % LINES RT

RANGE _____ **HIGH SCORE** _____

PSY173 LINE BISECT, L HAND RT., NO LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY174 LINE BISECT, L HAND RT., % LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY175 LINE BISECT, L HAND RT., NO. LINES CTR

RANGE _____ **HIGH SCORE** _____

PSY178 LINE BISECT, L HAND LFT., NO LINES RT

RANGE _____ **HIGH SCORE** _____

PSY179 LINE BISECT, L HAND LFT., % LINES RT

RANGE _____ **HIGH SCORE** _____

PSY180 LINE BISECT, L HAND LFT., NO. LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY181 LINE BISECT, L HAND LFT., % LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY182 LINE BISECT, L HAND LFT., NO. LINES CTR

RANGE _____ **HIGH SCORE** _____

PSY185 LINE BISECT, L HAND CTR., NO LINES RT

RANGE _____ **HIGH SCORE** _____

PSY186 LINE BISECT, L HAND CTR., % LINES RT

RANGE _____ **HIGH SCORE** _____

PSY187 LINE BISECT, L HAND CTR., NO. LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY188 LINE BISECT, L HAND CTR., % LINES LFT

RANGE _____ **HIGH SCORE** _____

PSY189 LINE BISECT, L HAND CTR., NO. LINES CTR

RANGE _____ **HIGH SCORE** _____

PSY192 LINE BISECT, L HAND TIME

RANGE _____ **HIGH SCORE** _____

Luria-Nebraska Neuropsychological Battery – Motor

DATE ADDED	6/1/1982
DATE DROPPED	10/31/1991
DESCRIPTION	The score is the number of incorrectly executed motor tasks.
REFERENCE	Golden, C. J., Hammeke, T. A., & Purisch, A. D. (1980). The Luria-Nebraska Neuropsychological Battery: Manual. Los Angeles: Western Psychological Services.

PSY045 LURIA MOTOR: OPPOSITE KNOCKS # ERRORS

RANGE 0 - 10 **HIGH SCORE** poor

PSY046 LURIA MOTOR: HAND SQUEEZES # ERRORS

RANGE 0 - 4 **HIGH SCORE** poor

PSY047 LURIA MOTOR: KNOCK 1 LEFT 2 RIGHT # ERRORS

RANGE 0 - 4 **HIGH SCORE** poor

PSY048 LURIA MOTOR: OPPOSITE INTENSITY # ERRORS

RANGE 0 - 4 **HIGH SCORE** poor

Luria-Nebraska Neuropsychological Battery – Rhythm

DATE ADDED	4/14/1983
DATE DROPPED	8/31/1996
DESCRIPTION	The score is the number of incorrectly executed rhythm tasks.
REFERENCE	Golden, C. J., Hammeke, T. A., & Purisch, A. D. (1980). The Luria-Nebraska Neuropsychological Battery: Manual. Los Angeles: Western Psychological Services.

PSY136 LURIA RHYTHM ERRORS PITCH ITEMS 52, 53 & 54 (4/4/1983 – 8/31/1996)

RANGE 0 - 16 **HIGH SCORE** poor

PSY137 LURIA RHYTHM ERRORS NUMBER ITEMS 58, 59, & 60 (4/14/1983 – 8/31/1996)

RANGE 0 - 10 **HIGH SCORE** poor

PSY242 HAPPY BIRTHDAY, ITEM 57 (4/19/1984 – 2/26/1992)

RANGE 0 - 1 **HIGH SCORE** poor

Mini-Mental State Examination (MMSE)

DATE ADDED	3/16/2015
DATE DROPPED	
DESCRIPTION	The MMSE is collected by the clinical core at the time of the cognitive assessment. Prior to November 2021, the MMSE was collected by the clinical core at the time of the clinical assessment. This test is a 30-point questionnaire that takes between 5 and 10 minutes and examines functions including registration (repeating named prompts), attention and calculation, recall, language, ability to follow simple commands and orientation.
REFERENCE	Folstein MF, Folstein SE, McHugh PR. ""Mini-mental state". A practical method for grading the cognitive state of patients for the clinician". Journal of Psychiatric Research, 1975; 12 (3): 189–98.

BALL Apple

RANGE 0 - 1 **HIGH SCORE** good

BALL2 Apple Recall

RANGE 0 - 1 **HIGH SCORE** good

COUN County or alternate “Nearest major river”

RANGE 0 - 1 **HIGH SCORE** good

DRAW Drawing

RANGE 0 - 1 **HIGH SCORE** good

FLAG Penny

RANGE 0 - 1 **HIGH SCORE** good

FLAG2 Penny recall

RANGE 0 - 1 **HIGH SCORE** good

FOLD Fold in half

RANGE 0 - 1 **HIGH SCORE** good

INT089A World backwards total

RANGE 0 - 5 **HIGH SCORE** good

INT089AR1 World backwards D

RANGE 0 - 1 **HIGH SCORE** good

INT089AR2 World backwards L

RANGE 0 - 1 **HIGH SCORE** good

INT089AR3 World backwards R

RANGE 0 - 1 **HIGH SCORE** good

INT089AR4 World backwards O

RANGE 0 - 1 **HIGH SCORE** good

INT089AR5 World backwards W

RANGE 0 - 1 **HIGH SCORE** good

INT548 City/town

RANGE 0 - 1 **HIGH SCORE** poor

KSBJ1 Month of the year

RANGE 0 - 1 **HIGH SCORE** good

KSBJ2 Year

RANGE 0 - 1 **HIGH SCORE** good

LAP Put on floor/table

RANGE 0 - 1 **HIGH SCORE** good

LEVE Floor of the building

RANGE 0 - 1 **HIGH SCORE** good

LOC Level of cons alertresponsive, Alert/Responsive | drowsy, Drowsy | stuporous, Stuporous | comatoseunresponsive, Comatose/Unresponsive)

RANGE **HIGH SCORE**

LOCA State

RANGE 0 - 1 **HIGH SCORE** good

MMSE Total MMSE score (using D-L-R-O-W)

RANGE 0 - 30 **HIGH SCORE** good

MMSE_SUM Sum of all item-scores (30 points max)

RANGE 0 - 30 **HIGH SCORE** good

MMSELOC The administration of the MMSE was: 1. In ADRC/clinic, 2. In home, 3. In person-other

RANGE 1 - 4 **HIGH SCORE** n/a

MMSEORDA Time

RANGE 0 - 5 **HIGH SCORE** good

MMSEORLO Place

RANGE 0 - 5 **HIGH SCORE** good

MSQ01 Date

RANGE 0 - 1 **HIGH SCORE** good

MSQ02 Day of the week

RANGE 0 - 1 **HIGH SCORE** good

MSQ03 Building

RANGE 0 - 1 **HIGH SCORE** good

PENC Pencil/pen

RANGE 0 - 1 **HIGH SCORE** good

PHRA Repetition phrase

RANGE 0 - 1 **HIGH SCORE** good

REDO Reading

RANGE 0 - 1 **HIGH SCORE** good

RIGH Take in right hand

RANGE 0 - 1 **HIGH SCORE** good

SEAS Season

RANGE 0 - 1 **HIGH SCORE** good

SENT Writing

RANGE 0 - 1 **HIGH SCORE** good

TREE Table

RANGE 0 - 1 **HIGH SCORE** good

TREE2 Table recall

RANGE 0 - 1 **HIGH SCORE** good

WATC Watch

RANGE 0 - 1 **HIGH SCORE** good

Montreal Cognitive Assessment (MoCA)

DATE ADDED	2/10/2010
DATE DROPPED	
DESCRIPTION	The Montreal Cognitive Assessment (MoCA) is collected by the clinical core at the time of the clinical assessment for participants enrolled in the Memory and Aging Project. The MoCA test is administered at the cognitive assessment for participants enrolled in the COMPASS study. MoCA is a screening scale that evaluates the following cognitive domains: Visuospatial/executive, Language, Memory, Attention, Abstraction, Delayed recall, and Orientation. The MoCA is scored as the number of correctly completed items, with lower scores indicative of poorer performance and greater cognitive impairment.
REFERENCE	Nasreddine, Ziad S et al. "The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment." Journal of the American Geriatrics Society vol. 53,4 (2005): 695-9.

MOCACOMP Was any part of MoCA administered?

RANGE 0 - 1 **HIGH SCORE** n/a

MOCAREAS Was any part of MoCA administered? If No, enter reason code, 95–98

RANGE 95 - 98 **HIGH SCORE** n/a

MOCALAN Language of MoCA administration

RANGE 1 - 3 **HIGH SCORE** n/a

MOCALANX Language of MoCA administration — Other specify

RANGE **HIGH SCORE** n/a

MOCAHEAR Subject was unable to complete one or more sections due to hearing impairment

RANGE 0 - 1 **HIGH SCORE** n/a

MOCATOTS MoCA Total Raw Score — uncorrected

RANGE 0 - 30 **HIGH SCORE** good

MOCADIGI MoCA: Attention — Digits

RANGE 0 - 2 **HIGH SCORE** good

MOCALETT MoCA: Attention — Letter A

RANGE 0 - 1 **HIGH SCORE** good

MOCASER7 MoCA: Attention — Serial 7s

RANGE 0 - 3 **HIGH SCORE** good

MOCAREPE MoCA: Language — Repetition

RANGE 0 - 2 **HIGH SCORE** good

MOCAFLUE MoCA: Language — Fluency

RANGE 0 - 1 **HIGH SCORE** good

MOCAABST MoCA: Abstraction

RANGE 0 - 2 **HIGH SCORE** good

MOCARECN MoCA: Delayed recall — No cue

RANGE 0 - 5 **HIGH SCORE** good

MOCARECC MoCA: Delayed recall — Category cue

RANGE 0 - 5 **HIGH SCORE** good

MOCARECR MoCA: Delayed recall — Recognition

RANGE 0 - 5 **HIGH SCORE** good

MOCAORDT MoCA: Orientation — Date

RANGE 0 - 1 **HIGH SCORE** good

MOCAORMO MoCA: Orientation — Month

RANGE 0 - 1 **HIGH SCORE** good

MOCAORYR MoCA: Orientation — Year

RANGE 0 - 1 **HIGH SCORE** good

MOCAORDY MoCA: Orientation — Day

RANGE 0 - 1 **HIGH SCORE** good

MOCAORPL MoCA: Orientation — Place

RANGE 0 - 1 **HIGH SCORE** good

MOCAORCT MoCA: Orientation — City

RANGE 0 - 1 **HIGH SCORE** good

MOCAVIS Subject was unable to complete one or more sections due to visual impairment

RANGE 0 - 1 **HIGH SCORE** n/a

MOCATRAI MoCA: Visuospatial/executive — Trails

RANGE 0 - 1 **HIGH SCORE** good

MOCACUBE MoCA: Visuospatial/executive — Cube

RANGE 0 - 1 **HIGH SCORE** good

MOCACLOC MoCA: Visuospatial/executive — Clock contour

RANGE 0 - 1 **HIGH SCORE** good

MOCACLON MoCA: Visuospatial/executive — Clock numbers

RANGE 0 - 1 **HIGH SCORE** good

MOCACLOH MoCA: Visuospatial/executive — Clock hands

RANGE 0 - 1 **HIGH SCORE** good

MOCANAMI MoCA: Language — Naming

RANGE 0 - 3 **HIGH SCORE** good

MOCAREGI MoCA: Memory — Registration (two trials)

RANGE 0 - 10 **HIGH SCORE** good

MOCALOC MoCA: Location 1, In ADRC or clinic|2, In home|3, In person - other

RANGE 1-3 **HIGH SCORE** n/a

Multilingual Naming Test (MINT)

DATE ADDED	3/16/2015
DATE DROPPED	
DESCRIPTION	Gollan TH, Weissburger G, Runnqvist E, Montaya RI, Cera CM. Self-ratings of spoken language dominance: A Multilingual Naming Test (MINT) and preliminary norms for young and aging Spanish-English bilinguals. Bilingualism: Language and Cognition. 2011; 13:215-8.
REFERENCE	Ivano I, Salmon GP, Gollan TH. The Multilingual Naming Test in Alzheimer's Disease: Clues to the Origin of Naming Impairments. J Int Nauropsycol Soc. 2013; 19:272-283.

MINTPCNC Number correct with phonemic cue

RANGE 0 - 32 **HIGH SCORE** n/a

MINTPCNG Number of phonemic cues given

RANGE 0 - 32 **HIGH SCORE** poor

MINTSCNC Number correct with semantic cues

RANGE 0 - 32 **HIGH SCORE** n/a

MINTSCNG Number of semantic cues given

RANGE 0 - 32 **HIGH SCORE** n/a

MINTTOTS Total score of correctly named items

RANGE 0 - 32 **HIGH SCORE** good

MINTTOTW Total correct without semantic cue

RANGE 0 - 32 **HIGH SCORE** good

Number Span Test

DATE ADDED	3/16/2015
DATE DROPPED	
DESCRIPTION	The participant is read number sequences of increasing length and asked to repeat them. The longest span forward length is the length of the highest digit sequence the participant is able to repeat correctly. This is a widely used test of working memory (or attention).
REFERENCE	Reproduced by permission of the author, Joel Kramer, PsyD; do not copy or distribute without author's permission. Form created as part of the Uniform Data Set of the National Alzheimer's Coordinating Center, copyright © 2013 University of Washington.

DIGBACCT Number of correct trials

RANGE 0 - 14 **HIGH SCORE** good

DIGBACLS Longest span backward

RANGE 0, 2 - 8 **HIGH SCORE** good

DIGFORCT Number of correct trials

RANGE 0 - 14 **HIGH SCORE** good

DIGFORSL Longest span forward

RANGE 0, 3 - 9 **HIGH SCORE** good

Number Symbol Test – Web-based

DATE ADDED	7/1/2020
DATE DROPPED	
DESCRIPTION	Using a symbol-number key shown on screen, participants are asked to match as many symbols and numbers as possible in 90 seconds. This test measures processing speed and visual short term memory.
REFERENCE	Nicosia J, Aschenbrenner AJ, Balota DA, Sliwinski MJ, Tahan M, Adams S, Stout SS, Wilks H, Gordon BA, Benzinger TLS, Fagan AM, Xiong C, Bateman RJ, Morris JC, Hassenstab J. Unsupervised high-frequency smartphone-based cognitive assessments are reliable, valid, and feasible in older adults at risk for Alzheimer's disease. J Int Neuropsychol Soc. 2023 Jun;29(5):459-471. Pratt DN, Luther L, Kinney KS, Osborne KJ, Corlett PR, Powers AR 3rd, Woods SW, Gold JM, Schiffman J, Ellman LM, Strauss GP, Walker EF, Zinbarg R, Waltz JA, Silverstein SM, Mittal VA. Comparing a Computerized Digit Symbol Test to a Pen-and-Paper Classic. Schizophr Bull Open. 2023 Sep 28;4(1).

NUMSYM Number of correct trials

RANGE 0 - 93 **HIGH SCORE** good

Positive and Negative Affect Schedule (PANAS)

DATE ADDED	4/1/1993
DATE DROPPED	11/1/1994
DESCRIPTION	This 20-item test was given twice. The first administration was the first measure of the cognitive battery and the second administration was at the end of the testing. The data include all 20 items of the first administration and all 20 items of the second administration.
REFERENCE	Watson, D., & Clark, L.A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS Scales. Journal of Personality and Social Psychology, 54, 1063-1070.

PANAS1 - PANAS20 1 = YES, 0 = NO, Response to each word

RANGE **HIGH SCORE**

PANAS21 - PANAS40 1 = YES, 0 = NO, Response to each word

RANGE **HIGH SCORE**

PANASN Negative affect at first administration

RANGE 0 - 10 **HIGH SCORE**

NOTES Score is number of YES answers to items 2, 4, 6, 7, 8, 11, 13, 15, 18, 20

PANASNR Negative affect at second administration

RANGE 0 - 10 **HIGH SCORE**

NOTES Score is number of YES answers in items 22, 24, 26, 27, 28, 31, 33, 35, 38, 40

PANASP Positive affect at first administration

RANGE 0 - 10 **HIGH SCORE**

NOTES Score is number of YES answers to items 1, 3, 5, 9, 10, 12, 14, 16, 17, 19

PANASPR Positive affect at second administration

RANGE 0 - 10 **HIGH SCORE**

NOTES Score is number of YES answers to items 21, 23, 25, 29, 30, 32, 34, 36, 37, 39

Psychomotor Vigilance Task (PVT)

DATE ADDED	12/1/2023
DATE DROPPED	
DESCRIPTION	A simple reaction time task where participants must stop a “stopwatch” from counting up. Each trial begins with a zeros on screen (000.00), then after an unpredictable time (ranging from 1-10 seconds) the counter starts going up, participants press the spacebar to stop the counter. Reaction Time feedback is provided after each trial. Throughout, participants are randomly asked to report on their current thoughts as an index of mind wandering during the task.
REFERENCE	Dinges, D. F., & Powell, J. W. (1985). Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations. Behavior Research Methods, Instruments, & Computers, 17, 652-655. (Original Citation)
	Loh, S., Lamond, N., Dorrian, J., Roach, G., & Dawson, D. (2004). The validity of psychomotor vigilance tasks of less than 10-minute duration. Behavior Research Methods, Instruments, & Computers, 36, 339-346. (Validity of Brief Version)
	Welhaf, M., & Kane, M. J. (2023). A Combined Experimental–Correlational Approach to the Construct Validity of Performance-Based and Self-Report-Based Measures of Sustained Attention. Attention, Perception, & Psychophysics. (Online Version)

PVT_MW Mind Wandering Rate during the PVT

RANGE 0 - 1 **HIGH SCORE** poor

PVT_Slow20 Mean Reaction Time of the slowest 20% of trials

RANGE undefined **HIGH SCORE** poor

Reaction Time

DATE ADDED 3/1/1999

DATE DROPPED 9/6/2001

DESCRIPTION

REFERENCE Abboud, A. & Sugar, D. (1990-97). SuperLab (Version 1.03). [Computer Software]. Phoenix: Cedrus Corporation.

CHOICERT CHOICE REACTION TIME TEST (NO DISTRACTION)

RANGE _____ **HIGH SCORE** _____

NOTES This task was similar to the simple reaction time task but there were four blocks of 18 trials each (total trials = 72). On half of the 18 trials in a block, the stimulus is "X" and on the other half the stimulus is "O." Participant pressed the "X" key

INTERFRT CHOICE REACTION TIME WITH DISTRACTION

RANGE _____ **HIGH SCORE** _____

NOTES Identical to the choice reaction time experiment but done while listening to a tape recording of a weather report.

SIMPLERT SIMPLE REACTION TIME TEST

RANGE _____ **HIGH SCORE** _____

Reading Span

DATE ADDED	11/16/2009
DATE DROPPED	9/1/2014
DESCRIPTION	Participants must remember the last word of sentences presented on the computer screen while judging if the sentence makes a statement that is true or false. The number of sentences read prior to recall increases from 1 to 7 in blocks of three trials for each span length (i.e., number of sentences read prior to recall). For example, on each trial in the first block, the participant reads the sentence and judges if it is true or false; the next screen displays question marks and the participant immediately recalls the last word of the sentence. On each trial of the second block, the participant reads the first sentence and judges if it is true or false, then reads the second sentence and judges if it is true or false, is presented with the screen with question marks and then recalls the last word of each of the two preceding sentences. For a trial to be scored as correct the order of the recalled words must be the same as the order in which the sentences were presented. The test is discontinued when the participant fails to get at least two correct trials in a block of three trials. One of two scores can be used: readspan or readtot.
REFERENCE	R Daneman, M., & Carpenter, P.A. (1980). Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Behavior, 19, 450-466.

READSPAN Reading span length

RANGE 0 - 7 **HIGH SCORE** good

READTOT Reading total correct trials

RANGE 0 - 21 **HIGH SCORE** good

Sentence Formulation

DATE ADDED	2/22/1984
DATE DROPPED	8/15/1991
DESCRIPTION	The participant was asked, "Tell me a sentence". After verbally stating a sentence, the participant was asked, "Please write it for me." Beginning 7/29/89 the sentence was tape-recorded; the tapes are available in the MAP office.
REFERENCE	Devised for MAP.

PSY201 SENTENCE FORMULATION REQUEST

RANGE 0 - 1 **HIGH SCORE** n/a

NOTES 0 = NO, 1 = YES

PSY210 WRITTEN: CURSIVE 1 PRINTED 2 ILLEGIBLE 3

RANGE 1 - 3 **HIGH SCORE** n/a

NOTES 1 = SENTENCE WRITTEN IN CURSIVE, 2 = SENTENCE PRINTED, 3 = SENTENCE WRITTEN ILLEGIBLY

Sentence Generation

DATE ADDED	5/6/1992
DATE DROPPED	7/1/1996
DESCRIPTION	The participant is asked to "Write any complete sentence on this piece of paper."
REFERENCE	Devised for MAP.

PSY253 SENTENCE GENERATION

RANGE 1 **HIGH SCORE** good

NOTES “C”, “M”, “R”, and “T” are other scores that may apply.

Simon Task

DATE ADDED	4/1/2009
DATE DROPPED	7/1/2020
DESCRIPTION	The participant sees a large arrow pointing to the right (60 trials) or left (60 trials) on the computer and presses the P key when the arrow points right and the Q key when it points left. One third of the trials represent the neutral condition; the arrows (half pointing right, half point right) are shown in the middle of the screen. One third of the trials represent the congruent condition; arrows pointing right are shown on the right side of the screen and arrows pointing left are shown on the left side of the screen. The remaining third of the trials reflect a mismatch between the direction of the arrow and the position on the screen; arrows pointing right are on the left side and arrows pointing left are on the right side.
REFERENCE	Castel, A.D., Balota, D.A., Hutchison, K.A., Logan, J.M., & Yap, M.J. (2007). Spatial attention and response control in healthy younger and older adults and individuals with Alzheimer's disease: Evidence for disproportionate selection breakdowns in the Simon task. Neuropsychology, 21, 170-182. Simon, J.R. (1969). Reactions toward the source of stimulation. Journal of Experimental Psychology, 81, 174-176.

SIMON Percentage correct responses on all 120 trials

RANGE 0 - 100 **HIGH SCORE** good

SIMONNUMBER Number of correct responses on all 120 trials

RANGE 0 - 120 **HIGH SCORE** good

Slosson Oral Reading Test (SORT-R)

DATE ADDED	12/9/1998
DATE DROPPED	
DESCRIPTION	Collected at baseline(T1) visit only. Scoring is from the SORT-R manual
REFERENCE	Richard, L. & Nicholson, Charles L. Slosson Oral Reading Test-Revised. East Aurora, NY: Slosson Education Publications, Inc., 1990.

SLOSSON SORT-R raw score

RANGE 0 - 200 **HIGH SCORE** good

Stroop

DATE ADDED	11/21/1996
DATE DROPPED	7/24/2000
DESCRIPTION	Administered and scored on computer. Scoring consists of median latencies and errors scored for each of the three different conditions: neutral, congruent incongruent.
REFERENCE	Stroop, J. R. (1935). Studies of interference in serial verbal reactions. Journal of Experimental Psychology: General, 18, 643-662.

ERRORC Median errors congruent

RANGE _____ **HIGH SCORE** _____

ERRORI Median errors incongruent

RANGE _____ **HIGH SCORE** _____

ERRORN Median errors neutral

RANGE _____ **HIGH SCORE** _____

MDNRTC Median latencies congruent

RANGE _____ **HIGH SCORE** _____

MDNRTI Median latencies incongruent

RANGE _____ **HIGH SCORE** _____

MDNRTN Median latencies neutral

RANGE _____ **HIGH SCORE** _____

Stroop Color Only – Web-based

DATE ADDED	9/1/2014
DATE DROPPED	
DESCRIPTION	9/1/2014: The participant sees a word printed in one of these 4 different colors (red, blue, yellow, green) and is directed to say the color in which the word is typed. A microphone is used to capture response time. The examiner hits the labeled key that reflects the participant's response, or hits the key labeled mic, for a mic error. A microphone error occurs when the participant's initial response is not picked up by the mic, or when participant triggers the mic by some accidental means (a cough, touching microphone, etc.) that would render the response time for that item irrelevant. For any response in which the participant self-corrects the original response is keyed in to reflect the response that corresponds with the reaction time. A practice trial consists of 16 items. The actual task consists of 104 trials. Practice trials are not included in the scoring.7/1/2020: The participant sees a word (red, blue, yellow, green or any of several non-color words) printed in one of these 4 different colors. The participant is directed to respond to the color in which the word is written by pressing the R key for red and the G key for green with their left-hand fingers, and the Y key for yellow and the B key for blue with their right-hand fingers. There is one practice trial, and the actual task consists of 104 items. The practice trial is not included in the scoring.
REFERENCE	Davidson, D. J., Zacks, R. T., &Williams, C. C. (2003). Stroop Interference,practice and aging. Aging Neuropsychology and Cognition, 10, 85-98. Golden & Freshwater (2002). The Stroop Color and Word Test: A Manual for Clinical and Experimental Uses. Wood Dale, IL: Stoelting Co. Stroop, J. R. (1935). Studies of interference in serial verbal reactions. Journal of Experimental Psychology: General, 18, 643-662.

STROOPCOLOR Number of correct responses out of 104 trials

RANGE 0 - 104 **HIGH SCORE** good

Stroop Switch

DATE ADDED	9/1/2014
DATE DROPPED	7/1/2020
DESCRIPTION	The participant again sees a word (red, blue, yellow or green) printed in one of these 4 different colors. A prompt for either WORD or COLOR appears on the screen before each trial. If the prompt reads WORD, the participant reads the word. If the prompt reads COLOR, the participant says the color in which the word is written. A microphone is used to capture response time and examiner records on a paper answer sheet whether the response was correct, incorrect, self-corrected or a microphone error occurred. There are two practice trials containing 40 trials total, and the actual task consists of 88 items. Practice trials are not included in the scoring.

REFERENCE

Davidson, D. J., Zacks, R. T., &Williams, C. C. (2003). Stroop Interference,practice and aging. Aging Neuropsychology and Cognition, 10, 85-98.

Duchek, J.M., Balota, D.A., Tse, C.S., Holtzman, D.M., Fagan, A.M., Goate, A.M. (2009) The utility of intraindividual variability in selective attention tasks as an early marker for Alzheimer's disease. Neuropsychology, Nov 23; (6) 746-58.

Golden & Freshwater (2002). The Stroop Color and Word Test: A Manual for Clinical and Experimental Uses. Wood Dale, IL: Stoelting Co.

Hutchison, K.A., Balota, D.A., Duchek, J.M. (2010) The utility of Stroop task switching as a marker for early-stage Alzheimer's disease. Psychol Aging, Sep; 25(3): 545-59

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. Journal of Experimental Psychology: General, 18, 643-662.

STROOPSWITCH Number of correct responses out of 88 trials

RANGE 0 - 88 **HIGH SCORE** good

Sustained Attention To Response Task (SART)

DATE ADDED	12/1/2023
DATE DROPPED	
DESCRIPTION	A go/no-go task where participants are instructed to response to stimuli from one category (i.e., animals or “go” trials) and withhold responses to stimuli from another category (i.e., crops/vegetables or “no-go” trials). The task is mainly “go” trials. Throughout, participants are randomly asked to report on their current thoughts as an index of mind wandering during the task.
REFERENCE	Manly, T., Robertson, I. H., Galloway, M., & Hawkins, K. (1999). The absent mind:: further investigations of sustained attention to response. Neuropsychologia, 37(6), 661-670. (Original Citation)
	Welhaf, M., & Kane, M. J. (2023). A Combined Experimental–Correlational Approach to the Construct Validity of Performance-Based and Self-Report-Based Measures of Sustained Attention. Attention, Perception, & Psychophysics. (Online Version)

SART_COV Coefficient of Variation (RT standard deviation/ Mean RT) to correct “go” trials.

RANGE undefined **HIGH SCORE** poor

SART_MW Mind Wandering Rate during SART

RANGE 0 - 1 **HIGH SCORE** poor

SART_NOGOACC No-Go Accuracy Rate on SART

RANGE 0 - 1 **HIGH SCORE** poor

Switching Task (CVOE)

DATE ADDED	4/1/2009
DATE DROPPED	
DESCRIPTION	Participants see letter-digit pairs (e.g., N14) in the center of the screen. In the first block of 50 trials (10 practice, 40 test) they press the P key if the letter is a vowel and the Q key if it a consonant. For the next 50 trials (10 practice, 40 test) they press the P key if the digit is even and the Q key if it is odd. In the final block of 62 mixed trials (10 practice, 52 test) the instructions (consonant and vowel or odd and even) that are shown in the upper right and upper left corners of the screen change every two trials. Thus, the participant makes consonant vowel decisions for two trials and then the odd even decisions and so forth. Practice trials are not included in the scoring.7/1/2020: Modified to web-based platform.
REFERENCE	Rogers, R.D., & Monsell, S. (1995). Costs of a switch between simple cognitive tasks. Journal of Experimental Psychology: General, 124, 207-231.

SWITCH Percentage correct responses out of total 132 trials

RANGE 0 - 100 **HIGH SCORE** good

SWITCHCV Number of correct responses on consonant/vowel choice block out of 40 trials

RANGE 0 - 40 **HIGH SCORE** good

SWITCHMIXED Number of correct responses on mixed consonant/vowel and even/odd block out of 52 trials

RANGE 0 - 52 **HIGH SCORE** good

SWITCHOE Number of correct responses on even/odd choice block out of 40 trials

RANGE 0 - 40 **HIGH SCORE** good

Syntax in Written Sentences

DATE ADDED	2/22/1984
DATE DROPPED	7/1/1996
DESCRIPTION	DEVELOPMENTAL SENTENCE SCORING (DSS). DSS was developed to analyze the growth of children's language. Points are assigned to eight categories of grammatical constructions based on the order or emergence of different forms in children's speech. An utterance total (derived by summing together the total points for each category plus 1 point if the utterance is a grammatical sentence) and/or a language sample average can be computed. The categories of personal pronouns and indefinite pronouns are combined into a single pronoun category and the categories of yes/no questions and wh-questions are combined into a single question category.
REFERENCE	Brown, R. (1974). A First Language. Cambridge, MA: Harvard University Press.
	Cheung, H., & Kemper, S. (1991). Competing complexity metrics and adults' production of complex sentences. Applied Psycholinguistics, 13, 53-76.
	Kintsch, W., & Keenan, J.M. (1973). Reading rate and retention as a function of the number of propositions in the base structure of sentence. Cognitive Psychology, 5, 257-274.
	Lee, L. (1974). Developmental Sentence Analysis. Evanston, IL: Northwestern University Press.
	Turner, A., & Greene, E. (1977). The Construction and Use of Propositional Text Base. Boulder, CO: University of Colorado Psychology Department.

CONJ CONJUNCTIONS

RANGE _____ **HIGH SCORE** _____

FIRSTVB MAIN VERB

RANGE _____ **HIGH SCORE** _____

MCU MEAN CLAUSES PER UTTERANCE

RANGE _____ **HIGH SCORE** _____

MLU MEAN LENGTH OF UTTERANCE

RANGE _____ **HIGH SCORE** _____

NEG NEGATIVES

RANGE _____ **HIGH SCORE** _____

PRONS PRONOUNS (INDEFINITE AND PERSONAL)

RANGE _____ **HIGH SCORE** _____

PROPTOT COUNT FOR PROPOSITIONS

RANGE _____ **HIGH SCORE** _____

QUESTS YES/NO & WH-QUESTIONS

RANGE _____ **HIGH SCORE** _____

SECONDVB EMBEDDED AND SUBORDINATE VERBS

RANGE _____ **HIGH SCORE**

SENTI GRAMMATICAL SENTENCE

RANGE _____ **HIGH SCORE** _____

TOTAL SUM OF THE ABOVE

RANGE _____ **HIGH SCORE** _____

Tapping Task – Web-based

DATE ADDED	9/1/2014
DATE DROPPED	12/1/2023
DESCRIPTION	The participant hears a set of tones that create a regular beat and is directed to tap the spacebar in time with the beat. After practicing tapping in time with the tones, the participant is told that the tones will discontinue after several repetitions but that they should continue to tap on the spacebar in the same rhythm until STOP appears on the screen. There are two practice trials before the actual test consisting of 24 trials total with a rhythm of 1250 ms. During the actual test, the tones are sounded at a rhythm of 1500 ms. and 109 trials are required. Practice trials are not included in the scoring. 7/1/2020: Modified to web-based platform.
REFERENCE	Bangert AS, Balota DA (2012) Keep up the pace: declines in simple repetitive timing differentiate healthy aging from the earliest stages of Alzheimer's disease. J Int Neuropsychol Soc Nov 29;18 (6):1052-63. Duchek JM, Balota DA, Ferraro FR (1994) Component analysis of a rhythmic finger tapping task in individuals with senile dementia of the Alzheimer type and in individuals with Parkinson's disease. Neuropsychology 8: 218–226.

TAPPING Median response time out of 109 trials

RANGE undefined **HIGH SCORE** n/a

Token Test

DATE ADDED	6/1/1982
DATE DROPPED	1/17/1990
DESCRIPTION	Used test to assess auditory comprehension in persons with developmental and acquired disorders affecting language, where the patient is verbally required to provide a gestural response (pointing to or moving plastic tokens) in response to a verbal command.
REFERENCE	DeRenzi, E. (1979). A shortened version of the Token Test. In F. Boller & M. Dennis (Eds.), Auditory comprehension: Clinical and Experimental Studies with the Token Test. New York: Academic Press.

PSY130	TOKEN TEST # CORRECT PART 1			
	RANGE	0 - 7	**HIGH SCORE**	good
PSY131	TOKEN TEST # CORRECT PART 2			
	RANGE	0 - 7	**HIGH SCORE**	good
PSY132	TOKEN TEST # CORRECT PART 3			
	RANGE	0 - 7	**HIGH SCORE**	good
PSY133	TOKEN TEST # CORRECT PART 4			
	RANGE	0 - 7	**HIGH SCORE**	good
PSY134	TOKEN TEST # CORRECT PART 5			
	RANGE	0 - 7	**HIGH SCORE**	good
PSY135	TOKEN TEST # CORRECT PART 6			
	RANGE	0 - 7	**HIGH SCORE**	good
PSY130 + PSY131 + PSY132 + PSY133 + PSY134 + PSY135	Summary score			
	RANGE	0 - 36	**HIGH SCORE**	good

Trail Making Form A

DATE ADDED	7/1/1979
DATE DROPPED	9/1/2005
DESCRIPTION	This is a test of processing speed and executive function. Although both Parts A and B depend on visuomotor and perceptual-scanning skills, Part B also requires considerable cognitive flexibility in shifting from number to letter sets under time pressure.
REFERENCE	Armitage, S.G. (1945). An analysis of certain psychological tests used for the evaluation of brain injury. Psychological Monographs, 60 (1, Whole No. 177), 1-48.

PSY018 TRAILMAKING FORM A IN SECONDS: Trailmaking, Part A

RANGE 0 - 180 **HIGH SCORE** poor

TMA TRAILMAKING A

RANGE 0 - 180 **HIGH SCORE** poor

TMASEC TRAILA_C divided by TMA

RANGE 0 and above **HIGH SCORE** good

TRAILA_C (Trail Making Form A) TRAILMAKING FORM A NUMBER OF DIGITS CONNECTED (Added 3/24/1994)

RANGE 0 - 24 **HIGH SCORE** good

Trail Making Form B

DATE ADDED	7/1/1979
DATE DROPPED	9/1/2005
DESCRIPTION	This is a test of processing speed and executive function. Although both Parts A and B depend on visuomotor and perceptual-scanning skills, Part B also requires considerable cognitive flexibility in shifting from number to letter sets under time pressure.
REFERENCE	Armitage, S.G. (1945). An analysis of certain psychological tests used for the evaluation of brain injury. Psychological Monographs, 60 (1, Whole No. 177), 1-48.

PSY252 TRAILMAKING FORM B IN SECONDS

RANGE 0 - 180 **HIGH SCORE** poor

TMB TRAILMAKING B

RANGE 0 - 180 **HIGH SCORE** poor

TMBSEC TRAILB_C divided by TMB

RANGE 0 and above **HIGH SCORE** good

TRAIL300 TRAILMAKING FORM B IN SECONDS: Trailmaking, Part B (1/28/1994 - 3/23/1994)

RANGE 0 - 300 **HIGH SCORE** good

TRAILB_C (Trail Making Form B) TRAILMAKING FORM B NUMBER OF DIGITS AND LETTERS CONNECTED (Added 3/24/1994)

RANGE 0 - 24 **HIGH SCORE** poor

Trail Making Test A and B

DATE ADDED	9/1/2005
DATE DROPPED	
DESCRIPTION	This is a test of processing speed and executive function. Although both Parts A and B depend on visuomotor and perceptual-scanning skills, Part B also requires considerable cognitive flexibility in shifting from number to letter sets under time pressure.The participant's performance is judged in terms of the time, in seconds, required to complete each Trail. The time to complete Part A (150-second maximum) and Part B (300-second maximum) will be the primary measure of interest (testing is stopped if the maximum is reached).
REFERENCE	Armitage, S.G. (1945). An analysis of certain psychological tests used for the evaluation of brain injury. Psychological Monographs, 60 (1, Whole No. 177), 1-48.

TRAILA The score is the number of seconds spent in connecting 25 numbered circles in sequential order. UDS variable reported maximum is 150 seconds.

RANGE 0 - 180 **HIGH SCORE** poor

TRAILA_C (Trail Making Test A and B) TRAILMAKING FORM A NUMBER OF DIGITS CONNECTED

RANGE 0 - 24 **HIGH SCORE** good

TRAILALI Number correct lines: The score is the number of lines correctly connected to 25 numbered circles in sequential order within the 150 second time limit. (Added 2/25/2008)

RANGE 0 - 24 **HIGH SCORE** good

TRAILARR Number of commission errors. (Added 2/25/2008)

RANGE 0 - 40 **HIGH SCORE** poor

TRAILB The score is the number of seconds spent connecting numbered circles (1-13) to circles containing letters of the alphabet (A-L) in alternating sequential order.

RANGE 0 - 300 **HIGH SCORE** poor

TRAILB_C (Trail Making Test A and B) TRAILMAKING FORM B NUMBER DIGITS AND LETTERS CONNECTED

RANGE 0 - 24 **HIGH SCORE** good

TRAILBLI Number of correct lines (Added 2/25/2008)

RANGE 0 - 24 **HIGH SCORE** good

TRAILBRR Number of commission errors (Added 2/25/2008)

RANGE 0 - 40 **HIGH SCORE** poor

Verbal Fluency: Phonemic Test

DATE ADDED	3/16/2015
DATE DROPPED	
DESCRIPTION	In this task, the participant is told a letter of the alphabet (F) and asked to state as many words as possible that begin with that letter within 60 seconds. After 60 seconds, this is repeated with a second letter (L). The primary measure of performance is the total number of correct F-words and L-words.
REFERENCE	Argye E. Hillis, MD; do not copy or distribute without author's permission. Form created as part of the FTLD Module to the Uniform Data Set of the National Alzheimer's Coordinating Center. Copyright © 2013 University of Washington.

UDSVERFC Number of correct F-words produced in 1 minute

RANGE 0 - 40 **HIGH SCORE** good

UDSVERFN Number of F-words repeated in 1 minute

RANGE 0 - 15 **HIGH SCORE** poor

UDSVERLC Number of correct L-words produced in 1 minute

RANGE 0 - 40 **HIGH SCORE** good

UDSVERLN Number of non-L-words and rule violation errors in 1 minute

RANGE 0 - 15 **HIGH SCORE** poor

UDSVERLR Number L-words repeated in 1 minute

RANGE 0 - 15 **HIGH SCORE** poor

UDSVERNF Number of non-F-words and rule violation errors in 1 minute

RANGE 0 - 15 **HIGH SCORE** poor

UDSVERTE Total number of F-word and L-word repetition errors

RANGE 0 - 30 **HIGH SCORE** poor

UDSVERTI Total number of non-F/L-words and rule violation errors

RANGE 0 - 30 **HIGH SCORE** poor

UDSVERTN Total number of F-words and L-words

RANGE 0 - 80 **HIGH SCORE** good

Visual Neglect

DATE ADDED	12/1/1983
DATE DROPPED	12/31/1989
DESCRIPTION	In this task, participants must cross out lines that are placed in random orientations on a piece of paper.
REFERENCE	Albert, M. L. (1973). A simple test of visual neglect. Neurology, 23, 658-664.

PSY196 VISUAL NEGLECT LINES NEGLECTED RIGHT. Score is number of lines omitted.

RANGE 0 - 12 **HIGH SCORE** poor

PSY197 VISUAL NEGLECT LINES NEGLECTED LEFT. Score is number of lines omitted.

RANGE 0 - 12 **HIGH SCORE** poor

PSY198 VISUAL NEGLECT LINES NEGLECTED CENTER. Score is number of lines omitted.

RANGE 0 - 16 **HIGH SCORE** poor

PSY199 VISUAL NEGLECT TIME (in seconds)

RANGE 0 - 180 **HIGH SCORE** poor

PSY200 VISUAL NEGLECT HANDEDNESS

RANGE 0 - 1 **HIGH SCORE** n/a

NOTES 0 = LEFT, 1 = RIGHT

PSY196 + PSY197 + PSY198 Summary score

RANGE 0 - 40 **HIGH SCORE** poor

WAIS: Block Design

DATE ADDED	7/1/1979
DATE DROPPED	7/14/2005
DESCRIPTION	The participant replicates models or pictures of two-color designs with blocks.
REFERENCE	Wechsler, D. (1955). Manual: Wechsler Adult Intelligence Scale. New York: Psychological Corporation.

PSY021 WAIS Block Design: Administered and raw scored according to WAIS manual.

RANGE 0 - 48 **HIGH SCORE** good

PSY022 WAIS Digit Symbol

RANGE 0 - 90 **HIGH SCORE** good

WAIS: Comprehension

DATE ADDED	7/1/1979
DATE DROPPED	12/2/1988
DESCRIPTION	Participants are asked questions about social situations or common concepts.
REFERENCE	Wechsler, D. (1955). Manual: Wechsler Adult Intelligence Scale. New York: Psychological Corporation.

PSY020 WAIS Comprehension: Raw score according to WAIS manual.

RANGE 0 - 14 **HIGH SCORE** good

WAIS: Digit Symbol

DATE ADDED	7/1/1979
DATE DROPPED	5/1/2020
DESCRIPTION	This test is presented on a single sheet of paper that requires the participant to match symbols to numbers according to a key on the top of the page. The participant copies the symbol into spaces below a row of numbers within a 90-second time limit.
REFERENCE	Wechsler, D. (1955). Manual: Wechsler Adult Intelligence Scale. New York: Psychological Corporation.

WAIS: Digit Symbol Copy (MAP)

DATE ADDED	12/1/1983
DATE DROPPED	10/3/1996
DESCRIPTION	Participants copy digits only, no coding. A maximum of 90 seconds is allowed.
REFERENCE	Devised for MAP.
	Wechsler, D. (1955). Manual: Wechsler Adult Intelligence Scale. New York: Psychological Corporation.

PSY089 Digit Symbol Copy

RANGE 0 - 90 **HIGH SCORE** good

PSY241 Digit Symbol Copy, Time: Time taken to complete Digit Symbol Copy (PSY089)

RANGE 0 - 90 **HIGH SCORE** poor

WAIS: Incidental Memory Recall (MAP)

DATE ADDED	5/1/1987
DATE DROPPED	8/15/1991
DESCRIPTION	Participant is asked to recall the Digit Symbol pairings.
REFERENCE	Devised for MAP. Wechsler, D. (1955). Manual: Wechsler Adult Intelligence Scale. New York: Psychological Corporation.

PSY245 Incidental Memory Recall: Total. Score equals number of symbols recalled.

RANGE 0 - 9 **HIGH SCORE** good

PSY246 Incidental Memory Recall: Matched. Score equals number of symbols recalled and correctly matched to numbers.

RANGE 0 - 9 **HIGH SCORE** good

WAIS: Information

DATE ADDED	7/1/2019
DATE DROPPED	7/1/2020
DESCRIPTION	The participant answers a series of questions about factual information. Administered and raw scored according to WAIS manual
REFERENCE	Wechsler, D. (1955). Manual: Wechsler Adult Intelligence Scale. New York: Psychological Corporation.

PSY019 WAIS Information

RANGE 0 - 29 **HIGH SCORE** good

WAIS: Picture Arrangement

DATE ADDED	5/15/1984
DATE DROPPED	2/12/1992
DESCRIPTION	Only the first three items were administered. No time limits were used.
REFERENCE	Wechsler, D. (1955). Manual: Wechsler Adult Intelligence Scale. New York: Psychological Corporation.

PSY230 WAIS PICTURE ARRANGEMENT: COULD NOT DO.

RANGE 0 - 1 **HIGH SCORE** poor

PSY231 WAIS PICTURE ARRANGEMENT: # CORRECT. SCORE IS THE NUMBER OF CORRECT SEQUENCES

RANGE 0 - 3 **HIGH SCORE** good

WAIS-R: Digit Symbol – Standard form

DATE ADDED	9/1/2005
DATE DROPPED	7/1/2020
DESCRIPTION	Paper-and-pencil cognitive test, which requires matching symbols to their corresponding numbers over a 90-second time interval.
REFERENCE	Wechsler, D. (1981). Manual: Wechsler Adult Intelligence Scale - Revised. New York: Psychological Corporation.

DIGSYM Administered and raw scored according to WAIS-R manual

RANGE 0 - 93 **HIGH SCORE** good

WAIS-R: Digit Symbol – UDS enlarged form

DATE ADDED	3/6/2006
DATE DROPPED	3/16/2015
DESCRIPTION	This is an enlarged Digit Symbol form that measures 15 x 24 cm rather than 9.5 x 13 cm as in the standard WAIS-R.
REFERENCE	Wechsler, D. (1981). Manual: Wechsler Adult Intelligence Scale - Revised. New York: Psychological Corporation.

WAIS This is an enlarged Digit Symbol form that measures 15 x 24 cm rather than 9.5 x 13 cm as in the standard WAIS-R.

RANGE 0 - 93 **HIGH SCORE** good

WAIS-III: Block Design

DATE ADDED	7/14/2005
DATE DROPPED	7/1/2020
DESCRIPTION	The participant replicates models or pictures of two-color designs with blocks. Administered and raw scored according to the WAIS-III manual.
REFERENCE	Wechsler, D. (1997). Manual: Wechsler Adult Intelligence Scale-III. New York: Psychological Corporation.

BLOCK WAIS-III Block Design

RANGE 0 - 68 **HIGH SCORE** good

WAIS-III: Information

DATE ADDED	3/6/2006
DATE DROPPED	3/16/2015
DESCRIPTION	The participant answers a series of questions about factual information. Administered and raw scored according to WAIS-III manual.
REFERENCE	Wechsler, D. (1997). Manual: Wechsler Adult Intelligence Scale-III. New York: Psychological Corporation.

INFORM WAIS-III Information

RANGE 0 - 28 **HIGH SCORE** good

WAIS-III: Similarities

DATE ADDED	8/1/2002
DATE DROPPED	7/1/2020
DESCRIPTION	Participant is asked how two objects or concepts are alike. Score reflects abstract reasoning abilities.
REFERENCE	Wechsler, D. (1997). Manual: Wechsler Adult Intelligence Scale-III. New York: Psychological Corporation.

SIM WAIS-III Similarities. Raw scored according to WAIS-III manual.

RANGE 0 - 33 **HIGH SCORE** good

WMS: Associate Learning

DATE ADDED	7/1/1979
DATE DROPPED	
DESCRIPTION	WMS Subtest VII. The participant is read a group of eight word pairs, then is read the first word of each pair, and is asked to supply the second word from memory.
REFERENCE	Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

ASSCMEM Summary Score = (PSY010 divided by 2) + PSY011

RANGE 0 - 21 **HIGH SCORE** good

PSY010 WMS ASSOCIATES RECALL – EASY

RANGE 0 - 18 **HIGH SCORE** good

PSY011 WMS ASSOCIATES RECALL – HARD

RANGE 0 - 12 **HIGH SCORE** good

WMS: Associate Learning – Recognition (MAP)

DATE ADDED	7/1/1979
DATE DROPPED	1/2/2004
DESCRIPTION	A recognition trial for the pairs from the WMS Associate Learning subtest is administered immediately following the third recall trial of the WMS Associate Learning subtest. The stimulus word of each pair is printed in large type at the top of a card with four words (including the correct response) printed in smaller type horizontally below. The easy and hard pairs are interspersed, as in the WMS Associate Learning subtest, and are presented in a different random order than used on any of the recall trials. This recognition trial is scored in the same manner as the standard recall version except there is only one recognition trial.
REFERENCE	Devised for MAP. Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY013 WMS ASSOCIATES RECOGNITION – EASY

RANGE 0 - 6 **HIGH SCORE** good

PSY014 WMS ASSOCIATES RECOGNITION – HARD

RANGE 0 - 4 **HIGH SCORE** good

PSY014 + (PSY013 ÷ 2) Summary score

RANGE 0 - 5 **HIGH SCORE** good

WMS: Digit Span

DATE ADDED	7/1/1979
DATE DROPPED	7/1/2020
DESCRIPTION	This test was modified into the NACC version (digiflen and digblen) on 9/1/2005 and removed on 2/13/2017 after crosswalk study ended
REFERENCE	Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY005 DIGITS FORWARD

RANGE 0 - 8 **HIGH SCORE** good

NOTES PSY005 was recoded as variable DIGFOR as of 9/1/2005 to conform to NACC field

PSY006 DIGITS BACKWARD

RANGE 0 - 7 **HIGH SCORE** good

NOTES PSY006 was recoded as variable DIGBACK as of 9/1/2005 to conform to NACC field

DIGFOR Digits forward

RANGE 0 - 8 **HIGH SCORE** good

NOTES This variable replaced PSY005 to conform to NACC field as of 9/1/2005

DIGBACK Digits backward

RANGE 0 - 7 **HIGH SCORE** good

NOTES This variable replaced PSY006 to conform to NACC field as of 9/1/2005

WMS: Visual Digit Span: Sequential (MAP)

DATE ADDED	7/1/1979
DATE DROPPED	8/17/1991
DESCRIPTION	This procedure is also modeled after the auditory digit span subtest of the Wechsler Memory Scale. Single digits, rather than strings of digits, are printed on cards. The cards are grouped in sets of 2 through 8 cards. There are two sets of cards at each level (i.e., 2 through 8) or a total of 14 sets of cards. Cards are presented serially with each card shown for 1 second. After the last card in the group is taken away, the participant is asked to recite the numbers from the cards in that set in the order given. If the first set at a level is recited correctly, the second set at that level is not administered. For example, if the participant repeats the first set of 2 digits correctly, the first set of 3 cards is presented next. If the participant does not recite the 2 digits from the first set of 2 cards correctly, the second set of 2 cards is presented. Testing is discontinued when a participant fails to recite in the correct order the digits on both sets of cards at a particular level (i.e., number of cards in a set). The score is the number of digits in the longest set recited correctly.
REFERENCE	Devised for MAP. Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY009 VISUAL DIGIT SPAN: SEQUENTIAL

RANGE 0 - 8 **HIGH SCORE** good

WMS: Visual Digit Span: Simultaneous (MAP)

DATE ADDED	7/1/1979
DATE DROPPED	8/17/1991
DESCRIPTION	This procedure is modeled after the auditory digit span subtest of the Wechsler Memory Scale. Strings of numbers ranging in length from 2 to 8 digits are printed horizontally on cards. There are two cards with strings of each length. Presentation of each string is for as many seconds as there are digits on the card. If the first string of a particular length is passed, the second string with that number of digits is not administered. For example, the first card with a string of 2 digits is presented for 2 seconds; then the card is removed. If the participant repeats the 2 digits correctly, the first string of 3 digits is presented next for 3 seconds. If the participant does not repeat the first card with a string of 2 digits correctly, the second card with a string of 2 digits is presented for 2 seconds. Testing is discontinued when a participant fails to repeat both of the strings of a particular length. The score is the number of digits in the longest string reported correctly.
REFERENCE	Devised for MAP. Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY008 VISUAL DIGIT SPAN: SIMULTANEOUS

RANGE 0 - 8 **HIGH SCORE** good

WMS: Information

DATE ADDED	7/1/1979
DATE DROPPED	1/1/1984
DESCRIPTION	Subtest I. Personal and current information. Scored according to WMS manual. The names of persons incumbent at the time of testing were scored as correct in Question 5 (the governor of Missouri) and Question 6 (the mayor of St. Louis). Similar questions were asked in the Clinical Assessment administered by physicians.
REFERENCE	Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY001 WMS INFORMATION

RANGE 0 - 6 **HIGH SCORE** good

WMS: Information (MAP)

DATE ADDED	1/1/1984
DATE DROPPED	8/14/1991
DESCRIPTION	This is a simplified version of WMS Information. It is scored for content accuracy by comparison with the current clinical assessment. The score is the sum of correct responses to Questions 1-6.
REFERENCE	Devised for MAP.
	Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY004 WMS LOGICAL MEMORY

RANGE 0 - 23 **HIGH SCORE** good

PSY070 MAP INFORMATION

RANGE 0 - 6 **HIGH SCORE** good

WMS: Logical Memory

DATE ADDED	7/1/1979
DATE DROPPED	9/1/2005
DESCRIPTION	Subtest IV. WMS Logical Memory. Scored according to WMS manual.
REFERENCE	Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY073 WMS LOGICAL MEMORY DELAYED RECALL

RANGE 0 - 23 **HIGH SCORE** good

PSY251 WMS LOGICAL MEMORY - 10 MINUTE RECALL (6/17/1991 - 9/1/2005)

RANGE 0 - 23 **HIGH SCORE** good

WMS: Logical Memory – Verbatim Scoring (MAP)

DATE ADDED	1/2/2004
DATE DROPPED	9/1/2005
DESCRIPTION	This is an alternate, verbatim scoring of the WMS Logical Memory stories A & B as used by Johnson et al. (2003). Record only those propositions that are recalled verbatim. No synonyms allowed.
REFERENCE	Devised for MAP. Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

LMVERA Story A

RANGE 0 - 35 **HIGH SCORE** good

LMVERB Story B

RANGE 0 - 34 **HIGH SCORE** good

WMS: Mental Control

DATE ADDED	7/1/1979
DATE DROPPED	7/1/2020
DESCRIPTION	Consists of three sub-items. Counting backwards from 20 to 1; repeating the alphabet, and counting by threes.
REFERENCE	Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

MENTCONT Summary score = PSY003 + PSY072 + PSY078

RANGE 0 - 9 **HIGH SCORE** good

PSY003 WMS MENTAL CONTROL COUNT BACK FROM 20

RANGE 0 - 3 **HIGH SCORE** good

PSY072 WMS MENTAL CONTROL ALPHABET

RANGE 0 - 3 **HIGH SCORE** good

PSY078 WMS MENTAL CONTROL SERIAL COUNTING BY 3

RANGE 0 - 3 **HIGH SCORE** good

WMS: Mental Control (MAP)

DATE ADDED	1/1/1984
DATE DROPPED	10/31/1991
DESCRIPTION	Each of the three parts is scored in the same manner as WMS Mental Control (i.e., bonus points for rapid performance and penalties for errors).
REFERENCE	Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY079 MAP MENTAL CONTROL COUNT BACK FROM 10

RANGE 0 - 3 **HIGH SCORE** good

PSY080 MAP MENTAL CONTROL SPELL NAME

RANGE 0 - 3 **HIGH SCORE** good

PSY081 MAP MENTAL CONTROL SERIAL COUNTING BY 2

RANGE 0 - 3 **HIGH SCORE** good

PSY079 + PSY080 + PSY081 Summary score

RANGE 0 - 9 **HIGH SCORE** good

WMS: Orientation

DATE ADDED	7/1/1979
DATE DROPPED	1/1/1984
DESCRIPTION	Subtest II. Orientation. Scored according to WMS manual. Similar questions were asked in the Clinical Assessment administered by physicians.
REFERENCE	Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY002 WMS ORIENTATION

RANGE 0 - 5 **HIGH SCORE** good

WMS: Orientation (MAP)

DATE ADDED	1/1/1984
DATE DROPPED	8/14/1991
DESCRIPTION	Simplified version of WMS Orientation. Score is sum of correct responses to Questions 1-5.
REFERENCE	Devised for MAP. Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY071 MAP ORIENTATION

RANGE 0 - 5 **HIGH SCORE** good

WMS: Sentence Recall (MAP)

DATE ADDED 2/22/1984

DATE DROPPED 9/11/1991

DESCRIPTION This procedure is administered immediately after the WMS Logical Memory Delayed Recall trial. Participant is asked to recall three sentences (PSY074) each containing only three pieces of information and then three sentences (PSY076) each containing only four pieces of information. Subsequently three additional phrases, each containing only two pieces of information (PSY239) and three additional phrases, each only one piece of information (PSY240) were added. The score is the sum of the pieces of information in the sentences repeated (almost verbatim). Some minor omissions are allowed. If only one word in a two-word byte is repeated, a half point (.5) is allowed.

REFERENCE Wechsler, D., & Stone, C.P. (1973). Manual: Wechsler Memory Scale. New York: Psychological Corporation.

PSY074 SENTENCE RECALL 3 BYTES A+B+C

RANGE 0 - 9 **HIGH SCORE** good

PSY076 SENTENCE RECALL 4 BYTES D+E+F

RANGE 0 - 12 **HIGH SCORE** good

PSY239 SENTENCE RECALL 2 BYTES G+H+I

RANGE 0 - 6 **HIGH SCORE** good

PSY240 SENTENCE RECALL 1 BYTE J+K+L

RANGE 0 - 3 **HIGH SCORE** good

PSY074 + PSY076 + PSY239 + PSY240 Summary score after 9/86

RANGE 0 - 30 **HIGH SCORE** good

PSY074 + PSY076 Summary score until 9/86

RANGE 0 - 21 **HIGH SCORE** good

WMS-R: Digit Span Forward

DATE ADDED	9/1/2005
DATE DROPPED	2/13/2017
DESCRIPTION	Administered according to WMS-R manual. Scored according to UDS guidebook, which yields two scores.
REFERENCE	Wechsler, D. (1987). Manual: Wechsler Memory Scale-Revised. San Antonio, Texas: Psychological Corporation.

DIGIF Total number of trials correct prior to two consecutive errors at the same digit length

RANGE 0 - 12 **HIGH SCORE** good

DIGIFLEN Digit span forward length

RANGE 0 - 8 **HIGH SCORE** good

WMS-R: Digit Span Backward

DATE ADDED	9/1/2005
DATE DROPPED	2/13/2017
DESCRIPTION	Administered according to WMS-R manual. Scored according to UDS guidebook, which yields two scores.
REFERENCE	Wechsler, D. (1987). Manual: Wechsler Memory Scale-Revised. San Antonio, Texas: Psychological Corporation.

DIGIB Total number of trials correct prior to two consecutive errors at the same digit length

RANGE 0 - 12 **HIGH SCORE** good

DIGIBLEN Digit span backward length

RANGE 0 - 7 **HIGH SCORE** good

WMS-R: Logical Memory Story IA – Immediate

DATE ADDED	9/1/2005
DATE DROPPED	2/13/2017
DESCRIPTION	Only Story A is administered. Scored according to WMS-R manual
REFERENCE	Wechsler, D. (1987). Manual: Wechsler Memory Scale-Revised. San Antonio, Texas: Psychological Corporation.

LOGIMEM Only Story A is administered. Scored according to WMS-R manual

RANGE 0 - 25 **HIGH SCORE** good

WMS-R: Logical Memory Story IIA – Delayed

DATE ADDED	9/1/2005
DATE DROPPED	2/13/2017
DESCRIPTION	Administered after WAIS-R Digit Symbol and scored according to WMS-R manual
REFERENCE	Wechsler, D. (1987). Manual: Wechsler Memory Scale-Revised. San Antonio, Texas: Psychological Corporation.

MEMUNITS Administered after WAIS-R Digit Symbol and scored according to WMS-R manual

RANGE 0 - 25 **HIGH SCORE** good

MEMTIME Minutes elapsed since Logical Memory IA-Immediate

RANGE 0 - 85 **HIGH SCORE** n/a

WMS-III: Letter-Number Sequencing

DATE ADDED	4/1/2009
DATE DROPPED	12/1/2023
DESCRIPTION	The participant is read a combination of numbers and letters and is asked to repeat them, saying the numbers first in ascending order and then the letters in alphabetical order. Administered and scored according to the WMS-III manual.
REFERENCE	Wechsler, D. (1997). Wechsler Memory Scale (3rd ed.): Administration and scoring manual. San Antonio, TX: Psychological Corporation.

LETTNUM WMS-III Letter Number Sequencing

RANGE 0 - 21 **HIGH SCORE** good

WMS-III: Logical Memory I – Immediate

DATE ADDED	7/14/2005
DATE DROPPED	7/1/2020
DESCRIPTION	The participant is read two short stories and is asked to recall them. Administered and scored according to WMS-III manual with the exception that Story B is only given once.
REFERENCE	Wechsler, D. (1997). Wechsler Memory Scale (3rd ed.): Administration and scoring manual. San Antonio, TX: Psychological Corporation.

LOGMEM WMS-III Logical Memory Immediate

RANGE 0 - 50 **HIGH SCORE** good

WMS-III: Logical Memory II – Delayed

DATE ADDED	7/14/2005
DATE DROPPED	7/1/2020
DESCRIPTION	Delayed recall trial administered and scored (recall total score) according to WMS-III manual.
REFERENCE	Wechsler, D. (1997). Wechsler Memory Scale (3rd ed.): Administration and scoring manual. San Antonio, TX: Psychological Corporation.

LMDELAY Delayed recall trial administered and scored (recall total score) according to WMS-III manual.

RANGE 0 - 50 **HIGH SCORE** good

WMS-III: Verbal Paired Associates

DATE ADDED	7/14/2005
DATE DROPPED	7/1/2020
DESCRIPTION	The participant learns eight paired associates of low association over 4 trials. Administered and scored according to WMS-III manual.
REFERENCE	Wechsler, D. (1997). Wechsler Memory Scale (3rd ed.): Administration and scoring manual. San Antonio, TX: Psychological Corporation.

PAIRS WMS-III Verbal Paired Associates I

RANGE 0 - 32 **HIGH SCORE** good

Wisconsin Card Sorting Test

DATE ADDED 2/19/2004

DATE DROPPED 12/31/2008

DESCRIPTION Computerized administration and scoring of the WCST according to Heaton et al. (1993). Note following change in procedure: the participant points to choice on the screen and the tester manipulates the mouse to make the response. The participant tells the tester if he or she wants to change the response and the tester clicks on the screen. See manual for definition of scores.

REFERENCE

Berg, E.A. (1948). A simple objective test for measuring flexibility in thinking. Journal of General Psychology, 39, 15-22.

Grant, D.A. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. Journal of Experimental Psychology, 34, 404-411.

Heaton, R.K., Chelune, G.J., Talley J.L., Kay, G.G., & Curtis, G. (1993). Wisconsin Card Sorting Test manual: revised and expanded. Odessa, FL: Psychological Assessment Resources.

WCSTCATC Categories completed

RANGE 0 - 6 **HIGH SCORE** good

WCSTCLRE Conceptual level responses (%)

RANGE 0 - 100 **HIGH SCORE** good

WCSTFAIL Failure to maintain set

RANGE 0 - 21 **HIGH SCORE** poor

WCSTLRN Learning to learn (%)

RANGE negative to positive **HIGH SCORE** good

WCSTNPE Nonperseverative errors

RANGE 0 - 128 **HIGH SCORE** poor

WCSTPERE Perseverative errors

RANGE 0 - 126 **HIGH SCORE** poor

WCSTPERR Perseverative responses

RANGE 0 - 126 **HIGH SCORE** poor

WCSTSPSC Special score: R=refused,C=cognitive confusion,I=physical difficulties,M=examiner decided to not administer,A=all administered

RANGE **HIGH SCORE**

WCSTTOTC Total number correct trials

RANGE 0 - 128 **HIGH SCORE** good

WCSTTOTE	Total errors			
	RANGE	0 - 128	**HIGH SCORE**	poor
WCSTTRAD	Number trials administered			
	RANGE	0 - 128	**HIGH SCORE**	poor
WCSTTRCM	Trials to first category			
	RANGE	10 - 129	**HIGH SCORE**	poor

Woodcock-Johnson Spatial Relations

DATE ADDED	7/14/2005
DATE DROPPED	7/1/2020
DESCRIPTION	Participant looks at a series of “whole” shapes with interior lines dividing the shape into regular and irregular pieces. Next to the whole shape is a group of six shape pieces, labeled with letters of the alphabet. The participant indicates which of the shape pieces would be needed to make up the “whole” shape. The 33 test items are presented in order of ascending difficulty and require two or three responses. The score is the number of correctly identified pieces.
REFERENCE	Woodcock, Richard W., McGrew, Kevin S., and Mather, Nancy (2001).Examiner's Manual. Woodcock-Johnson III Tests of Cognitive Abilities. Itaska,IL: Riverside Publishing.

SPACIAL Spatial Relations

RANGE 0 - 81 **HIGH SCORE** good

Word Fluency

DATE ADDED	7/1/1979
DATE DROPPED	2/13/2017
DESCRIPTION	Participants are asked to name as many words that begin with the letter S as they can in 1 minute.
REFERENCE	Thurstone, L. E., & Thurstone, T. G., (1949). Examiner manual for the SRA Primary Mental Abilities Test. Chicago: Science Research Associates.

PSY032 WORD FLUENCY LETTER S

RANGE 0 and above **HIGH SCORE** good

PSY033 WORD FLUENCY LETTER P

RANGE 0 and above **HIGH SCORE** good

Zung Depression Scale

DATE ADDED	7/1/1979
DATE DROPPED	6/1/1982
DESCRIPTION	Raw scores were converted to SDS scores using the conversion table.
REFERENCE	Zung, W. W. K. (1967). Depression in the normal aged. Psychosomatics, 8, 287-292.

PSY036 ZUNG DEPRESSION: SDS SCALE AT T1

RANGE 0 - 100 **HIGH SCORE** more depressed

Rey Auditory Verbal Learning Test (RAVLT)

DATE ADDED	1/14/2025
DATE DROPPED	
DESCRIPTION	The RAVLT assesses immediate memory span, new learning, susceptibility to interference, and recognition memory. A list of 15 words (List A) is read aloud for five consecutive trials and each trial is followed by a free-recall test. After the fifth trial, an interference list of 15 different words (List B) is presented, followed by a free-recall test of that list. The words of List A (Trials 1-5) and List B are presented at the rate of one word for per second. Immediately afterward, delayed free-recall of List A is tested (Trial 6). After a 20- to 30-minute delay, another free-recall and recognition trial is administered.
REFERENCE	Schmidt, M. (1996). Rey Auditory Verbal Learning Test: A handbook. Los Angeles, CA: Western Psychological Services.
	Strauss, E., Sherman, E. M. S., & Spreen, O. (2006). A compendium of neuropsychological tests: Administration, norms, and commentary (3rd ed.). Oxford University Press.
	Mayo Normative Studies: Regression-Based Normative Data for the Auditory Verbal Learning Test for Ages 30-91 Years and the Importance of Adjusting for Sex
	Nikki H. Stricker et al., Journal of the International Neuropsychological Society (2021), 27, 211-226.

REY1REC Rey Auditory Verbal Learning: Trial 1 total recall

RANGE 0 - 15 **HIGH SCORE** good

REY1INT Rey Auditory Verbal Learning: Trial 1 intrusions

RANGE UNLIMITED **HIGH SCORE** poor

REY2REC Rey Auditory Verbal Learning: Trial 2 total recall

RANGE 0 - 15 **HIGH SCORE** good

REY2INT Rey Auditory Verbal Learning: Trial 2 instrusions

RANGE UNLIMITED **HIGH SCORE** poor

REY3REC Rey Auditory Verbal Learning: Trial 3 total recall

RANGE 0 - 15 **HIGH SCORE** good

REY3INT Rey Auditory Verbal Learning: Trial 3 intrusions

RANGE UNLIMITED **HIGH SCORE** poor

REY4REC Rey Auditory Verbal Learning: Trial 4 total recall

RANGE 0 - 15 **HIGH SCORE** good

REY4INT Rey Auditory Verbal Learning: Trial 4 intrusions

RANGE UNLIMITED **HIGH SCORE** poor

REY5REC Rey Auditory Verbal Learning: Trial 5 total recall

RANGE 0 - 15 **HIGH SCORE** good

REY5INT Rey Auditory Verbal Learning: Trial 5 intrusions

RANGE UNLIMITED **HIGH SCORE** poor

REY6REC Rey Auditory Verbal Learning: Trial 6 total recall

RANGE 0 - 15 **HIGH SCORE** good

REY6INT Rey Auditory Verbal Learning: Trial 6 intrusions

RANGE UNLIMITED **HIGH SCORE** poor

REYDREC Rey Auditory Verbal Learning: total delayed recall

RANGE 0 - 15 **HIGH SCORE** good

REYDINT Rey Auditory Verbal Learning: delayed intrusions

RANGE UNLIMITED **HIGH SCORE** poor

REYTCOR Rey Auditory Verbal Learning: recognition total correct

RANGE 0 - 15 **HIGH SCORE** good

REYFPOS Rey Auditory Verbal Learning: recognition total false positives

RANGE 0 - 15 **HIGH SCORE** poor

Ambulatory Research in Cognition (ARC)

DATE ADDED	8/21/2019
DATE DROPPED	
DESCRIPTION	The Ambulatory Research in Cognition (ARC) smartphone application is based on principles from ecological momentary assessment (EMA) and administers brief tests of associative memory, processing speed, and working memory up to 4 times per day over 7 consecutive days. ARC was designed to be administered unsupervised using participants' personal devices in their everyday environments.
REFERENCE	Nicosia J, Aschenbrenner AJ, Balota DA, Sliwinski MJ, Tahan M, Adams S, Stout SS, Wilks H, Gordon BA, Benzinger TLS, Fagan AM, Xiong C, Bateman RJ, Morris JC, Hassenstab J. Unsupervised high-frequency smartphone-based cognitive assessments are reliable, valid, and feasible in older adults at risk for Alzheimer's disease. J Int Neuropsychol Soc.2023 Jun;29(5):459-471. doi: 10.1017/S135561772200042X.

ARC_ID ARC Identification Number

RANGE 999999 **HIGH SCORE** n/a

VISIT ARC visit number. Cycles completed every three months.

RANGE 18 **HIGH SCORE** n/a

SESSIONSCOMPLETED Number of ARC testing sessions completed

RANGE 28 **HIGH SCORE** n/a

VISITSTARTDATE N/A

RANGE N/A **HIGH SCORE** n/a

SYMBOLSMEDIANRT Median response time on accurate Symbols trials, in milliseconds

RANGE 100000 **HIGH SCORE** poor

SYMBOLSCOV Symbols coefficient of variation, an index of attention consistency

RANGE UNLIMITED **HIGH SCORE** poor

PRICES_ERR Mean prices test error rate, in percent

RANGE 100 **HIGH SCORE** poor

GRIDS Mean Euclidean distance from correct location

RANGE UNLIMITED **HIGH SCORE** poor

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Knight PACC: The Knight Preclinical Alzheimer's Cognitive Composite (Knight PACC) is a composite measure of cognition that was specifically chosen to represent cognitive tasks that are sensitive to early changes in preclinical AD by assessing memory, attention, and processing speed concurrently. The Knight PACC contains measures that have been consistently collected at the Knight ADRC since approximately 2002, including the free recall total score from the Free & Cued Selective Reminding Test, the Digit Symbol Substitution test from the Wechsler Adult Intelligence Test-Revised (or a digital version of this test developed de novo by Drs. Jason Hassenstab and Andrew Aschenbrenner called Number Symbol), the completion time in seconds from the Trailmaking Test Part B, and the total correct score from the animal naming test. Thus, the Knight PACC is unique from other "PACCs" in that it does not contain the Mini Mental State Examination (MMSE) or the Montreal Cognitive Assessment (MoCA) or the Logical Memory subtest from the Wechsler Memory Scale. These tests were avoided for several reasons, including ceiling effects and excessive practice effects. The Knight PACC has been validated extensively with respect to clinical status, AD biomarkers, and AD genetic risk. The Knight PACC is expressed as a z-score with a mean of 0 and a standard deviation of 1. Positive values indicate performance above the mean and negative values indicate performance below the mean. Please refer to and cite the following publication if you choose to use the Knight PACC:

McKay NS, Millar PR, Nicosia J, Aschenbrenner AJ, Gordon BA, Benzinger TLS, Cruchaga CC, Schindler SE, Morris JC, Hassenstab J. Pick a PACC: Comparing domain-specific and general cognitive composites in Alzheimer disease research. Neuropsychology. 2024 Jul;38(5):443-464. PMCID: PMC11176005.

Domain-specific cognitive composites: Similar to the Knight PACC, ADRC investigators developed domain-specific composites for use by investigators that combine test versions across UDS2 and UDS3 using equipercentile equating. Thus, these domain-specific composites will be widely available for participants with data collected from approximately 2005 to the time of this writing.

A factor analysis was performed to derive each of the composite domains that were further validated with analyses of clinical status, AD biomarker levels, and genetic risk for AD (see McKay et al., 2024 Neuropsychology for more details; full reference below). There are currently four domain-specific composites available for use: Episodic memory, semantic memory, working memory, and attention & processing speed. Each are expressed as z-scores with a mean value of 0 and a standard deviation of 1. Positive values indicate performance above the mean and negative values indicate performance below the mean. Please refer to and cite the following publication if you choose to use the provided cognitive composites:

McKay NS, Millar PR, Nicosia J, Aschenbrenner AJ, Gordon BA, Benzinger TLS, Cruchaga CC, Schindler SE, Morris JC, Hassenstab J. Pick a PACC: Comparing domain-specific and general cognitive composites in Alzheimer disease research. Neuropsychology. 2024 Jul;38(5):443-464. PMCID: PMC11176005.

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Pick a PACC: Comparing Domain-Specific and General Cognitive Composites in Alzheimer Disease Research

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Objective: We aimed to illustrate how complex cognitive data can be used to create domain-specific and general cognitive composites relevant to Alzheimer disease research. ***Method:*** Using equipercentile equating, we combined data from the Charles F. and Joanne Knight Alzheimer Disease Research Center that spanned multiple iterations of the Uniform Data Set. Exploratory factor analyses revealed four domain-specific composites representing episodic memory, semantic memory, working memory, and attention/processing speed. The previously defined preclinical Alzheimer disease cognitive composite (PACC) and a novel alternative, the Knight-PACC, were also computed alongside a global composite comprising all available tests. These three composites allowed us to compare the usefulness of domain and general composites in the context of predicting common Alzheimer disease biomarkers. ***Results:*** General composites slightly outperformed domain-specific metrics in predicting imaging-derived amyloid, tau, and neurodegeneration burden. Power analyses revealed that the global, Knight-PACC, and attention and processing speed composites would require the smallest sample sizes to detect cognitive change in a clinical trial, while the Alzheimer Disease Cooperative Study-PACC required two to three times as many participants. ***Conclusions:*** Analyses of cognition with the Knight-PACC and our domain-specific composites offer researchers flexibility by providing validated outcome assessments that can equate across test versions to answer a wide range of questions regarding cognitive decline in normal aging and neurodegenerative disease.

Key Points

Question: What is the key question this article addresses? Can inconsistent cognitive data be used to create meaningful domain-specific and general cognitive composites relevant to Alzheimer disease research. ***Findings:*** What are the primary findings? Factor analyses reveal four underlying composites within Uniform Data Set cognitive data: episodic memory, semantic memory, working memory, and attention and processing speed. ***Importance:*** What are the key scientific and practical implications of the findings? The mini mental state examination may not be appropriate to be included within cognitive composites, which are being designed to detect cognitive decline in the context of clinical trials. ***Next Steps:*** What directions should be explored in future research? These domain-specific metrics could be used to complement research on general cognitive decline in Alzheimer disease, particularly in individuals presenting with atypical presentations of Alzheimer disease.

Keywords: factor analysis, Alzheimer, preclinical Alzheimer disease cognitive composite, magnetic resonance imaging, positron emission tomography

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All data used to create these composites are available to qualified investigators by request from the Knight Alzheimer Disease Research Center of Washington University in St. Louis. All code used to create images and run analyses is available on GitHub.

Nicole S. McKay played a lead role in formal analysis and writing–original draft and an equal role in conceptualization, methodology, and writing–review and editing. Peter R. Millar played a supporting role in formal analysis and writing–original draft and an equal role in conceptualization, methodology, and

continued

Alzheimer disease (AD) is the most common form of dementia and is becoming increasingly prevalent as the global population ages (Alzheimer's Association, 2019). A frightening prospect for those diagnosed with AD is the inevitable loss of cognitive abilities. With its increasing prevalence, it is imperative that research focuses on understanding AD so that treatments or interventions can be deployed. Investigating the mechanisms that underlie cognitive decline in complex disorders such as AD is dependent upon the acquisition of high-quality data over extended periods of time. As such, longitudinal observational studies are critical as they allow researchers to monitor the onset and progression of neurodegenerative diseases within individuals.

Longitudinal studies designed years or decades ago must keep pace with scientific advances. For longitudinal studies that assess cognition, this would ideally mean implementing the same cognitive tests to monitor changes linked to specific underlying disease mechanisms without the need for complicated statistical procedures to harmonize across different versions of tests. However, over the decades in which longitudinal studies take place, it is likely that scientific advances in disease trajectory understanding will occur, yielding more sensitive and accurate cognitive measures. Designers of longitudinal studies of cognition have the unenviable task of balancing the need to flexibly evolve alongside advances in knowledge while also standardizing and harmonizing measures to ensure the integrity of legacy data that links underlying disease to outcome measures.

The United States National Institute on Aging (NIA), via the National Alzheimer's Coordinating Center, has been attempting to balance these two important aspects of longitudinal research design since at least 2005, when the Uniform Data Set (UDS) was introduced to standardize tasks and measures collected at NIA-funded Alzheimer's Disease Research Centers (ADRCs; Beekly et al., 2007; Morris et al., 2006; Weintraub et al., 2009). The original form of the UDS included clinical, cognitive, and diagnostic measures relevant to understanding AD. Implementing this standardized set of measures across multiple centers ensured the data were comparable across different cohorts. However, a major issue with the second version of the UDS (UDS2) was that many tests were proprietary, and hence researchers outside of these ADRCs were unable to administer the tasks without having their own independent licenses for each measure. Additionally, because some of the measures were developed nearly 40 years ago, license holders have also been unwilling to authorize the use of prior versions of tests when updated versions are available. To allow a wider net of researchers to use the standardized battery, a third version of the UDS was released (UDS3) in 2015, aiming to replace proprietary cognitive tasks in the original batteries with similarly structured nonproprietary measures that would be made freely available (Besser et al., 2018). For example, the proprietary Logical Memory subtest from the Wechsler Memory Scale-Revised (Wechsler, 1981) used in UDS2 was replaced with the nonproprietary Craft Story 21, developed by Suzanne Craft, PhD (Besser et al., 2018). This major overhaul of the UDS battery has resulted in a large amount of longitudinal data collected across at least 32 NIA-funded ADRCs and thousands of participants who have been assessed with both UDS2 and UDS3 measures.

To address the change from UDS2 to UDS3, researchers conducted an extensive "crosswalk" study using equipercentile equating to unite measures introduced in UDS3 with their counterparts from UDS2 (Monsell et al., 2016). The equipercentile equating method provides an equivalence score and confidence interval for each of the measures. This method is thought to be well-suited for equating neuropsychological measurements, given that it does not require the two tests to be scored on the same range, has no assumption of score distribution, forces imputed variables to be within the range of the matched test, and provides a single value per score. While there are clear advantages to the replacement and subsequent equating of these tests across UDS versions, this method is not without its limitations. For example, the mini mental state examination (MMSE; Folstein et al., 1975) was replaced in UDS3 with the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005). In cognitively normal and more educated samples, the MMSE has a pronounced ceiling effect (Nieuwenhuis-Mark, 2010), thus, the equated scores at the higher end of the MoCA produce very little variance on MMSE scores. Scores of 29 or 30 on the MMSE are very common in ADRC samples, and these could equate to MoCA scores ranging from 24 to 30 (Monsell et al., 2016). This range is critically important when considering that some studies and clinical trials use MoCA scores as inclusion cutoffs to define cognitive impairment (i.e., MoCA < 24 or MoCA < 26; Carson et al., 2018). When the two equated measures have similar distributions, like Logical Memory and Craft Story 21, these issues are greatly reduced. In these cases, the crosswalk approach provides a valuable standardized method for AD researchers to understand changes in cognitive measures within their longitudinal studies.

Even with standardized tests and equated variables to address changes in tests over time, longitudinal cohort studies typically have large data sets consisting of many cognitive tasks spanning various cognitive domains. Prior work has highlighted that examining many different tests individually produces results that are less valid, less reliable, prone to collinearity issues, and of lower statistical power (Ayutyanont et al., 2014). Therefore, many researchers turn to computing cognitive composites as an alternative to analyzing individual cognitive tasks, often derived using either a theory- or data-driven method (Donohue et al., 2014; Papp et al., 2021; Papp et al., 2017). Within AD research, the preclinical AD cognitive composite (PACC) is a widely used theory-driven composite first

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proposed in 2014 (Donohue et al., 2014). The original PACC included a mental status measure (MMSE; Folstein et al., 1975), delayed story memory (Logical Memory; Wechsler, 1997a), a recall verbal list learning test (Free and Cued Selective Reminding Test [FCSRT]; Grober et al., 2008), and a processing speed measure (the Digit Symbol Substitution Test from the Wechsler Adult Intelligence Scale-Revised [WAIS-R]; David Wechsler, 1981). Subsequent versions of the PACC have added semantic memory measures and expanded the FCSRT to include cued recall scores (Papp et al., 2017). While the original PACC and its derivatives have been widely used, there is some concern that including measures with poor psychometric properties may limit the utility of the composite, particularly for studies concerned with detecting the earliest cognitive changes prior to symptom onset in AD. The MMSE, as mentioned above, can produce a high rate of ceiling effects and also has poor test–retest reliability (Gross et al., 2018; Jutten et al., 2018; Spencer et al., 2013). Ceiling effects can have a tremendous impact on an equally weighted composite like the PACC due to the artificial reduction in standard deviation (Bateman et al., 2017; Lim et al., 2016). In addition, episodic memory measures like Logical Memory, which are traditionally administered without alternate forms, have considerable retest effects (Calamia et al., 2013; Hassenstab, Ruvolo, et al., 2015), which can vary depending upon the number and frequency of exposures to the test materials (Aschenbrenner et al., 2022) and ultimately make longitudinal interpretation of the composite difficult.

The PACC has become quite popular in both observational studies and clinical trials. However, there is no consensus on the measures that should be used in the PACC, and it is common for studies using existing data to substitute measures that may or may not be theoretically or psychometrically acceptable substitutes (Donohue et al., 2014). Thus, it can be confusing when different articles describe a "PACC" that may or may not include the same cognitive tasks. Given the breadth of cognitive measures available, there is also a risk that substituted tasks may have vastly different psychometric properties (e.g., MMSE vs. MoCA) and/or capture different longitudinal performance trajectories (e.g., story memory tasks with alternate forms vs. no alternate forms). These "modified PACC" analyses have added a new layer of complexity to assessing cognitive change across centers using the UDS measures and provide an argument in favor of implementing data-driven factor analytic approaches.

The above-outlined issues highlight a clear need within the field for reliable, valid, and well-powered cognitive composites that allow researchers to interpret data that span UDS2 and UDS3. Here, using data derived from the Charles F. and Joanne Knight Alzheimer Disease Research Center (Knight ADRC), we unified data collected across both UDS2 and UDS3 using the technique outlined in the crosswalk study (Monsell et al., 2016). To explore the underlying cognitive factors within this harmonized data set, we implemented a data-driven factor analysis. We hypothesized that our harmonized data set would form similar factor structures as the nonequated UDS2 and UDS3 data sets. The present study further aimed to compare different cognitive factors in their relationships with commonly studied AD biomarkers. To achieve this aim, composites were calculated for each of the identified factors, as well as the previously established Alzheimer Disease Cooperative Study (ADCS-PACC; Donohue et al., 2014), the Knight-PACC (defined below), and an overall global composite comprising 13 tests administered at the Knight ADRC. We hypothesized that composites derived from factor analyses would strongly associate with common biomarkers of AD in a manner comparable to theoretically defined composites, such as the ADCS and Knight-PACCs, as well as the global composite, cross-sectionally. We further hypothesized that baseline levels of β-amyloid (Aß) and tau would predict composite scores and that these factor-derived composites would strongly predict future progression to cognitive impairment. Finally, we propose that the psychometric characteristics, that is, sensitivity to preclinical AD and test–retest reliability, of these data-derived measures should be well-suited for application in future clinical trials assessing domain-based cognitive outcomes. The goal of the present study was to evaluate the usefulness of a data-driven, equipercentile equating approach to form composite cognitive measures and to compare the outcomes of this approach to theory-driven cognitive measures. Our resulting composites reflect unique cognitive constructs, are parsimonious, face-valid, and can be used in cases where latent variable approaches may not be suitable.

Method

Participants

Data were acquired from 2,034 middle- and older-aged adults (M = 72.77, SE = 0.21 at first visit) who were enrolled in longitudinal memory and aging studies at the Knight ADRC of Washington University in St. Louis. All individuals completed at least one clinical and cognitive assessment, while subsets of these individuals completed magnetic resonance imaging (MRI; n = 1,335), Aß-positron emission tomography (PET; n = 1,060), and tau-PET imaging (n = 548) within 3 years of completing cognitive assessments. Longitudinal cognitive data (three or more visits) were available for 389 individuals. Using the Clinical Dementia Rating® (CDR®; Morris, 1993), participants were assessed to be either cognitively normal (CDR = 0, n = 1,246) or cognitively impaired (CDR > 0, n = 788). Included participants had baseline CDR values that spanned CDR values of 0.0, 0.5, 1.0, and 2.0, which correspond to cognitively normal, very mild dementia, mild dementia, and moderate dementia, respectively. Importantly, the majority of our dementia sample had a CDR score of 0.5 (Supplemental Figure 1). Basic demographic variables were also recorded. Data used for this study were collected between 2005 and 2020. All protocols were approved by the Human Research Protection Office at Washington University in St. Louis, and all participants provided informed consent before all procedures.

Cognitive Battery

Participants were assessed on a broad range of abilities using a battery of cognitive tests administered by trained psychometrists blinded to participant cognitive status. The tests comprising the Knight ADRC cognitive battery differed by year of study recruitment, in line with updated recommendations from the creators of the UDS (Beekly et al., 2007). To account for variation within the tests across time, complementary tasks were equated using equipercentile-based harmonization methods previously outlined (Monsell et al., 2016). Briefly, this prior work provided tables that were utilized to convert scores from tests in the UDS-3 to their equivalent UDS-2 task. Given that this method preserves percentile of performance, this transformation allows researchers with stratified data to convert UDS-3 scores into equated UDS-2 variables for longitudinal

evaluation. Conversion tables are available in the cited publication (Monsell et al., 2016) as well as online: https://naccdata.org/data-collection/forms-documentation/crosswalk.

Using the established conversion tables, the Delayed Craft Story task (Craft et al., 1996) was equated with the Delayed Logical Memory IIA task (Wechsler, 1997b), the Digit Span Forward and Backward tasks (Wechsler, 1997a) with the Number Span Forward and Backward scores (Weintraub et al., 2009), and the Boston Naming Test (Goodglass & Kaplan, 1983) with the Multilingual Naming Test (Ivanova et al., 2013). In addition to these equated tests, this report considers other common cognitive tasks collected in AD research including the FCSRT (Grober et al., 1998), the Wechsler Memory Scale-Revised Associate Memory and Letter–Number sequencing subtasks (Wechsler, 1997b), the Vegetable and Animal Naming Tests (Goodglass & Kaplan, 1983), the Trail Making Test parts A and B (Armitage, 1946), the Digit Symbol subtask from the WAIS-R (Wechsler, 1981), as well as the less commonly used Consonant–Vowel Odd-Even switching task (Huff et al., 2015). Several tests that have been administered at the Knight ADRC were excluded from analysis due to large numbers of missing variables, being too closely related to a second included measure, or because of issues with their psychometric properties. A table summarizing the missing data and excluded cognitive variables is reported in the Supplemental Table SM1.

Factor Analyses

Given the large number of cognitive tests spanning a vast range of skills, it was of interest to evaluate whether the Knight ADRC cognitive data could be reduced to meaningful latent variables using data reduction techniques. It was also of interest to compare data-driven dimensionality reduction to theory-driven reduction within this data set. To this end, an exploratory factor analysis (EFA) was conducted. To minimize the influence of variance attributable to disease-related decline, the EFA was conducted only on participants who were assessed as cognitively normal (CDR = 0) at their most recent assessment (n = 1,368). Importantly, by leveraging the most recent visit for each individual, we were able to best approximate the Knight ADRC cognitive battery currently in use. Specific information regarding the demographic composition of the EFA subsample is reported in the Supplemental Table SM2.

Examination of the resulting scree plot identified three factors with eigenvalues above one, which together explained 59% of the variance in the cognitive data (Supplemental Figure 2). Subsequently, an EFA with three orthogonal factors was implemented using a varimax rotation. Examination of the resulting three factors and their loadings revealed that the second and third factors grouped together tasks specialized for attention and processing speed and working memory, respectively (Figure 1A). However, the first factor grouped together six memory tasks, representing both episodic and semantic skills. This merging of such similar tasks was not unexpected (Carroll, 1993; Kane & Miyake, 2008); however, to maximize the theoretical applicability of the derived factors, we proposed to split this large memory factor into two theory-motivated subfactors: episodic memory and semantic memory (Figure 1B). To ensure that the theoretically modified four-factor model was not a result of biases introduced by our equipercentile-equated variables, two additional EFAs were run in a subset of individuals (n = 406) who had completed both UDS2 and UDS3 versions of the Knight ADRC cognitive batteries in two sequential visits within 2 years. The resulting factor structures for each of these models were in line with the structure of our primary EFA of interest (Supplemental Figure SM3).

Cognitive Composites

Using the final four-factor model, composite scores for episodic memory, semantic memory, attention and processing speed, and working memory were computed in line with methods previously described (Aschenbrenner et al., 2015; McKay et al., 2022). Briefly, after standardizing each participant's raw score on each task to the mean and standard deviation of the scores recorded for the cognitively normal individuals' most recent visit, unweighted z-scores for each group of tasks were averaged together to form each composite score. Composite scores were calculated for all available visits in all participants, regardless of cognitive status, and were entered as the cognitive variables of interest for all subsequent analyses. In instances of missing data, composites were only computed for visits that were missing data for less than 30% of the composite-specific tests. Standardized scores for the subtasks of the Trail Making Test were reverse scored to ensure that, in all cases, higher composite scores represented better task performance. Finally, using the same method, we also computed a global composite comprising all 13 tests as an overall assessment of general cognitive performance. While researchers are free to compute these composites relative to their specific sample's control group, future public releases of the Knight ADRC cognitive data will release these composites calculated relative to a static control group. Moreover, an R package is available to facilitate this computation: https://github.com/jwisch/KnightADRCCompCalc/tree/main.

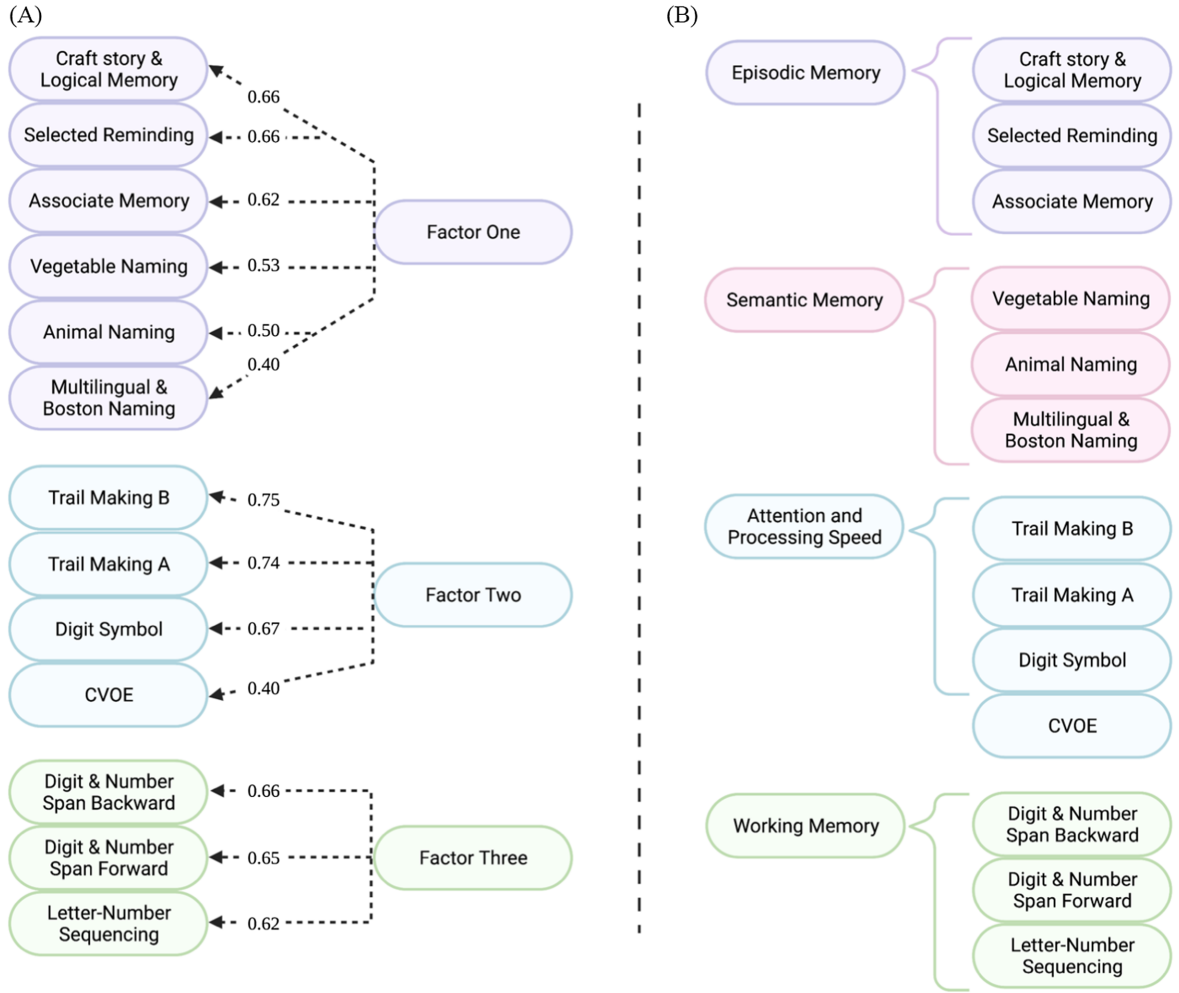
Knight Preclinical Alzheimer Cognitive Composite

In addition to the data-derived composites, we calculated a composite score that closely resembled the ADCS-PACC (Donohue et al., 2014) and other previously used composites (Aschenbrenner et al., 2018; Nicosia et al., 2023). This composite was specifically chosen to represent cognitive tasks that are sensitive to early changes in preclinical AD by assessing memory, attention, and processing speed concurrently. Importantly, the Knight-PACC does not include the MMSE or MoCA, despite these typically being used in similar PACCs (Donohue et al., 2014). The exclusion of these tests is a consequence of prior work indicating that they are prone to both ceiling and floor effects (Hoops et al., 2009; Nieuwenhuis-Mark, 2010). Specifically, in cognitively normal cohorts, a ceiling effect is commonly reported, as most individuals score perfectly with very little variance in performance over time (Spencer et al., 2013; Weintraub et al., 2009, 2018). In contrast, those who are cognitively impaired score very poorly but also tend to have little variance in performance, hitting a "floor" quickly. While these characteristics do make the MMSE a great tool for detecting gross, clinic-level impairment, they prevent the MMSE from being sensitive enough to detect small changes in performance that occur prior to large clinical-state shifts. By excluding these blunt tools of cognition from the Knight-PACC, we hope to position this composite as an indicator of minute shifts in cognition that occur across the preclinical disease period.

Subtle differences in the tasks that are implemented at the NIA-funded ADRCs mean that the Knight-PACC comprises slightly

Figure 1

Data Reduction of the 13 Cognitive Tasks Present in the Knight ADRC Cognitive Battery



Note. (A) Visual depiction of the resulting three-factor solution, and each loading weight, derived from the EFA. (B) Subsequent clustering of cognitive tests into final four factors based on a theoretical split of the largest factor from the EFA into two subcomponents: episodic memory, semantic memory. CVOE = consonant–vowel odd-even; ADRC = Alzheimer's Disease Research Center; EFA = exploratory factor analysis. See the online article for the color version of this figure.

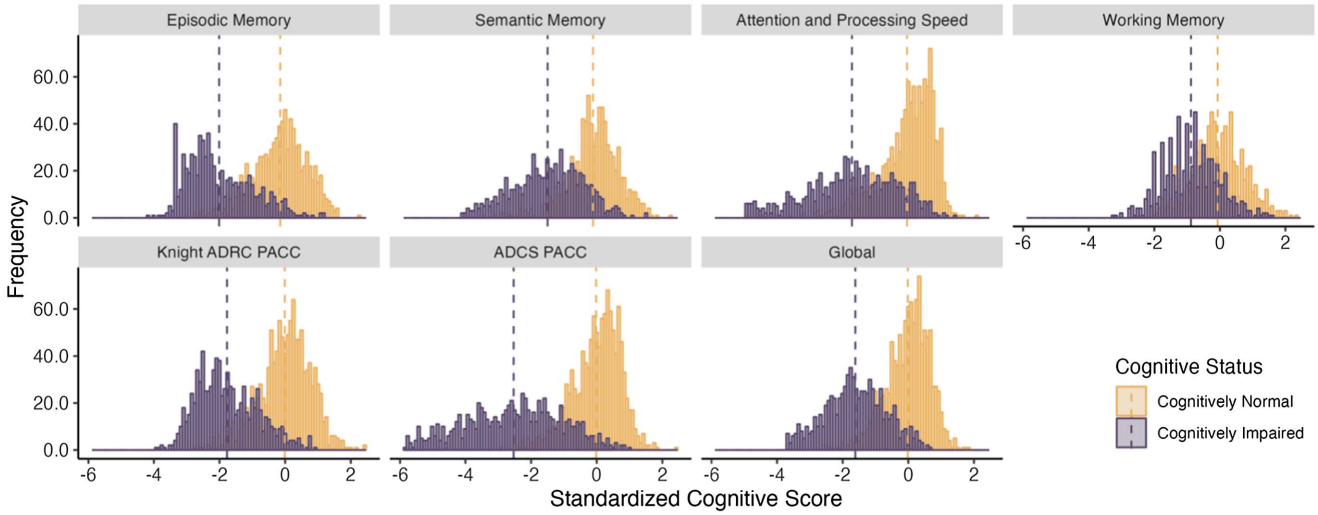
different measures than the ADCS-PACC. For example, UDS 2 and UDS 3 did not include a specific verbal list learning measure, but most centers use a list learning test as part of their annual cognitive assessments. Specifically, the Knight-PACC is comprised of the free recall score from the FCSRT (Grober et al., 1998), the total correct score from the Digit Symbol subtest of the WAIS-R (Wechsler, 1981), the total completion time from the Trail Making Test Part B (Armitage, 1946), and the total correct score from the Animal Naming Test (Goodglass & Kaplan, 1983). Following the method outlined for computing our domain-specific composites, the final Knight-PACC score was derived from the averaged *z*-scores of these tasks relative to the latest visit of the cognitively normal individuals of our cohort. We used the most recent visit for each individual, as these data would have the least data missing for currently collected cognitive tasks. In order to allow comparisons between the Knight-PACC and other major research centers, the ADCS-PACC score was also calculated using the MMSE, the Digit Symbol subtask of the revised WAIS (Wechsler, 1981), the Delayed Craft Story task (Craft et al., 1996), and the FCSRT (Grober et al., 1998). Distributions of all derived composites are visualized in Figure 2.

Cortical Thickness

T1-weighted images were used to derive cortical thickness measures using previously defined AD-specific regions of interest (Dincer et al., 2020). Average cortical thickness across these previously defined cortical regions of interest was available as part of the standard Knight ADRC data release and utilized as our MRI variable for all included MRI analyses. As outlined in previous work, these cortical regions represented areas of the cortex that were highly correlated to AD trajectory in older adults after controlling for the influence of age and sex. Briefly, for each hemisphere, cortical thickness spatial maps were created via vertex-wise analyses using a general linear model in FreeSurfer, and the resulting regions

Figure 2

Distributions of the Theory- and Data-Derived Composites at Most Recent Visit



Note. In all composites, the average score for participants assessed as cognitively impaired (CDR > 0, yellow) is higher than that for those assessed as cognitively normal (CDR = 0, purple). Dashed lines represent means for correspondingly colored group. Most recent visit was used as, given the ever-evolving cognitive battery of the Knight ADRC, this ensured the data most closely resembled the data being collected currently and in the near future. ADRC = Alzheimer's Disease Research Center; PACC = preclinical Alzheimer disease cognitive composite; ADCS = Alzheimer Disease Cooperative Study; CDR = clinical dementia rating. See the online article for the color version of this figure.

were thresholded so that only regions that were significantly changing in individuals on the AD trajectory compared to controls remained (Dincer et al., 2020). The Knight ADRC provides the averaged cortical thickness across these regions as an AD-specific summary MRI metric in their imaging data releases.

Aβ Summary

Aβ positivity was determined using a summary composite standardized uptake value ratio (SUVR) outlined elsewhere (Mishra et al., 2017; Su et al., 2013). This summary composite was derived as the bilateral average of the left- and right- lateral orbitofrontal, medial orbitofrontal, rostral middle frontal, superior frontal, superior temporal, middle temporal, and precuneus regions (Su et al., 2013). This prior work defined specific cutoff values for this region for each amyloid tracer. Specifically, those with a Pittsburgh Compound B-SUVR greater than or equal to 1.42 were considered to have pathological amyloid, while for florbetapir, the same was considered for those with an SUVR greater than or equal to 1.16. To standardize across the Pittsburgh Compound B and florbetapir tracers, the values were converted into centiloid units (Klunk et al., 2015) using separate linear transformations developed for each specific tracer (Su et al., 2019). These transformations were such that zero represented the mean Aβ burden of controls and 100 represented the mean Aβ burden for AD participants. Centiloid values for these summary amyloid regions were available as part of the Knight ADRC imaging data release and were utilized as our amyloid metric in all included analyses.

Tau-PET Summary

Our tauopathy summary averaged SUVRs from FreeSurfer regions of interest, including the bilateral entorhinal cortex, amygdala, inferior temporal cortex, and lateral occipital regions (Gordon et al., 2018; Su et al., 2015). These regions have previously been identified as the best in discriminating between cognitively normal and cognitively impaired participants (Mishra et al., 2017). Following the approach of Mishra et al., our participants were classified as tau-positive if their SUVR value within tau-PET summary regions was 1.22 or greater. Average SUVR values for these previously defined regions were utilized as our tau metric in all included analyses.

Statistical Analyses

Demographic Analyses

Multiple, independent analyses were implemented to establish the distribution of key demographic variables within our study sample by cognitive status. Using baseline cognitive visit data, differences in the distributions of age and years of education for the cognitively normal and cognitively impaired groups were tested using independent Welch two-sample *t*-tests, and effect sizes for each variable were quantified by evaluating Cohen's *d*. Similarly, distributions of sex, apolipoprotein ε4 (*APOE*-ε4) status, and self-identified race were compared using Kruskal–Wallis χ^2 tests, and effect sizes for each variable were quantified using the chi-square ω statistic.

Reliability Analyses

To establish the reliability of our calculated composites, intraclass correlations (ICC) were calculated for each composite using independent two-way mixed-effects models with absolute agreement. To ensure our measures of reliability were applicable for clinical studies, we restricted our analyses of ICC to individuals with at least four visits across at least 4 years, although once the subsample was established, all cognitive visits for these individuals

were included in the analyses to maximize power. Following established guidelines, ICC values above 0.75 were considered *good,* while ICC values above 0.90 were considered *excellent* (Bruton et al., 2000; Koo & Li, 2016).

Cross-Sectional Analyses

To understand the sensitivity of each domain-specific and theory-driven composite to preclinical AD, we evaluated the cross-sectional relationship between each composite score and age, as well as common neuroimaging biomarkers of AD. To ensure we were capturing the relationship with preclinical AD, these analyses were restricted to individuals who were cognitively normal (CDR = 0). Further, to ensure maximum sample size given historical changes in the Knight ADRC cognitive battery and interruptions due to COVID-19, each individual's most recent visit prior to 2020 was utilized.

To establish the relationship between cognition and age, multiple independent Pearson's partial correlations using age and composite scores as key variables were performed with mean-centered years of education, sex, and *APOE*-ε4 status included as covariates. Similarly, to establish the relationship between cognition and common neuroimaging biomarkers, multiple, independent Pearson's partial correlations using neuroimaging biomarkers and composite scores as key variables were performed, with mean-centered age, mean-centered years of education, sex, and *APOE*-ε4 status included as covariates. Across these partial correlations, the Aβ biomarker was defined as the average Aβ deposition (in centiloid units) across the previously outlined cortical summary region, the tau biomarker was defined as the tau SUVR calculated across the above-outlined tau summary regions, and the MRI biomarker represented the average cortical thickness across the previously described cortical signature of late-onset AD.

The ability for each cognitive composite to discriminate between common neuroimaging-based groupings was also tested. To establish how well these cognitive variables discriminated between Aβ positive and Aβ negative individuals, multiple independent analyses of covariates (ANCOVAs) were implemented with Aβ positivity as the grouping factor, cognitive composite as the dependent factor, and mean-centered age, mean-centered years of education, sex, and *APOE*-ε4 status were included as covariates. This analysis was further repeated to establish whether each composite was able to discriminate between tau-positive and tau-negative individuals. Finally, we were also interested in determining how our composites differed according to cognitive status. Using our full sample's most recent visit (prior to 2020), multiple independent ANCOVAs were run with cognitive status (normal, impaired) as the grouping factor, cognitive scores as the dependent factor, and mean-centered age, mean-centered years of education, sex, and *APOE*-ε4 status were included as covariates. For each ANCOVA-based analysis, η^2 was calculated as a measure of effect size.

Longitudinal Analyses

Another major aim of our study was to assess whether early measures of common neuroimaging biomarkers of AD could significantly predict future decline in cognitive performance measured by each of our data- and theory-driven composites. To ensure longitudinal models were robustly calculated, we restricted our analyses to a subsample of individuals with at least two cognitive visits after each baseline biomarker visit. To maximize sample size while avoiding biases introduced by few individuals with very large numbers of cognitive visits after their neuroimaging visits, we also restricted our data to only consider up to 6 years of cognitive follow-up. Using the resulting subsample, multiple independent mixed-effects models were implemented. In these models, composite scores were input as the dependent variables, while baseline biomarker values (summary cortical Aβ, summary tau accumulation, summary cortical thickness) were included as the independent variables. Each model considered the main effects of time in the study and baseline biomarker in addition to the interaction between these variables. Variation in the length of time retained in the study by individual was accounted for by the inclusion of an additional model term. Additionally, baseline CDR, mean-centered age, mean-centered years of education, sex, and *APOE*-ε4 status were included to account for variance attributable to these important demographic variables. To assess these relationships and their effect sizes within our data, we compared conditional R^2 and f^2 across composites for each biomarker, while the ability for each composite to predict novel data was assessed by comparing marginal R^2 and f^2. The longitudinal relationships between each neuroimaging biomarker and each cognitive composite will also be considered in the context of whether high versus low baseline values of each biomarker influence the predicted trajectory of cognitive decline.

To longitudinally assess how well each cognitive composite was able to predict a future transition from cognitively normal (CDR = 0) to cognitively impaired (CDR > 0) status, we also performed survival analyses for each calculated composite. Specifically, we used general linear models to estimate rates of decline over 4 years for individuals with at least two cognitive visits after 2015 but before 2020. We chose this narrow time period to ensure all composites were calculated with the same combination of equated variables per person. Using the rate of decline estimated for each individual, we classified individuals as having fast decline or slow decline for each composite based on a median split. Individuals included in these analyses were required to be cognitively normal at their baseline visit (CDR = 0). Survival analyses were then conducted where time to event was input as either an individual's time of first cognitive visit with a CDR greater than zero or time to their last cognitive visit if they did not transition in cognitive status. Cox proportional hazard ratios were then computed and compared to understand the likelihood of progression to impaired status for fast compared to slow decliners for each composite, and time to 50% progression was used to compare the relative sensitivity to symptomatic progression across each composite. All survival analyses included mean-centered age, mean-centered years of education, sex, and *APOE*-ε4 status as covariates.

Finally, we were interested in quantifying how useful each composite would be to detect cognitive decline within a clinical trial setting. Using a subsample of individuals with at least two cognitive visits between 2015 and 2020 and who had no missing data, we first estimated the rate of decline over 4 years using linear mixed-effects models. These models included cognitive score as the dependent variables, time in study for each individual, as well as an additional random effects variable to account for differences in time in the study and the number of time points per person. Mean-centered age, mean-centered years of education, sex, and *APOE*-ε4 status were

included as covariates. The resulting data were then submitted to independent power analyses that estimated the required sample size for each composite that would be needed in clinical trial arm (placebo vs. active) to detect a 50% treatment effect. These power analyses assumed a 1:1 ratio of individuals in each trial arm, annual testing across a 4-year period, and 80% power. Sample size estimates and their associated confidence intervals were compared to establish which measures are best suited for detecting change under such conditions. A second, identical power analysis was also conducted in a subsample of individuals who were amyloid positive at their baseline visit to better approximate an AD clinical trial, which often focuses recruitment efforts on those who are already showing signs of AD pathology.

Statistical Software

Analyses and visualizations were completed using R (Version 4.2.2; R Core Team, 2019), BioRender (Perkel, 2020), R packages from the tidyverse (Wickham et al., 2019), as well as the following additional R packages: corrplot (Wei et al., 2017), psych (Revelle, 2017), jtools (Long & Long, 2022), ggpubr (Kassambara, 2023), lme4 (Bates et al., 2015), survival (Therneau, 2015), longpower (Donohue et al., 2013), gtsummary (Sjoberg et al., 2021), sjplot (Lüdecke, 2023), survminer (Kassambara et al., 2017), data.table (Barrett et al., 2024), effectsize (Ben-Shachar et al., 2020), ppcor (Kim, 2015), ggbreak (Xu et al., 2021), and lmerTest (Kuznetsova et al., 2017).

Open Research and Transparency

At the time of publication, all data used to generate the figures and analyses presented within the current article are available by request from the Knight ADRC https://knightadrc.wustl.edu/data-request-form/. The data request process requires a brief description of project aims and variables requested. All code used to clean data, run analyses, and generate the presented figures is also freely available on Dr. Nicole S. McKay's GitHub repository: https://github.com/nicolesmckay/Knight_ADRC_Cognitive_Composites. Computation of these composites can be simplified using a custom *r* package available on Dr. Julie Wisch's GitHub repository: https://github.com/jwisch/KnightADRCCompCalc. Future public data releases of the Knight ADRC cognition data will provide composite scores relative to a frozen control group, although authors are free to compute these relative to their study-specific cohort. A preprint of this article has been freely available on *psyrxiv*, an open preprint server. No aspects of these analyses were publicly preregistered.

Results

Demographic information for the utilized cohort's baseline visit ($n = 2034$) is presented in Table 1. Briefly, 57% of our sample were female, 81% were White, and 36% were *APOE*-ε4 carriers. On average, the individuals considered in these analyses were 73 years old and had completed 15 years of education. Initial comparisons of demographic distributions by cognitive status indicated that cognitively impaired individuals were older, had fewer years of education, and were more likely to be *APOE*-ε4 carriers compared to cognitively normal individuals; however, no differences were found for distribution of race or sex across our two groups. Informed by these demographic summaries, alongside strong evidence that AD pathology may differ by sex (Buckley et al., 2020; Wisch et al., 2021), all analyses presented beyond Table 1 included sex, *APOE*-ε4 status, mean-centered years of education, and mean-centered age as covariates.

Table 1
Summary of Demographic Information

Characteristic	Cognitively normal	Cognitively impaired	Statistical estimate[a]	Significance	Effect size[b]	95% CI
n	1,246	788				
Age (*SE*; range)	70.70 (0.27; 42–103)	76.05 (0.29; 50102)	−13.47	1.61×10^{-39}	0.60	[−6.13, −4.57]
Education (*SE*; range)	15.93 (0.08; 629)	14.57 (0.11; 623)	10.25	7.32×10^{-24}	0.48	[1.10, 1.62]
Sex						
Male (%)	521 (42%)	362 (46%)	3.34	0.07		
Female	725 (58%)	426 (54%)				
APOE-ε4						
Carrier	430 (35%)	312 (40%)	111.18	5.40×10^{-26}	0.23	
Noncarrier	809 (65%)	446 (60%)				
Self-identified race						
White	1,017 (82%)	649 (82%)	0.16	0.69		
Black	217 (17%)	130 (16%)				
Asian	7 (<1%)	5 (<1%)				
Native Hawaiian/Pacific Islander	1 (<1%)	0 (0%)				
American Indian/Alaskan Native	1 (<1%)	0 (0%)				
Multiple	3 (<1%)	4 (<1%)				

Note. Demographics were recorded at participants' first Knight ADRC visit ($n = 2034$). Applicable statistical tests reveal that cognitively impaired individuals within our sample are significantly older, have completed fewer years of education, have a higher rate of carrying the *APOE*-ε4 allele, and are more evenly distributed in terms of sex. *APOE*-ε4 = apolipoprotein ε4; *SE* = standard error; ADRC = Alzheimer's Disease Research Center; CI = confidence intervals.
[a] Statistical estimates depict tested differences in the mean values or distributions of variables by cognitive status, estimates are derived from Welch two sample *t*-tests for continuous variables and Kruskal–Wallis χ^2 tests for categorical variables. [b] Effect sizes reflect Cohen's *d* and chi-square's *w*, as appropriate.

Composite Test–Retest Reliability

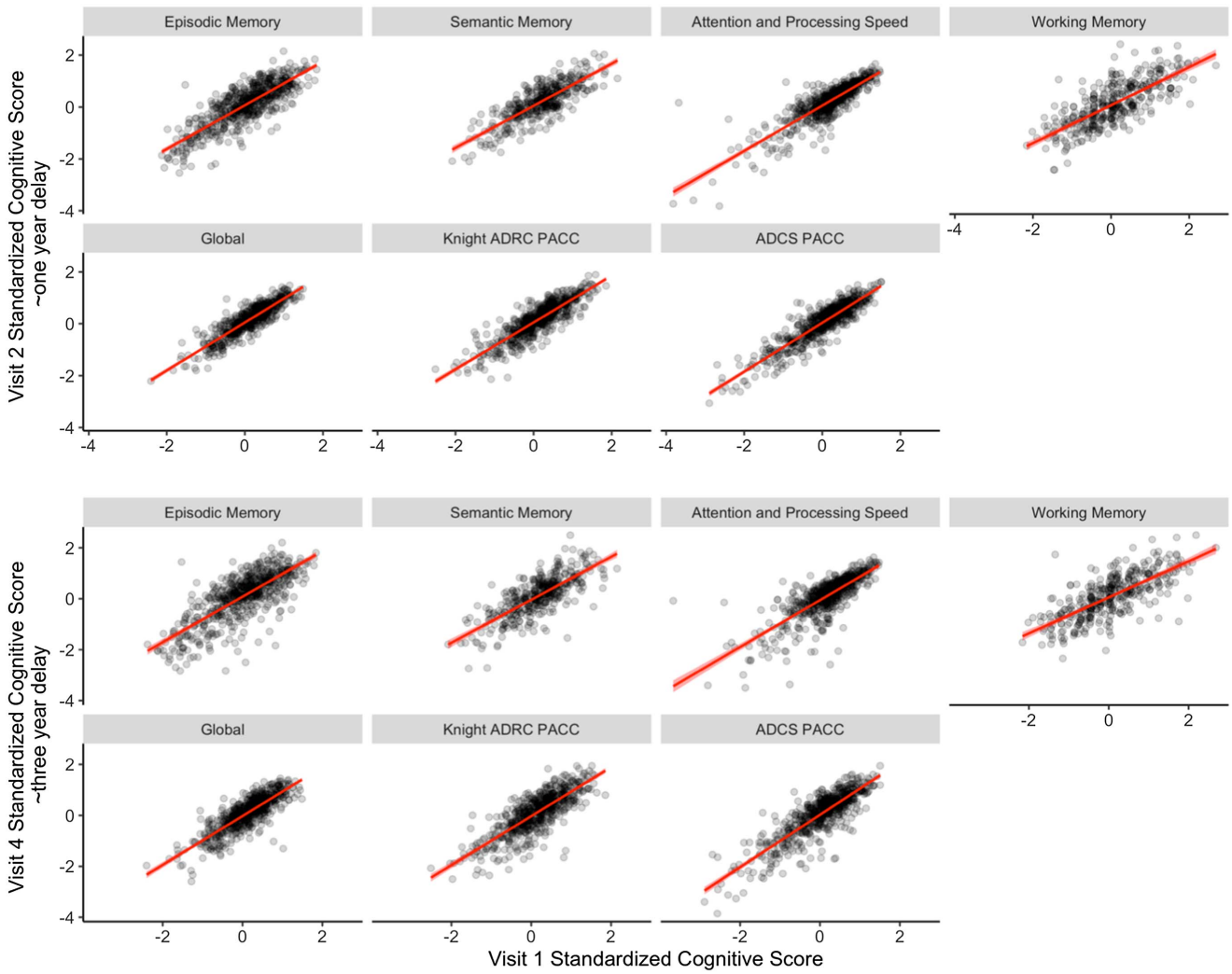
To evaluate the test–retest reliability of our composites, a subset of cognitively normal (CDR = 0) individuals (n = 389) who had completed at least four cognitive sessions (M = 7.2, SD = 0.14) over at least 4 years (M = 7.9, SD = 0.01) were considered. A minimum of 4 years of data were chosen as this is a common length of clinical trial, and we were interested in ensuring our cognitive composites were reliable across such lengths. Importantly, once we determined our subsample of individuals, their cognitive data for all subsequent visits were included in these reliability analyses. Initial exploration revealed highly consistent scores across the first and second testing visits for all composites except for working memory, and this pattern was repeated when visualizing the relationship between the first and fourth visit (Figure 3). Estimates of ICC were computed independently for each composite using two-way mixed-effects models with absolute agreement (Koo & Li, 2016; Table 2). Using previously established thresholds (Bruton et al., 2000), our analyses revealed ICC values higher than 0.75, indicating at least "good" reliability for all of our measures.

Cross-Sectional Assessment of Cognitive Composites

To assess the usefulness of the computed composites in an aging and preclinical AD context, multiple independent partial correlational analyses were implemented, pairing each of the seven derived composites with age, cortical thickness, Aβ accumulation, and tau deposition. Analyses were run using data from cognitively unimpaired individuals (CDR = 0), so that each composite's sensitivity to preclinical AD could be evaluated. To minimize spurious variability and maximize included participants, biomarker

Figure 3

Visualization of the Reliability Between Two Test Visit Scores



Note. Correlations between the first and second sessions for each composite show highly stable scores. Table 3 further analyzes these relationships taking into account all follow-up visits. ADRC = Alzheimer's Disease Research Center; PACC = preclinical Alzheimer disease cognitive composite; ADCS = Alzheimer Disease Cooperative Study. See the online article for the color version of this figure.

Table 2
Summary of Test–Retest Analyses

Composite	ICC (3,1)	*F*	*df*	CI
Episodic memory	0.76	51	352, 5280	[0.73, 0.79]
Semantic memory	0.75	48	352, 5280	[0.72, 0.77]
Attention and processing speed	0.83	78	352, 5280	[0.80, 0.85]
Working memory	0.78	56	352, 5280	[0.75, 0.80]
Global	0.83	92	352, 5280	[0.83, 0.87]
Knight-PACC	0.82	76	352, 5280	[0.80, 0.85]
ADCS PACC	0.78	58	352, 5280	[0.75, 0.81]

Note. Data to compute these values were derived from a subset of 389 individuals who completed at least four cognitive tests over at least four years. Test–retest reliability was estimated using a two-way mixed-effects model with absolute agreement (Koo & Li, 2016). In line with previous work, ICC values of between 0.75 and 0.90 represent good reliability (Bruton et al., 2000). ADCS = Alzheimer Disease Cooperative Study; PACC = preclinical Alzheimer disease cognitive composite; CI = confidence interval; ICC = intraclass correlations.

data for these analyses were only considered for each individual's most recent visit, and cognitive data were considered from their closest cognitive visit within 3 years of their imaging visit.

Cognition and Age

Using multiple independent partial Pearson correlational analyses, all seven derived composites were found to have significant weak to moderate negative correlations ($r = -0.11$:-0.48) with age when assessed cross-sectionally while accounting for the influence of sex, *APOE*-ε4 status, and mean-centered years of education. These relationships suggest that with older age, individuals have lower performance for cognitive processes represented by these composites. Comparing the relationship with age across these composites, the Knight-PACC score is most strongly correlated with age ($r = -0.48$, $p < .001$), while the derived working memory composite has the weakest correlation with age ($r = -0.11$, $p = 2.0 \times 10^{-3}$; Figure 4).

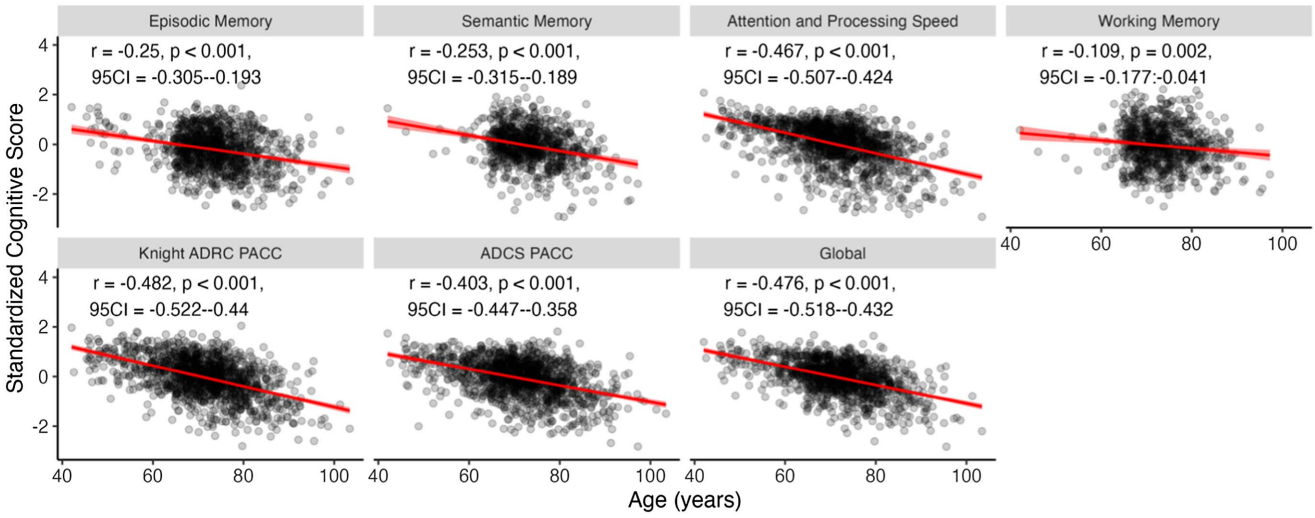
Cognition and Aβ Deposition

It was also of interest to quantify the relationship between cognitive performance on these composites and levels of accumulated Aβ measured using PET. In order to assess sensitivity to preclinical pathology, these analyses were run in a subsample of cognitively normal individuals (CDR = 0) who underwent Aβ-PET ($n = 811$). Using independent Pearson's partial correlation models, weak negative correlations were observed for most of our composites after accounting for the influence of sex, *APOE*-ε4 status, mean-centered years of education, and mean-centered age (Figure 5A). The strongest correlation was observed for the episodic memory composite ($r = -0.15$, $p < .001$), while the relationships between preclinical Aβ and cognition were not statistically different from zero for the semantic ($r = -0.07$, $p = .13$) and working memory composites ($r = 0.03$, $p = .51$).

Cognition and Tau Accumulation

Similarly, independent partial Pearson's correlational analyses were conducted in a subset of cognitively unimpaired individuals (CDR = 0) who had completed a tau-PET scan ($n = 419$). These analyses revealed weak negative relationships between preclinical tauopathy assessed across summary tau regions and some of our composite measures after accounting for the influence of sex, *APOE*-ε4 status, mean-centered years of education, and mean-centered age (Figure 5B). These relationships were such that higher

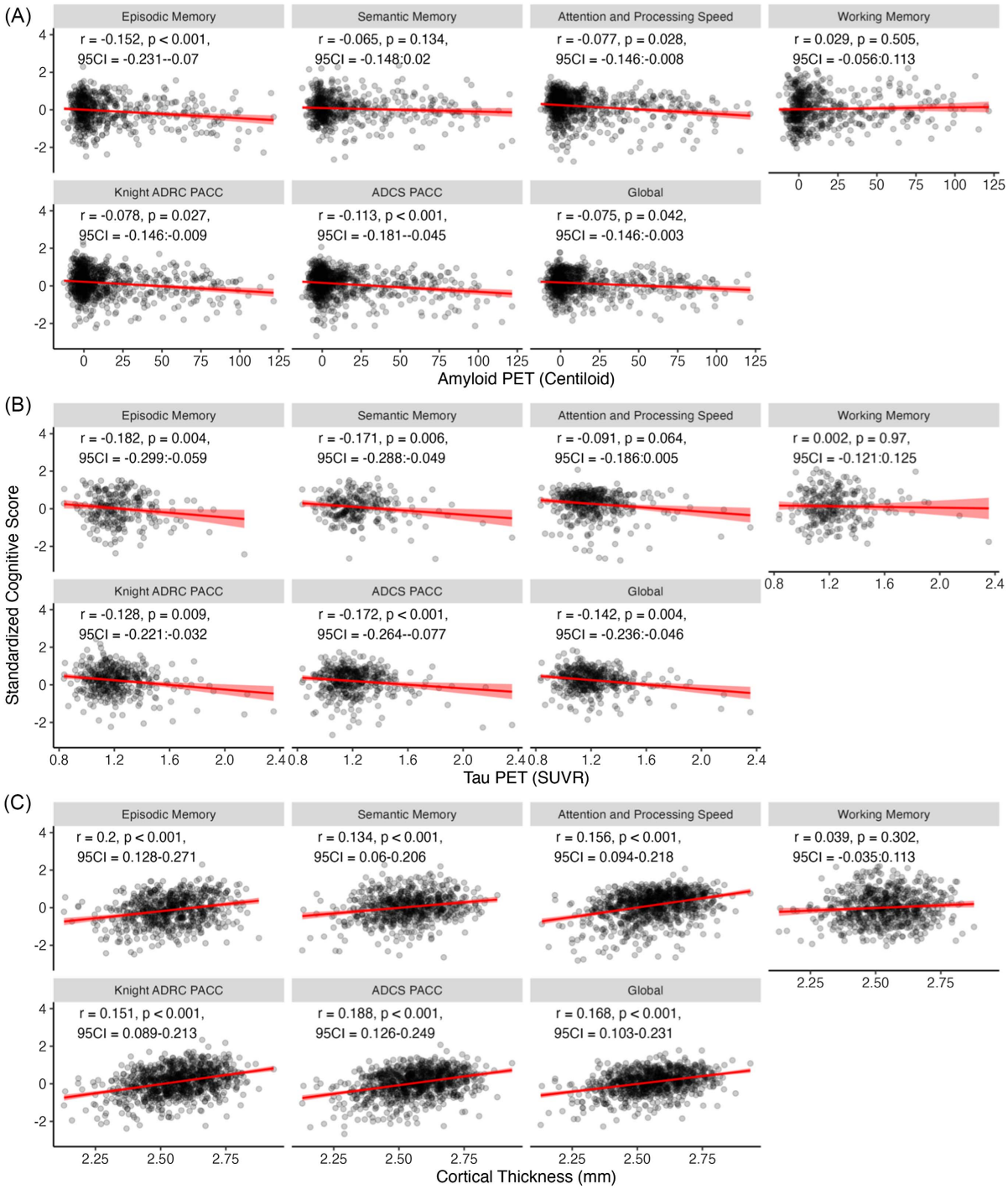
Figure 4
Cognition and Age



Note. Scatterplots depicting the relationship between age and our seven cognitive composites of interest after accounting for the influence of sex and years of education. These statistically significant relationships depict weak to moderate negative correlations, where *r* depicts the Pearson's partial correlation coefficient ($n = 1{,}356$, depending on the composite of interest). ADRC = Alzheimer's Disease Research Center; PACC = preclinical Alzheimer disease cognitive composite; ADCS = Alzheimer Disease Cooperative Study; CI = confidence interval. See the online article for the color version of this figure.

Figure 5

Visualization of the Cross-Sectional Relationships Between Cognition and AD Biomarkers



Note. Scatterplots depict correlational models of the relationship between each cognitive composite and the AD imaging biomarkers of interest. Here, *r* depicts partial Pearson's correlation coefficients, which were modeled to account for the influence of sex, age, and years of education. Importantly, the sample size was independently determined for each biomarker based on the availability of matched cognitive data. (A) Depiction of the relationship between Aβ accumulation measured by PET and each cognitive composite (n = 720–738, depending on composite). (B) The relationship between tau accumulation measured across our tauopathy regions and cognition (n = 332–336, depending on composite). (C) Depiction of the relationship between cortical thickness and each cognitive composite (n = 9981,010, depending on composite). AD = Alzheimer disease; PET = positron emission tomography; ADRC = Alzheimer's Disease Research Center; PACC = preclinical Alzheimer disease cognitive composite; ADCS = Alzheimer Disease Cooperative Study; CI = confidence interval; SUVR = standardized uptake value ratio; Aβ = β-amyloid. See the online article for the color version of this figure.

tau levels were associated with lower performance on our episodic memory, semantic memory, Knight-PACC, ADCS-PACC, and global composite scores, although no relationship was apparent for the attention and processing ($r = 0.09$, $p = .06$) or working memory composites ($r = 0.01$, $p = .97$). Of our assessed composites, the episodic memory composite was most strongly correlated ($r = -0.18$, $p = < 0.001$).

Cognition and Cortical Thickness

After accounting for the influence of sex, *APOE*-ε4 status, mean-centered years of education, and mean-centered age, most of our composites were significantly positively correlated with cortical thickness ($n = 931$; Figure 5C). That is, as cortical thickness declines, the performance measured for six of our composites also declines. However, the relationship between working memory performance and cortical thickness did not statistically differ from zero ($r = 0.04$, $p = .30$), indicating no significant relationship between these variables. Of our assessed composites, the episodic memory composite was most strongly correlated ($r = 0.20$, $p < .001$).

Finally, in order to better understand how these cognitive composites relate to important clinical classifications in AD, further comparisons were made to examine whether these composites were able to differentiate individuals by cognitive status (cognitively normal vs. cognitively impaired; $n = 1{,}996$), Aβ-positivity (Aβ-negative vs. Aβ-positive; $n = 1{,}349$), and tau-positivity (tau-positive vs. tau-negative; $n = 507$), using multiple ANCOVAs. In line with our hypotheses, after controlling for the influence of sex, *APOE*-ε4 status, mean-centered years of education, and mean-centered age, comparisons revealed that cognitively impaired participants had significantly lower performance than cognitively normal participants on all seven composites (Figure 6A). Further, Aβ-positive participants had reduced performance on all seven composites compared to Aβ-negative participants (Figure 6B), and tau-positive participants had lower performance than tau-negative participants in all composites (Figure 6C). Effect size reports for these comparisons indicated that for CDR, the effects were moderately strong, but for Ab-positivity and tau-positivity, the effects were small and very small, respectively. These results likely reflect the preclinical nature of this cohort.

Longitudinal Assessment of Cognitive Factors

To assess the relationships between common AD biomarkers and longitudinal performance on these cognitive scores, multiple independent mixed-effects models were implemented. Each model considered the main effects of time in the study and baseline biomarker in addition to the interaction between these variables. Variation in the length of time retained in the study by individual was accounted for by the inclusion of an additional model term. Finally, baseline CDR, sex, *APOE*-ε4 status, mean-centered years of education, and mean-centered age were also included as covariates.

Aβ Accumulation and Longitudinal Cognition

Baseline cortical Aβ levels were found to predict longitudinal cognitive performance for all derived cognitive composites ($n = 489 - 599$; Table 3). Subsequent follow-up analyses confirmed that the amount of Aβ measured at baseline using PET imaging influenced the rate of cognitive decline in the subsequent 6 years, such that those with the highest baseline Aβ levels had the greatest decline in cognition compared to those with the lowest baseline Aβ levels (Figure 7A). Comparisons of the explained variances (marginal and conditional R^2) and corresponding effect sizes (Cohen's f^2) for these models revealed that the global composite explained the most overall variance in our data, with the largest associated effect size (conditional $R^2 = 0.94$, $f^2 = 15.66$), while the working memory composite explained the least with a relatively small effect size (conditional $R^2 = 0.82$, $f^2 = 4.55$). Comparisons of marginal R^2 revealed that the ADCS-PACC explained the most local variance in this data (marginal $R^2 = 0.33$, $f^2 = 13.29$), while the working memory composite explained the least local variance (marginal $R^2 = 0.10$, $f^2 = 4.55$). Additionally, we observed comparably high conditional (> 90%) and marginal (> 30%) values for the episodic memory, attention and processing, and Knight-PACC composites (Table 3; Figure 7A).

Tau Deposition and Longitudinal Cognition

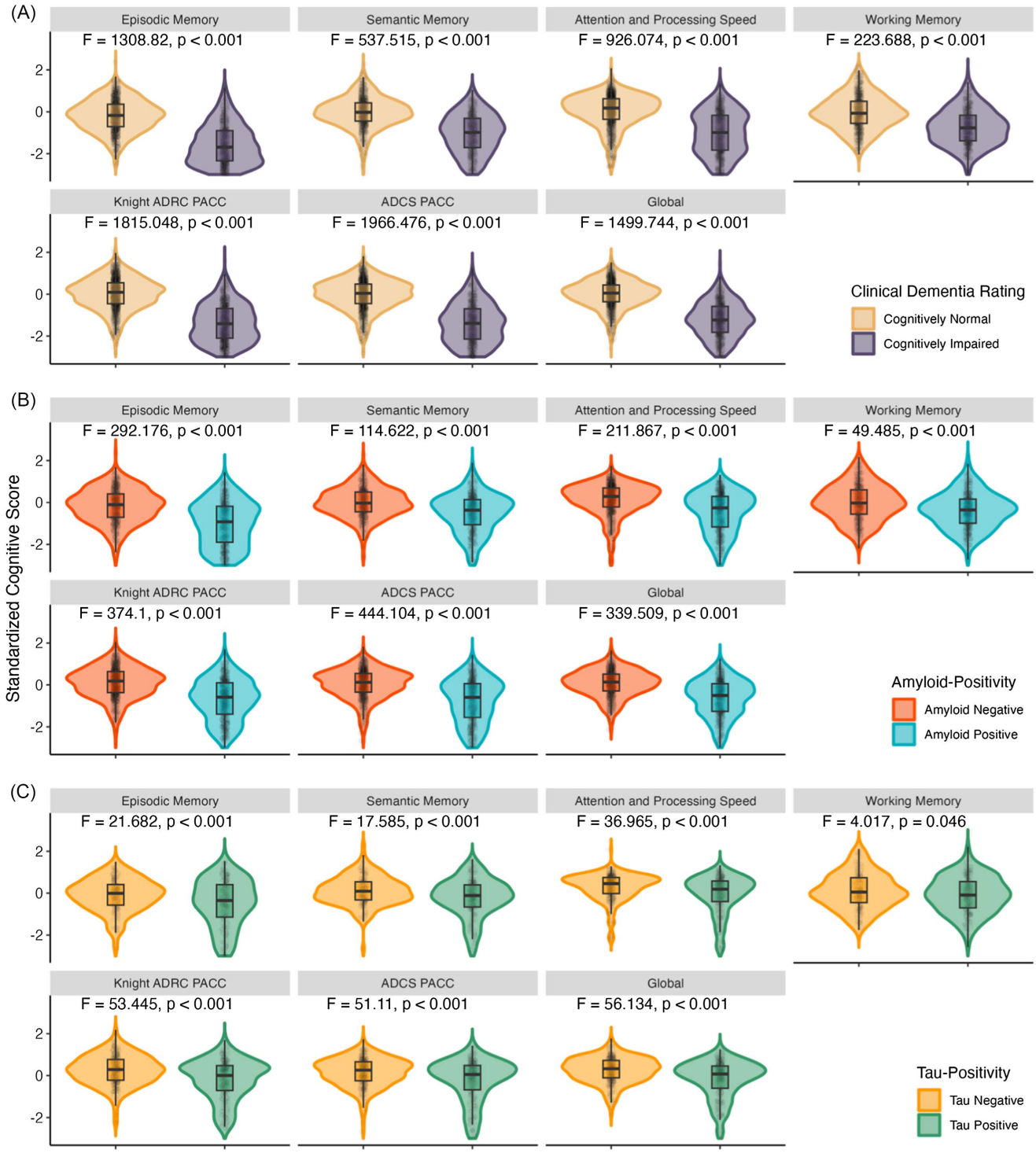
Our summary measure of tau accumulation was found to be a significant predictor of longitudinal cognitive performance for all cognitive composites except the working memory composite ($n = 380$–492; Table 3). For most composites, the magnitude of baseline tau deposition observed corresponded to the level of cognitive decline over the subsequent years of cognitive testing (Figure 7B). That is, those with the highest levels of tau measured using PET at their baseline visit had the greatest decline in cognitive performance compared to those with lower baseline tau levels. Comparisons revealed that the ADCS-PACC composite explained the most overall variance in our data given the considered covariates, with the largest associated effect size (conditional $R^2 = 0.92$, $f^2 = 11.50$). It should also be noted that the global and episodic memory composites explained very similar proportions of variance in the data with only marginally smaller effect sizes (conditional $R^2 = 0.91$, $f^2 = 10.10$). Comparisons of marginal R^2 revealed that the ADCS-PACC is likely the best predictor for novel data and accounts for the most local variance (marginal $R^2 = 0.45$, $f^2 = 11.50$). In contrast to the Ab analyses, the working memory as well as the semantic memory composites explained far less of the global (working memory: conditional $R^2 = 0.84$, $f^2 = 5.25$; semantic memory: conditional $R^2 = 0.80$, $f^2 = 4.0$) and local (working memory: marginal $R^2 = 0.14$, $f^2 = 5.25$; semantic memory: marginal $R^2 = 0.26$, $f^2 = 4.0$) variation in the data compared to all other composites.

Cortical Thickness and Longitudinal Cognition

In line with our tau-based analyses, baseline cortical thickness significantly predicted longitudinal changes in cognition for all derived factors except the working memory composite ($n = 654$–764; Table 3). Subsequent analyses revealed that those with the thinnest cortex at baseline had the steepest declines in cognition across the subsequent 6 years of follow-up assessments (Figure 7C). Model comparisons revealed that the global composite explained the most overall variance in our data, given the considered covariates with the largest associated effect size (conditional $R^2 = 0.95$, $f^2 = 19.00$), while the working memory composite explains the least with a relatively small effect size (conditional $R^2 = 0.83$, $f^2 = 4.88$). Also,

Figure 6

Binarized Biomarker Relationships With Cognition



Note. Cross-sectional summary violin plots depicting cognitive scores for each of the calculated composites, separated by three common grouping factors in AD research. Differences in average scores were statistically evaluated using multiple one-way analysis of variance, where sex, age, and years of education were included as covariates. All measures are reported relative to an α level of 0.05, with effect sizes and confidence intervals. (A) Comparisons between those who are classified as cognitively impaired ($n = 829$) or cognitively normal ($n = 586$) according to their CDR score. (B) Cognitive performance for all seven composites is observed to be significantly lower in those who are classified to have pathological levels of Aβ ($n = 314$) using thresholds determined in prior work compared to those who are Aβ negative ($n = 424$). (C) Individuals with pathological levels of tau ($n = 183$), as defined in prior studies, are found to have significantly lower cognitive scores on all seven of the derived composites compared to controls ($n = 153$). AD = Alzheimer disease; CDR = clinical dementia rating; ADRC = Alzheimer's Disease Research Center; PACC = preclinical Alzheimer disease cognitive composite; ADCS = Alzheimer Disease Cooperative Study; Aβ = β-amyloid. See the online article for the color version of this figure.

Table 3
Relationship Between Baseline Biomarkers and Cognitive Composites

Biomarker	Cognitive composite	N	B[a] (Cognition × Time)	CI	Predictor p value[b]	Marginal R^2/ conditional R^2	Global effect size[c]
Aβ-PET	Episodic memory	489	−0.09	[−0.10, −0.07]	1.7×10^{-19}	0.30/0.91	10.10
	Semantic memory	494	−0.04	[−0.06, −0.02]	4.7×10^{-6}	0.19/0.87	6.69
	Attention and processing speed	598	−0.08	[−0.10, −0.06]	9.1×10^{-19}	0.23/0.91	10.10
	Working memory	494	−0.02	[−0.04, 0.0]	0.02	0.10/0.82	4.55
	Knight-PACC	599	−0.06	[−0.07, −0.04]	9.0×10^{-15}	0.29/0.92	11.50
	Global	591	−0.06	[−0.07, −0.05]	1.1×10^{-24}	0.30/0.94	15.66
	ADCS-PACC	599	−0.13	[−0.15, −0.11]	1.5×10^{-32}	0.33/0.93	13.29
Tau-PET	Episodic memory	380	−0.09	[−0.15, −0.03]	2.0×10^{-3}	0.34/0.91	10.10
	Semantic memory	387	−0.09	[−0.14, −0.04]	1.9×10^{-3}	0.26/0.80	4.00
	Attention and processing speed	489	−0.06	[−0.10, −0.02]	3.0×10^{-3}	0.28/0.86	6.14
	Working memory	387	−0.03	[−0.08, 0.01]	0.16	0.14/0.84	5.25
	Knight-PACC	490	−0.07	[−0.11, −0.03]	1.3×10^{-4}	0.32/0.90	9.00
	Global	490	−0.06	[−0.09, −0.04]	9.8×10^{-6}	0.37/0.91	10.10
	ADCS-PACC	492	−0.12	[−0.16, −0.08]	4.0×10^{-8}	0.45/0.92	11.50
MRI	Episodic memory	654	0.04	[0.03, 0.06]	2.4×10^{-6}	0.26/0.92	11.50
	Semantic memory	658	0.05	[0.04, 0.07]	1.2×10^{-9}	0.26/0.89	8.09
	Attention and processing speed	760	0.06	[0.04, 0.07]	2.0×10^{-11}	0.26/0.92	11.50
	Working memory	658	0.01	[−0.0, 0.03]	0.08	0.14/0.83	4.88
	Knight-PACC	763	0.04	[0.03, 0.05]	5.8×10^{-10}	0.30/0.93	13.29
	Global	761	0.05	[0.03, 0.06]	7.9×10^{-15}	0.31/0.95	19.00
	ADCS-PACC	764	0.08	[0.06, 0.10]	2.7×10^{-17}	0.27/0.94	15.66

Note. Summary data extracted from each linear mixed-effects model describing the relationship between baseline levels of pathology measured by three neuroimaging biomarkers (Aβ-PET, tau-PET, and MRI) and our seven cognitive composites. Note, in all analyses, N represents the maximum number of individuals within the Knight ADRC cohort with the relevant biomarker scans and cognitive data. Aβ = β-amyloid; PET = positron emission tomography; MRI = magnetic resonance imaging; ADCS = Alzheimer Disease Cooperative Study; PACC = preclinical Alzheimer disease cognitive composite; CI = confidence interval; ADRC = Alzheimer's Disease Research Center.
[a] B represents the estimate from the linear mixed model for the interaction between time in the study and the specific cognitive composite. [b] Predictor p value represents the p value associated with the interaction between cognition and time in the study. [c] Cohen's f^2 calculated using the conditional R^2.

in line with the PET analyses, comparisons of marginal R^2 revealed that the global composite is also the best predictor for novel data, explaining the most local variance (marginal $R^2 = 0.31$, $f^2 = 19.00$), while the working memory composite explained the least local variance (marginal $R^2 = 0.14$, $f^2 = 4.88$). Importantly, the episodic memory, attention and processing, Knight-PACC and ADCS-PACCs each explained at least 90% of overall variance, and the Knight-PACC also explained at least 30% of local variance in the data.

Predicting Symptomatic Progression

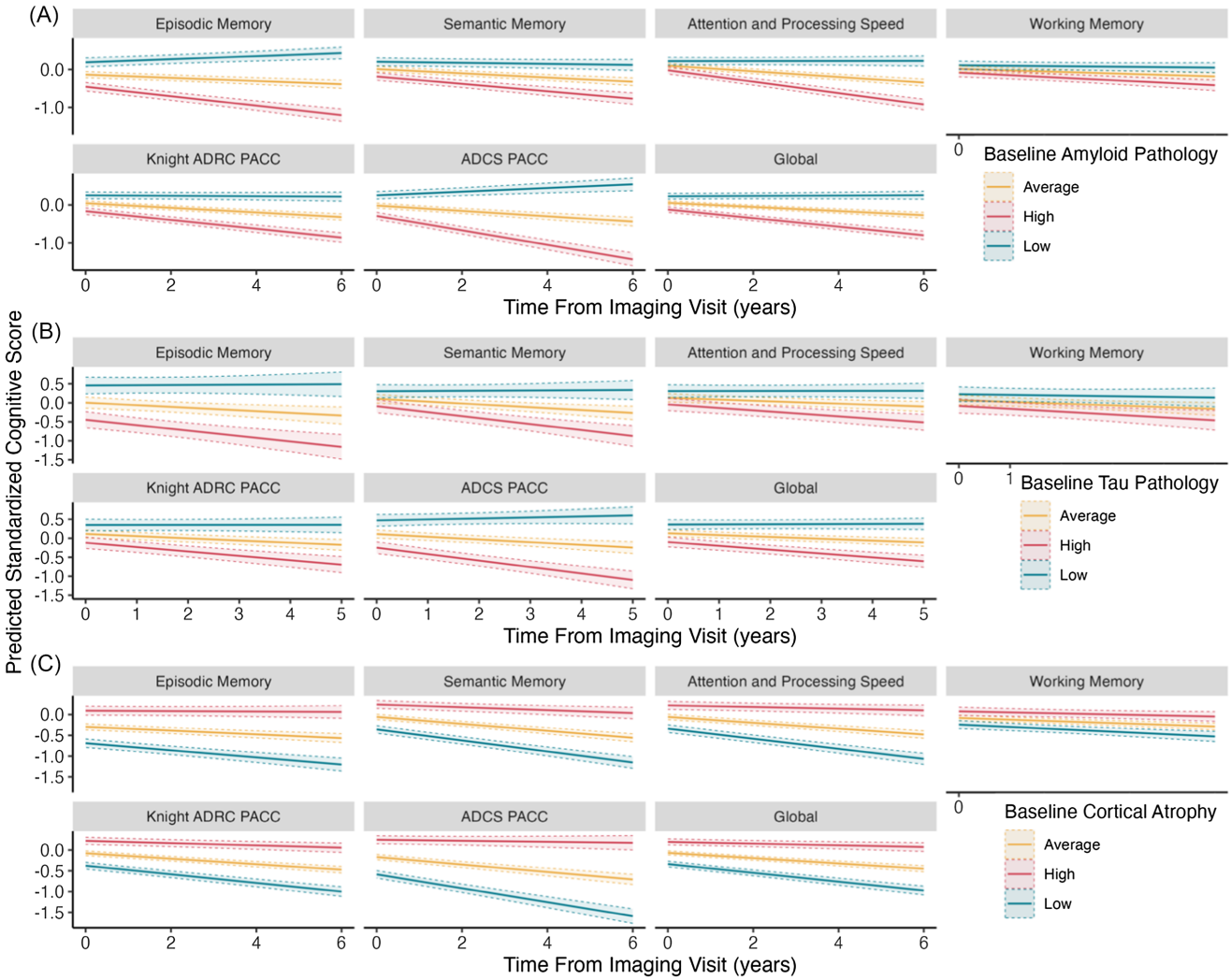
It was of further interest to compare how sensitive our cognitive composites are to symptomatic progression as measured by a shift on the CDR scale. These analyses were conducted on participants classified as cognitively normal (CDR = 0) at their baseline study visit and who had at least two cognitive assessments, including all composites, within a 4-year period ($n = 341$, where 102 individuals progressed to CDR > 0). To ensure all individuals were rated on the same versions of each task, all data for these analyses were restricted to between 2015 and 2020. Rates of decline for each of the composites were calculated for each individual across 4 years using simple linear regression models. We classified individuals as having high- or low-rates of cognitive decline in each composite using a median split, and the resulting classifications were entered into survival analyses. Time to symptomatic onset was operationalized as the time, in years, from an individual's baseline visit to the visit in which they were first classified as having a CDR greater than 0. In cases where individuals never progressed, time to final study visit within this period was used instead. Using a Cox proportional hazards model with sex, *APOE*-ε4 status, mean-centered years of education, and mean-centered age as covariates, adjusted hazard ratios (HRs) and their 95% confidence intervals were estimated (Table 4). For each model, the adjusted cumulative incidence of time to symptomatic progression was increased in the individuals with high cognitive decline for each derived composite. Comparison of the HRs for each composite suggests that the rate of decline on the global composite is the most predictive of symptomatic progression. That is, the higher an individual's rate of decline across 4 years was for this composite, the higher the likelihood of progression to symptomatic status (HR = 5.49, 95% CI [3.23, 9.32]). Similar values were revealed for the Knight-PACC and attention and processing composites, while, in line with all previous analyses, the working memory composite had only a minimal impact on survival (Table 4). Survival curves were also plotted (Figure 8).

Power Analyses

To assess the usefulness of our proposed composites in a clinical trial setting, power analyses were computed in a subset of individuals with longitudinal cognitive data spanning 2015–2020 ($n = 379$). Simulated trials were run with a 1:1 allocation of the treatment and placebo arms, assuming a 50% treatment effect on the composite score, a trial length of 4 years, annual testing, and a power of 80%. These simulations were run for all 379 individuals as well as in a subset of individuals who were already Aβ positive ($n = 118$) to improve ecological validity, given that most AD trials recruit those

Figure 7

Longitudinal Models of Biomarkers and Cognition



Note. Visualization of the modeled relationship between pathological burden at baseline and future cognitive performance for Aβ-PET (A), tau-PET (B), and MRI (C). Each line depicts the model prediction for those with a median baseline burden (yellow), as well as the predictions for those who are one standard deviation above the median baseline pathological burden (red) and one standard deviation below the median baseline pathological burden (blue). As demonstrated in the expanded mixed model analyses, the working memory composite returns a relatively weaker model of prediction for each of the PET and MRI biomarkers. Aβ = β-amyloid; PET = positron emission tomography; MRI = magnetic resonance imaging; ADRC = Alzheimer's Disease Research Center; PACC = preclinical Alzheimer disease cognitive composite; ADCS = Alzheimer Disease Cooperative Study. See the online article for the color version of this figure.

who already have some pathological burden due to their increased risk of symptomatic AD progression. Overall, the global (n = 133, 95% CI [88, 224]), Knight-PACC (n = 142, 95% CI [92, 249]), and attention and processing speed (n = 161, 95% CI [104, 286]) measures were estimated to require the smallest sample sizes to observe a 50% treatment effect over 4 years. Moreover, confidence intervals around these composites were relatively precise compared to other measures (Figure 9). Similarly, when restricting eligibility for the trial to Aβ positive individuals, these same three composites were estimated to require the smallest sample sizes (Knight-PACC: n = 61, 95% CI [35, 134]; attention and processing speed: n = 88, 95% CI [49, 210]; global: n = 94, 95% CI [55, 197]). In contrast, the episodic memory (n = 662, 95% CI [286, 2880]), ADCS-PACC (n = 519, 95% CI [257, 1549]), and the working memory (n = 404, 95% CI [193, 1309]) composites were estimated to require relatively larger sample sizes for the full trial as well as the restricted trial (episodic memory: n = 309, 95% CI [122, 1871]; working memory: n = 506, 95% CI [150, 19776]; ADCS-PACC: n = 160, 95% CI [77, 527]). Further, the confidence intervals around these estimated sample sizes for both trial designs were much less precise (Figure 9). See Supplemental Figure SM4 for power estimates across a wider range of treatment effect sizes.

Table 4
Predicting Symptomatic Progression Using Cognitive Composites

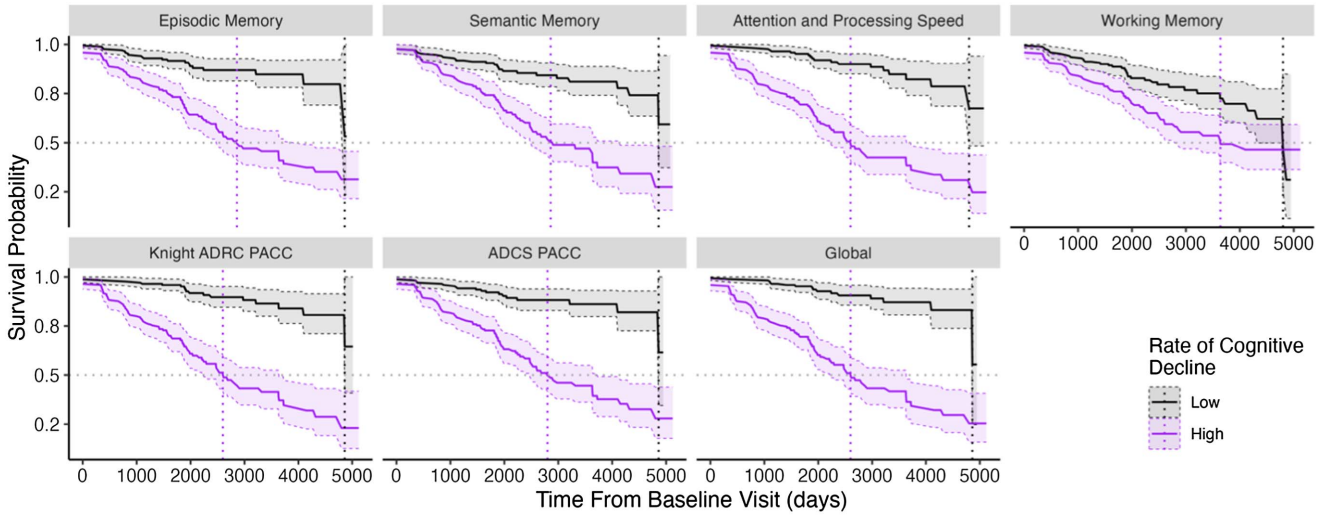
Composite	*N*	% Progression	Hazard ratio: Low versus high	95% CI[a]	Predictor p[b]	Model LR[c]	Model p[d]
Episodic memory	341	30.0%	3.80	[2.35, 6.17]	5.6×10^{-8}	84.04	1.2×10^{-16}
Semantic memory	341	30.0%	2.81	[1.79, 4.40]	6.6×10^{-6}	71.08	6.1×10^{-14}
Attention and processing speed	341	30.0%	4.86	[2.92, 8.11]	1.3×10^{-9}	95.28	5.2×10^{-19}
Working memory	341	30.0%	1.71	[1.14, 2.56]	0.01	55.45	1.1×10^{-10}
Knight-PACC	341	30.0%	4.87	[2.92, 8.14]	1.4×10^{-9}	94.60	7.2×10^{-19}
Global	341	30.0%	5.49	[3.23, 9.32]	3.0×10^{-10}	101.40	2.7×10^{-20}
ADCS-PACC	341	30.0%	4.05	[2.47, 6.65]	3.4×10^{-8}	86.46	3.2×10^{-17}

Note. Summary data extracted from Cox proportional hazard models run to determine how well each cognitive composite can predict the progression of individuals from cognitively normal (CDR = 0) to cognitively impaired (CDR > 0). ADCS = Alzheimer Disease Cooperative Study; PACC = preclinical Alzheimer disease cognitive composite; CI = confidence interval; CDR = clinical dementia rating; LR = likelihood ratio.
[a] 95% confidence intervals represent the intervals around the calculated hazard ratio. [b] Predictor p represents the p value specifically related to the effect of cognitive composite grouping within the model. [c] Model LR represents the likelihood ratio of the model. [d] Model p represents the p value associated with this likelihood ratio test.

Discussion

The present study found evidence that data sets comprising UDS2, UDS3, or combined UDS2 and UDS3 data produce equivalent factor structures. Specifically, in all three cases, our cognitive data were reduced to three distinct factors representing general memory, attention and processing speed, and working memory tasks. Given that the resulting memory factor spanned multiple subdomains, we postulated that this large factor encompasses two distinct memory processes, representing episodic and semantic tasks. In all cases, the resulting four factors represented the same clusters of tasks across data sets. That is, in the equated UDS2 and UDS3 data, each final factor comprised the equivalent tests as the independent UDS2 and UDS3 factor solutions. The stability of these factors across these data sets provides strong evidence that our derived composites, based on previously defined equated variables (Monsell et al., 2016), can unify data sets that span multiple iterations of the UDS cognition battery. Importantly, this ability to use cognitive measures that consistently capture domain-specific structure across previously stratified longitudinal data has the potential to greatly increase the number of data points that can be utilized in future analyses across ADRCs. These increases in sample size directly improve the chance of detecting subtle cognitive changes across time, which we expect to occur in aging and AD cohorts, due largely to increases in statistical power.

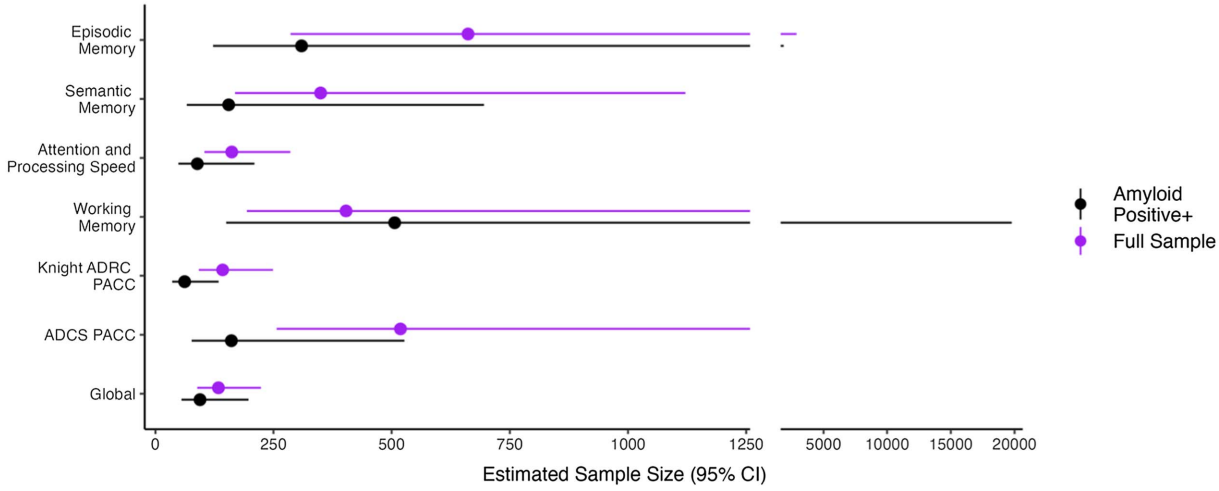
Figure 8
Kaplan–Meier Curves



Note. Visualization of survival curve analyses. Here, dashed gray lines represent the 50% survival level, and dashed red lines display the point, in years, where the survival probability crosses this 50% line. Using data from 741 individuals, we calculated the rate of cognitive decline over longitudinal visits and split individuals into two groups by composite. The high rate of decline group represents individuals with a steep (above median) rate of decline, and the low group represents those with a below-median rate of decline. ADRC = Alzheimer's Disease Research Center; PACC = preclinical Alzheimer disease cognitive composite; ADCS = Alzheimer Disease Cooperative Study. See the online article for the color version of this figure.

Figure 9

Sample Size Estimates



Note. Estimated required sample size (and 95% confidence interval) to detect a longitudinal treatment effect of 50% across a 4-year trial, with annual testing and 80% power, for each of the seven cognitive composites. Two trial types were simulated for these analyses: one that recruited all participants (full sample, black) and one that recruited only participants that were already amyloid positive (amyloid positive, purple). ADRC = Alzheimer's Disease Research Center; PACC = preclinical Alzheimer disease cognitive composite; ADCS = Alzheimer Disease Cooperative Study; CI = confidence interval. See the online article for the color version of this figure.

Given the importance of cognitive outcomes for assessing the efficacy of potential therapeutic agents in clinical trials, we were highly interested in computing test–retest reliability to ensure these composites were statistically sound to be administered to the same individual multiple times. Using data from individuals with at least four completed cognitive sessions, we found all seven composites had "good" levels of test–retest reliability across this longitudinal data. Of our tested composites, the attention and processing, Knight-PACC, and global composites showed the highest levels of test–retest reliability, while the working memory, episodic memory, semantic memory, and ADCS-PACC were observed to have lower reliability. It is important to interpret these results with some caution, given that we were assessing reliability over time (years) in a sample of older adults, it is likely our ICC measures do not purely represent reliability. That is, these values likely also capture age-related decline. Despite this, all seven composites were evaluated to have acceptable levels of reliability, such that they could be utilized for longitudinal research or clinical trials. This metric is important to consider when choosing measures for inclusion in these types of studies, as it represents the degree to which a measure yields consistent results when it is administered multiple times to the same individual, as is customary in studies of aging and AD.

A critical aim of this article is to establish whether domain-specific composites were well-suited to answering AD questions. To accomplish this, we compared domain-specific outcomes to two different PACC scores as well as a global cognitive composite. Using cross-sectional data, we found that cognitive scores were lower with older age across all composites, in line with our hypotheses. Importantly, the strength of this negative relationship with age varied by composite, ranging from moderate associates with the Knight-PACC, global, and attention and processing composites to very weak associations with the working memory composite. These findings are in line with prior work showing differential associations of cognitive performance with aged by cognitive domain (Park & Reuter-Lorenz, 2009). Similarly, we found negative relationships between cognitive performance measured by most tested composites and greater pathology measured by Aβ-PET, tau-PET, and structural MRI. These relationships were consistently found with the episodic memory, ADCS-PACC, Knight-PACC, and global composites, although the magnitudes of these relationships were relatively weak. Interestingly, our working memory composite was only associated with the tau summary measure, potentially reflecting that tau pathology is most closely tied to cognitive decline in amyloid/tau/neurodegeneration accounts of AD. However, when interpreting these associations, it is important to consider that these relationships were tested on a cognitively normal cohort of individuals. In such cohorts, levels of preclinical AD pathology are likely low, which may account for the relatively small effect sizes reported. Across these correlational analyses, the Knight-PACC was most strongly correlated with age, while our episodic memory composite was most strongly correlated with Aβ-, tau-, and cortical thickness burden. In contrast, across the measures of age, Aβ deposition, tauopathy, and cortical thickness, the working memory composite consistently had very weak or nonexistent relationships, potentially reflecting that this domain of cognition is not specifically altered with age or greater AD pathology or that these particular measures of working memory might not be as sensitive to age or AD as other external working memory tasks. Finally, using commonly implemented grouping variables, we also confirmed that all composites associated with lower cognitive performance in symptomatic, Aβ-positive, or tau-positive individuals compared to their relevant controls.

To further assess and compare the utility of these composites for AD research, we examined whether baseline levels of common AD

biomarkers could predict the longitudinal decline of performance on each of our composites. Using our defined summary measures, baseline levels of Aβ deposition, tauopathy, and cortical thickness significantly predicted a subsequent 6-year decline in cognition for all composites. The degree of prediction varied by cognitive composite and neuroimaging biomarkers. Models of prediction found neuroimaging biomarkers were consistently good at predicting decline in the Knight-PACC, attention and processing, global, and ADCS-PACC composites. In line with our other analyses, these neuroimaging biomarkers were not strong predictors of working memory performance. To explore these relationships further, we also categorized individuals by average, above-average, or below-average levels of these biomarkers. As predicted, those with the highest baseline levels of each biomarker had greater cognitive decline as measured by all composites, although the degree of separation between predicted models for high-pathology compared to low-pathology individuals differed greatly by composite. Assessing the proportion of variance explained by each model as well as effect size, we consistently found that the attention and processing, Knight-PACC, global, and ADCS-PACC composites predicted the collected data for each imaging biomarker, while the working memory composite explained the least amount of variance in the data and had the smallest effect sizes. These patterns were also reflected in the marginal variances explained by these models, representing the ability of these models to generalize to novel data. Here, we propose that it may also be more interesting to consider the composites independently from the global score, given the statistical power benefit that this composite possesses due to the number of tests it comprised, and the unique properties of the MMSE likely driving the ADCS-PACC to appear well-suited for these analyses. For example, when ignoring these two composites, the factors explaining the most variance in our Ab, tau, and cortical thickness analyses are the Knight-PACC and attention and processing speed composites. Given that these analyses assessed how baseline pathological burden influenced future cognitive decline, they may provide insight into which cognitive domains decline across the trajectory of AD development (Morris et al., 2022). Although it is important to note that each of these biomarkers varies in specificity to AD pathology, such that Aβ burden may represent a specific AD marker, cortical atrophy is much less specific to AD (Dincer et al., 2020).

To further assess the usefulness of these composites for clinical trials or longitudinal research, we also evaluated their sensitivity for predicting progression from cognitively normal to impaired status. Using survival analyses quantified by Cox proportional hazard ratios, we found that those with above-average rates of decline were much more likely to progress to symptomatic status in the following years. In line with our other included analyses, the hazard ratio values indicated that high rates of decline in the attention and processing speed, the Knight-PACC, and global composites had the greatest association with future cognitive status progression. Individuals with above-average decline on these measures were approximately six times more likely to progress to symptomatic status than those with the lowest rate of performance decline. In contrast, high rates of change in performance for the working memory composite were much less predictive of future cognitive status progression, with individuals with the highest decline in performance on these tasks less than twice as likely to have a future progression to symptomatic cognitive status. This ability to discriminate between stable and future-progressing participants is useful for consideration in clinical trial planning as it could be used to target individuals at higher risk of progression as well as for better monitoring of subtle, meaningful cognitive decline over time.

To understand which of our composites would be suited for potential future clinical trials, we calculated the minimum sample sizes required for each composite across two simulated trial designs. The first design was simulated to enroll participants regardless of baseline amyloid status with a 1:1 allocation for the placebo and treatment arms. Our simulation assumed a 50% treatment effect on the composite score, annual testing for a total of four years, and 80% power. Given these parameters, power analyses revealed minimum sample size estimates that would need to be recruited by composite. We calculated that the global composite would require the lowest number of individuals, with 133 needed in each study arm, closely followed by the Knight-PACC and attention and processing speed composites, which returned 1.1 and 1.2 times as many individuals per study arm, respectively. In contrast, the episodic memory composite was calculated to require 5.0 times as many individuals per study arm, while the ADCS-PACC and working memory composite required 3.9 and 3.0 times as many individuals per study arm, respectively. Our second simulation was designed with the same study parameters but restricted eligibility to only those who were already amyloid positive, to replicate the design of many AD clinical trials (Kiselica, 2021; Sevigny et al., 2016). Estimated sample sizes for the composites followed a similar pattern as with the first simulation, although the exact ordering of the lowest three and highest three sample size estimates changed slightly. In the Ab-positive trial, we estimated that the attention and processing composite would require 61 individuals per study arm, while the Knight-PACC and global composites would require 1.4 and 1.5 times as many individuals per study arm, respectively. In contrast, the working memory, episodic memory, and ADCS-PACC required 8.3, 5.1, and 2.6 times as many individuals per study arm, respectively, although these estimates were accompanied by relatively imprecise confidence intervals. While it is not surprising that the global composite would also be highlighted by this analysis given its increased statistical power, the burden that completing all 13 included tests within this composite would place on participants underscores the impressively low number of individuals needed for the Knight-PACC and attentional control composites. Further, the relatively large sample size estimates reported for the ADCS-PACC, particularly when compared to the Knight-PACC, may demonstrate the negative influence of the MMSE's psychometric properties, which reduce its statistical power for detecting subtle changes in cognition (Spencer et al., 2013).

Despite converging evidence across our analyses that these unified UDS composites are informative, there are several important limitations to keep in mind. For example, the generalizability of these results may be limited by the sample demographics of the Knight ADRC data, which are predominantly White and highly educated. A major limitation of our presented work is the lack of a validation cohort to test whether these composites are consistent across groups. While such an analysis is out of the scope of the current work, we strongly encourage other researchers to adapt our composites and report their relationships with AD biomarkers in their respective data repositories. Our converging UDS-2 and UDS-3 factor analyses, alongside previously reported use of the equipercentile equated variables and the robust analytical process

outlined within, provide a strong foundation for our composites. However, with the increasing efforts at this center to recruit from more diverse participant populations, future iterations of this work could address how well these composites generalize across broader samples. Further, as previously discussed, there are known issues with the equipercentile approach taken to unifying tasks from the UDS2 and UDS3 (Kolen & Brennan, 2013). Specifically, when using this method, an anchor test is required, resulting in the unification of tasks being unidirectional; that is, an equivalent score of the MMSE can be determined for any given MoCA score, but the reverse is not possible. Equipercentile equating also provides error estimates around each interpolated score, which cannot be incorporated in subsequent analyses. This results in a loss of potentially informative variance in the resulting data. Despite these methodological limitations, our results join a body of literature that has successfully used this method for equating neuropsychological tests, including in a similar study cohort (Monsell et al., 2016). It is also important to acknowledge the relatively weak outcomes demonstrated when using our working memory composite. These results may reflect that one, or more, of the grouped tasks within this factor are not sensitive enough to detect a decline in working memory performance, even if it does exist. Alternatively, these results could be interpreted as evidence that working memory is relatively spared across age and with higher AD pathology (but see McCabe et al., 2010; Park, 2002). While our analyses are not designed to answer this question, it is important to note that the tasks chosen for inclusion in the UDS battery were deliberately included to represent general cognition and episodic memory, rather than working memory. Moreover, these tasks are optimized for observing dramatic changes in cognitive performance that are associated with clinical presentations of neurodegenerative diseases. Therefore, it is unsurprising that some of these UDS tasks are not well-suited for the detection of subtle cognitive decline observed in healthy aging and preclinical AD, which the Knight ADRC cohort is designed to examine. That said, we strongly believe this grouping of the UDS tasks will allow researchers to probe domain-specific questions in a systematic way and across UDS versions, which has not previously been possible.

Overall, we report that domain-specific cognitive composites offer complementary information to general, or global, cognitive composites regarding cognitive abilities over time. This is particularly important for understanding the cognitive decline associated with AD, which is known to impact domains beyond memory (Balota & Duchek, 2015; Huff et al., 2015; Hutchison et al., 2010; McKay et al., 2021). There is a clear need for these domain composites, as it has been demonstrated that decreases in cognition begin years prior to AD-symptom onset and that the decline in performance may be domain-specific (Hassenstab, Monsell, et al., 2015). Evidence has also been reported demonstrating that practice effects are differentially prevalent by domain (Hassenstab, Ruvolo, et al., 2015). Domain-specific composites may also offer a unique advantage in cohorts that include individuals presenting with rarer, atypical forms of AD that are specifically characterized by their cognitive impact on the individual (Dickerson et al., 2017; Graff-Radford et al., 2021; Polsinelli & Apostolova, 2022). While our results support that the ADCS-PACC may be adequate for detection of preclinical AD individuals, it is likely that the inclusion of the MMSE makes this composite insensitive to measuring cognitive change in broader populations. Our proposed Knight-PACC is an alternative general composite that does not consider the MMSE, is sensitive to change in the preclinical stages of AD, and similarly relies on a small number of tasks, reducing participant burden. Further, the Knight-PACC provides distinct, but complementary, information to our proposed domain-specific composites, which should be deployed when researchers investigate questions regarding performance on specific cognitive domains across older adult cohorts. Taken together, we propose that supplementing analyses of cognition with the Knight-PACC—a composite sensitive to preclinical AD—and domain-specific composites, where appropriate, offer researchers the ability to curate cognitive outcomes that are well-suited to answer a wide range of questions regarding cognitive decline in aging and AD.

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