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Data and Analysis Report
Factor structure of the Harmonized Cognitive Assessment Protocol neuropsychological battery in the Health and Retirement Study

Summary

This document summarizes the data and factor analyses of Health and Retirement Study Harmonized Cognitive Assessment Protocol (HCAP). In this report I describe the data used, with a focus on the HCAP neuropsychological and mental status performance indicators (Sections 1-3) revisions (and dropping of some indicators) to those data to deal with low correlations with other cognitive data, very low response categories, and other distribution problems (Sections 4-5).

I then go on to describe the approach to psychometric modeling (factor analysis), including the description of various kinds of models estimated, criteria for assessing model fit, and additional data handling (section 6).

Beginning with section 6.4, I describe results of single factor models for *a priori* specified models involving the HCAP data. Domains hypothesized include: Orientation (ORI); Memory, immediate episodic (MIE); Memory, delayed episodic (MDE); Memory, recognition (MRE); Set shifting (SSH)[1]; Attention, speed (ASP); Language, fluency (LFL); and Visuospatial (VIS).

For all but ORI, VIS and SSH, the *a priori* models were confirmed as reasonably good models. The VIS and ORI models were both proposed as two indicator models. In both of these, a large variance indicator was included with a small variance indicator (e.g., 10 item sum from MMSE vs TICS name president; CERAD construtional praxis immediate vs MMSE copy polygons). In both cases the inclusion of the item with less variance was found to be redundant, and I am recommending retaining a single indicator to represent the domain.

For the SSH (Set Shifting) domain, I dropped the items capturing *errors* on various tests. I first proposed dropping these after looking at distributional properties and bivariable correlations (section 3). Their exclusion was confirmed in the confirmatory factor analysis models (adding them contributes little to the measurement of the SSH domain, and in fact makes it slightly less reliable).

In section 7, I move to a correlated factors model. Results of these models prompt combining SSH and ASP into a single executive function (EFX) domain, combining delayed episodic memory (MDE) and recognition memory (MRE) into a single domain and dropping immediate episodic memory (MIE).

In section 8, I report on a second-order factor model based on the final correlated factors model. in section 9, I report on the generation of factor scores using maximum likelihood estimation and the single factor models implied from the correlated factors model.

[1]The Set Shifting domain was referred to as executive functioning in earlier HRS and HCAP reports. We use Set Shifting in the unidimensional models, as we end up combining what we call set shifting (FKA executive functioning) and attention, speed domains in a combined Executive Functioning domain.

Contents

1 Data handling

1.1 File using

using `hc16hp_r_20220603.dta` from Ryan McCammon. This file had different missing value handling.

2 Selection of participants

We limited the analysis to participants with at least 1 non-missing value on the constructed HCAP measures. Before applying this restriction, there were 3496 records in the data file. After applying this restriction, there are 3347 records in the data file. We are dropping 149 (4% of 3496) participants from the psychometric data analysis.

It is worth noting that 0 participants were dropped based on this restriction but had a non-missing MMSE score. Also, 0 participants retained for the psychometric analysis had a missing value on the MMSE total score.

3 Information about analytic variables

3.1 MMSE 10 items (number of correct, 0-10)

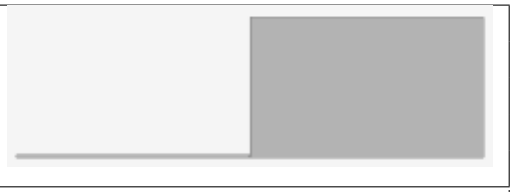
vdori1 (Orientation)

Distinct values	11		
Missing N (%)	7 (0%)		
At max N (%)	2156 (65%)		
At min N (%)	2 (0%)		
Corr(MMSE)	.78		
Mean (SD)	9.32 (1.35)	Range	[0.00 - 10.00]
skewness	-3.24	kurtosis	15.66
Range of correlation coefficients with other items			
max	.55	vdmre1 (CERAD word list recognition task (0-20))	
min	-.18	vdexf4 (Errors, Cancellation number of incorrectly marked letters)	
median	.35	IQI	[.24 - .4]

Notes:
`vdori1` captures orientation to time and place using 10 items from the MMSE. It is coded as the sum of the number of `h1rmse1-h1rmse10` that have a value of 1, with 97, 98, and 99 responses treated as missing values. Persons who do not have at least 1 item in the list that has a response of 1 or 5 are treated as missing. This sum has a Cronbach's alpha of 0.632.

3.2 TICS name president correct (0,1)

vdori2 (Orientation)

Distinct values	2		
Missing N (%)	128 (4%)		
At max N (%)	3157 (98%)		
At min N (%)	62 (2%)		
Corr(MMSE)	.32		
Range of correlation coefficients with other items			
max	.32	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	-8.5e-02	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.14	IQI	[.11 - .17]

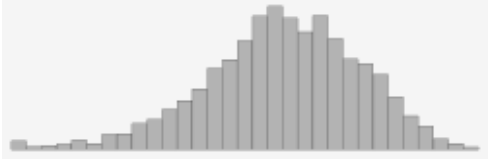
Notes:
`vdori2` identifies whether the respondent can correctly identify the President. It is a simple recode of the TICS name the President item. Responses of 7, 8 , 9 are treated as missing.

Cautionary statement on distribution. This categorical variable (`vdori2`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdori2` as a categorical variable.

vdori2	Count	Propor~n
0	62	.0192606
1	3,157	.9807394

3.3 CERAD word list immediate sum of 3 trials (0-30)

vdmie1 (Memory, immediate episodic)

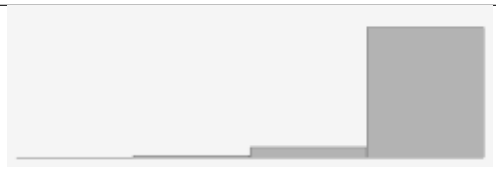
Distinct values	31		
Missing N (%)	9 (0%)		
At max N (%)	5 (0%)		
At min N (%)	17 (1%)		
Corr(MMSE)	.62		
Mean (SD)	17.42 (5.23)	Range	[0.00 - 30.00]
skewness	-0.47	kurtosis	3.31
Range of correlation coefficients with other items			
max	.8	vdmde1 (CERAD word list delayed (0-10))	
min	-.14	vdexf4 (Errors, Cancellation number of incorrectly marked letters)	
median	.4	IQI	[.23 - .49]

Notes:

`vdmie1` is the sum of three learning trials on the CERAD 10 item word list. Coded values of 97, 98, and 99 are treated as missing values. Persons who do not have at least 1 item in the list that has a response between 0 and 10 are treated as missing. This sum has a Cronbach's alpha of 0.892.

3.4 MMSE 3 word recognition (0-3)

vdmie2 (Memory, immediate episodic)

Distinct values	4		
Missing N (%)	13 (0%)		
At max N (%)	3036 (91%)		
At min N (%)	5 (0%)		
Corr(MMSE)	.45		
Range of correlation coefficients with other items			
max	.29	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	-.11	vdexf6 (Errors, fluency)	
median	.18	IQI	[.14 - .21]

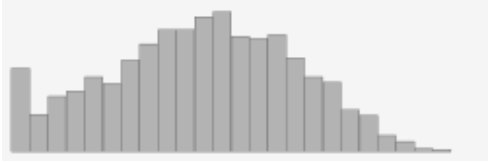
Notes:
`vdmie2` represents the number of words immediately recalled on a 3 word list. It is the first registration trial of the MMSE. It is simply a recoded version of the original variable h1rmse11t1, with responses of 97, 98 , 99 treated as missing.

Cautionary statement on distribution. This categorical variable (`vdmie2`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdmie2` as a categorical variable.

vdmie2	Count	Propor~n
0	5	.0014997
1	51	.0152969
2	242	.0725855
3	3,036	.9106179

3.5 Logical memory immediate (0-25)

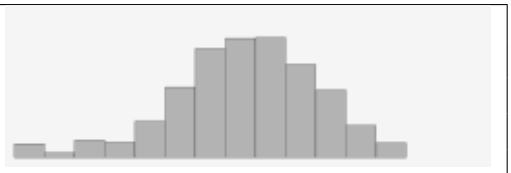
vdmie3 (Memory, immediate episodic)

Distinct values	24		
Missing N (%)	41 (1%)		
At max N (%)	4 (0%)		
At min N (%)	154 (5%)		
Corr(MMSE)	.52		
Mean (SD)	9.83 (5.10)	Range	[0.00 - 23.00]
skewness	-0.08	kurtosis	2.33
Range of correlation coefficients with other items			
max	.84	vdmde2 (Logical memory delayed (0-25))	
min	-.11	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.36	IQI	[.19 - .47]

Notes:
`vdmie3` is the number correct on the WMS-IV Logical Memory I immediate story recall task. It is simply a renaming of ‘.

3.6 Brave man immediate (0-12)

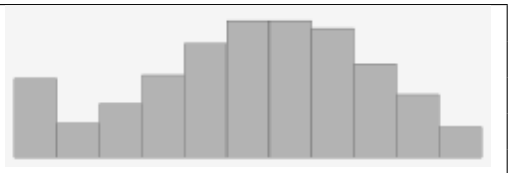
vdmie4 (Memory, immediate episodic)

Distinct values	13		
Missing N (%)	15 (0%)		
At max N (%)	69 (2%)		
At min N (%)	65 (2%)		
Corr(MMSE)	.5		
Mean (SD)	7.11 (2.44)	Range	[0.00 - 12.00]
skewness	-0.53	kurtosis	3.40
Range of correlation coefficients with other items			
max	.59	vdmde5 (Brave man delayed score (0-12))	
min	-.13	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.29	IQI	[.18 - .38]

Notes:
This item `vdmie4` is simply a renaming of h1rbmimmscore. No accomodation for missing or other non-response codes has been used.

3.7 CERAD word list delayed (0-10)

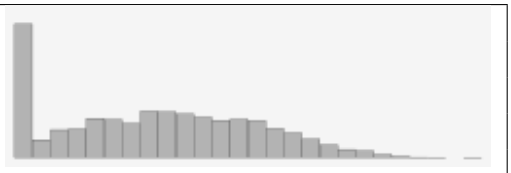
vdmde1 (Memory, delayed episodic)

Distinct values	11		
Missing N (%)	16 (0%)		
At max N (%)	107 (3%)		
At min N (%)	276 (8%)		
Corr(MMSE)	.57		
Mean (SD)	5.11 (2.65)	Range	[0.00 - 10.00]
skewness	-0.28	kurtosis	2.35
Range of correlation coefficients with other items			
max	.8	vdmie1 (CERAD word list immediate sum of 3 trials (0-30))	
min	-.12	vdexf6 (Errors, fluency)	
median	.39	IQI	[.21 - .51]

Notes:
`vdmde1` is the number correct on the CERAD delayed 10 word recall task. It is simply a renaming of h1rwldelscore.

3.8 Logical memory delayed (0-25)

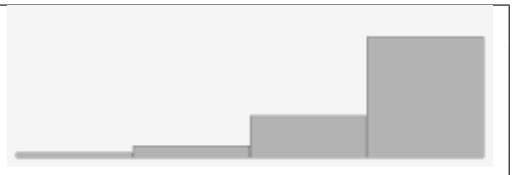
vdmde2 (Memory, delayed episodic)

Distinct values	25		
Missing N (%)	238 (7%)		
At max N (%)	1 (0%)		
At min N (%)	580 (19%)		
Corr(MMSE)	.48		
Mean (SD)	7.34 (5.44)	Range	[0.00 - 25.00]
skewness	0.22	kurtosis	2.09
Range of correlation coefficients with other items			
max	.84	vdmie3 (Logical memory immediate (0-25))	
min	-.1	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.36	IQI	[.16 - .48]

Notes:
`vdmde2` is the number correct on the WMS-IV Logical Memory I delayed story recall task. There are 25 story points to be recalled, and the source variable is the sum of these that are recalled. `'var` is basically a renaming of h1rlmdelscore. **Special handling:** if the HRS variable `h1rlmdeltest` has a value of 9 (imputed) the created variable `vdmde2` is set to missing.

3.9 MMSE 3 word delayed recall (0-3)

vdmde3 (Memory, delayed episodic)

Distinct values	4		
Missing N (%)	60 (2%)		
At max N (%)	2218 (67%)		
At min N (%)	87 (3%)		
Corr(MMSE)	.57		
Range of correlation coefficients with other items			
max	.51	vdmde1 (CERAD word list delayed (0-10))	
min	-.12	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.3	IQI	[.18 - .38]

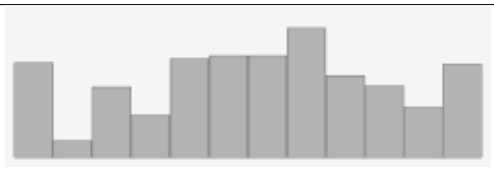
Notes:
`vdmde3` represents the number of words recalled after a delay on the MMSE 3 word list. It is simply a recoded version of the original variable h1rmse13, with responses of 97, 98 , 99 treated as missing.

Cautionary statement on distribution. This categorical variable (`vdmde3`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdmde3` as a categorical variable.

vdmde3	Count	Propor~n
0	87	.0264679
1	217	.0660176
2	765	.232735
3	2,218	.6747794

3.10 CERAD constructional praxis delayed (0-11)

vdmde4 (Memory, delayed episodic)

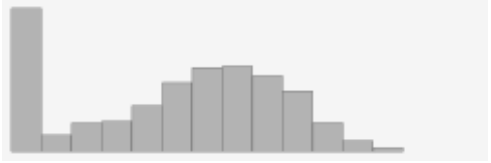
Distinct values	12		
Missing N (%)	42 (1%)		
At max N (%)	324 (10%)		
At min N (%)	328 (10%)		
Corr(MMSE)	.52		
Mean (SD)	5.81 (3.25)	Range	[0.00 - 11.00]
skewness	-0.17	kurtosis	2.16
Range of correlation coefficients with other items			
max	.59	vdvis1 (CERAD Constructional praxis)	
min	-.11	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.39	IQI	[.19 - .47]

Notes:

`vdmde4` is the number correct shapes drawn from memory after a delay on the CERAD Constructional Praxis task. This is a delayed recall of the geometric shapes drawn in the test of CERAD Constructional Praxis (immediate) task. Respondents are asked to draw the shapes from earlier in the interview to the best of their memory. It is simply a renaming of h1rcpdelscore.

3.11 Brave man delayed score (0-12)

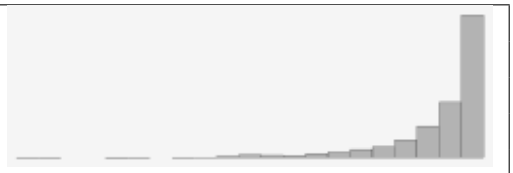
vdmde5 (Memory, delayed episodic)

Distinct values	13		
Missing N (%)	15 (0%)		
At max N (%)	19 (1%)		
At min N (%)	698 (21%)		
Corr(MMSE)	.41		
Mean (SD)	4.98 (3.35)	Range	[0.00 - 12.00]
skewness	-0.22	kurtosis	1.88
Range of correlation coefficients with other items			
max	.59	vdmie4 (Brave man immediate (0-12))	
min	-9.3e-02	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.3	IQI	[.14 - .4]

Notes:
This item `vdmde5` is simply a renaming of h1rbmdelscore. No accomodation for missing or other non-response codes has been used.

3.12 CERAD word list recognition task (0-20)

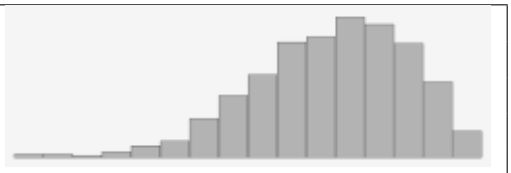
vdmre1 (Memory, recognition)

Distinct values	18		
Missing N (%)	24 (1%)		
At max N (%)	1654 (50%)		
At min N (%)	2 (0%)		
Corr(MMSE)	.58		
Mean (SD)	18.53 (2.36)	Range	[0.00 - 20.00]
skewness	-2.54	kurtosis	11.51
Range of correlation coefficients with other items			
max	.62	vdmde1 (CERAD word list delayed (0-10))	
min	-.16	vdexf4 (Errors, Cancellation number of incorrectly marked letters)	
median	.31	IQI	[.19 - .42]

Notes:
`vdmre1` is the number correct *yes* and number correct *no* on the CERAD delayed recognition task. This two item sum has an internal consistency reliability (alpha) coefficient of 0.36.

3.13 Logical memory recognition (0-15)

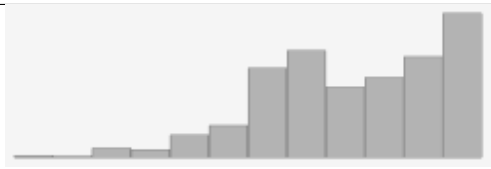
vdmre2 (Memory, recognition)

Distinct values	16		
Missing N (%)	108 (3%)		
At max N (%)	90 (3%)		
At min N (%)	12 (0%)		
Corr(MMSE)	.45		
Mean (SD)	10.29 (2.72)	Range	[0.00 - 15.00]
skewness	-0.66	kurtosis	3.52
Range of correlation coefficients with other items			
max	.62	vdmie3 (Logical memory immediate (0-25))	
min	-9.6e-02	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.3	IQI	[.17 - .38]

Notes:
`vdmre2` is the number correct on the WMS-IV Logical Memory I story recognition task. It is simply a renaming of `h1rlmrecscore` but missing codes (97, 98, 99) are treated as missing.

3.14 CERAD Constructional praxis

vdvis1 (Visuospatial)

Distinct values	12		
Missing N (%)	39 (1%)		
At max N (%)	715 (22%)		
At min N (%)	11 (0%)		
Corr(MMSE)	.48		
Mean (SD)	8.18 (2.33)	Range	[0.00 - 11.00]
skewness	-0.59	kurtosis	2.84
Range of correlation coefficients with other items			
max	.59	vdmde4 (CERAD constructional praxis delayed (0-11))	
min	-.15	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.28	IQI	[.18 - .37]

Notes:
`vdvis1` is CERAD constructional praxis immediate. The summary variable is a simple recode (for missing, other non-response codes as system missing) version of `h1rcpimmscore`

3.15 MMSE copy polygons

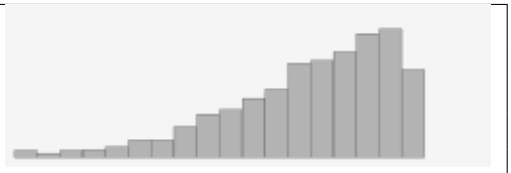
vdvis2 (Visuospatial)

Distinct values	2		
Missing N (%)	63 (2%)		
At max N (%)	1752 (53%)		
At min N (%)	1532 (47%)		
Corr(MMSE)	.42		
Range of correlation coefficients with other items			
max	.39	vdvis1 (CERAD Constructional praxis)	
min	-9.5e-02	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.19	IQI	[.12 - .24]

Notes:
`vdvis2` is the copy polygons item from the MMSE. It is based only on `h1rmse22`, with missing codes excluded (97, 98, 99).

3.16 Raven's progressive matrices

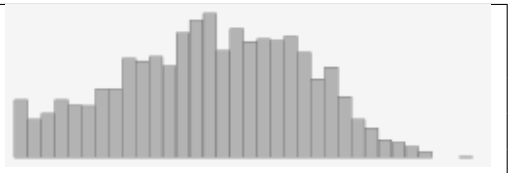
vdexf1 (Executive function)

Distinct values	18		
Missing N (%)	60 (2%)		
At max N (%)	301 (9%)		
At min N (%)	25 (1%)		
Corr(MMSE)	.57		
Mean (SD)	12.40 (3.69)	Range	[0.00 - 17.00]
skewness	-0.98	kurtosis	3.63
Range of correlation coefficients with other items			
max	.61	vdasp1 (Symbol Digit Modalities Test score)	
min	-.19	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.37	IQI	[.22 - .48]

Notes:
`vdexf1` is the score from Raven's progressive matrices. It is based only on `h1rrvscore`

3.17 Trails B time (observed 32-300 seconds)

vdexf2 (Executive function)

Distinct values	259		
Missing N (%)	520 (16%)		
At max N (%)	0 (0%)		
At min N (%)	29 (1%)		
Corr(MMSE)	.42		
Mean (SD)	0.17 (0.08)	Range	[0.00 - 0.39]
skewness	-0.14	kurtosis	2.36
Range of correlation coefficients with other items			
max	.67	vdasp1 (Symbol Digit Modalities Test score)	
min	-.14	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.28	IQI	[.13 - .39]

Notes:
`vdexf2` is

$$1 - \frac{\log(T_B)}{\log(300)}$$

where T_B is the number of seconds needed to complete the Trails B task, and 300 is the ceiling on the number of seconds allowed to complete the task. The resulting score is 0 when the participant took 300 seconds to complete the task (or did not complete the task in 300 seconds and was assigned a score of 300), and 1 when the task was completed in 0 seconds (unsurprisingly, we do not observe scores of 1). The *direction* of this log transformed score is such that higher scores (approaching 1) are better and indicate faster performance. Missing codes (i.e., not between 0 and 300 on the source variable(s)) are treated as missing. NB the reverse transformation is $300^{(1-B)}$ where B is the log transformed, log-normalized complement number of seconds to complete the Trails B task.

3.18 Errors, Cancellation number of missed letters

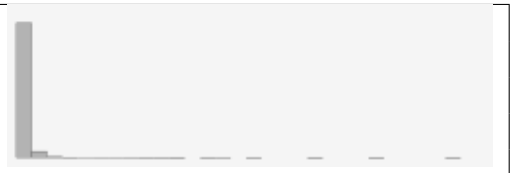
vdexf3 (Executive function)

Distinct values	41		
Missing N (%)	151 (5%)		
At max N (%)	1 (0%)		
At min N (%)	194 (6%)		
Corr(MMSE)	-8.9e-02		
Mean (SD)	5.06 (4.51)	Range	[0.00 - 54.00]
skewness	3.34	kurtosis	24.83
Range of correlation coefficients with other items			
max	.11	vdexf5 (Errors, Symbol Digit Modalities Test)	
min	-.15	vdexf1 (Raven's progressive matrices)	
median	-6.9e-02	IQI	[-8.7e-02 - -3.6e-02]

Notes:
This item `vdexf3` is simply a renaming of h1rlcmissed. The source item derives from the ELSA study. No accomodation for missing or other non-response codes has been used.

3.19 Errors, Cancellation number of incorrectly marked letters

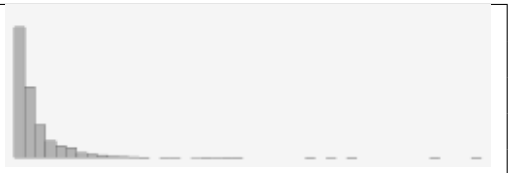
vdexf4 (Executive function)

Distinct values	17		
Missing N (%)	150 (4%)		
At max N (%)	1 (0%)		
At min N (%)	2988 (93%)		
Corr(MMSE)	-.2		
Mean (SD)	0.18 (1.19)	Range	[0.00 - 28.00]
skewness	12.36	kurtosis	200.98
Range of correlation coefficients with other items			
max	.1	vdexf3 (Errors, Cancellation number of missed letters)	
min	-.22	vdasp5 (Letter cancellation)	
median	-9.3e-02	IQI	[-.13 - -5.9e-02]

Notes:
This item `vdexf4` is simply a renaming of h1rlcscincorr. The source item derives from the ELSA study. No accomodation for missing or other non-response codes has been used.

3.20 Errors, Symbol Digit Modalities Test

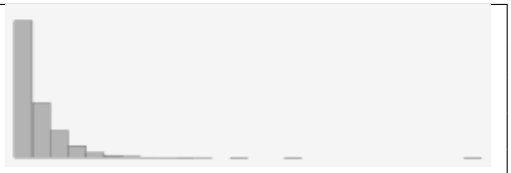
vdexf5 (Executive function)

Distinct values	25		
Missing N (%)	175 (5%)		
At max N (%)	1 (0%)		
At min N (%)	1434 (45%)		
Corr(MMSE)	-.19		
Mean (SD)	1.47 (2.59)	Range	[0.00 - 44.00]
skewness	5.79	kurtosis	65.53
Range of correlation coefficients with other items			
max	.11	vdexf3 (Errors, Cancellation number of missed letters)	
min	-.26	vdasp1 (Symbol Digit Modalities Test score)	
median	-.1	IQI	[-.14 - -6.7e-02]

Notes:
This item `vdexf5` is simply a renaming of h1rsdmerr with the additional restriction that values in `h1rsdmerr are not carried to \verb`vdexf5+ if a missing value code (997, 998, 999). **ISSUE:** Note that according to the *2016 Harmonized Cognitive Assessment Protocol (HCAP) Study Protocol Summary*, the SDMT score is the number of correct pairings minus any mistakes or skips. If that is accurate, then the information encoded in `vdexf5` is also contained in the SDMT score (in Attention Speed domain). This lack of independence creates a logical dependency that will violate the local independence assumption of factor analysis (and item response theory) models.

3.21 Errors, fluency

vdexf6 (Executive function)

Distinct values	14		
Missing N (%)	26 (1%)		
At max N (%)	1 (0%)		
At min N (%)	1891 (57%)		
Corr(MMSE)	-.11		
Mean (SD)	0.82 (1.36)	Range	[0.00 - 25.00]
skewness	4.09	kurtosis	43.54
Range of correlation coefficients with other items			
max	1.2e-02	vdexf5 (Errors, Symbol Digit Modalities Test)	
min	-.12	vdmde1 (CERAD word list delayed (0-10))	
median	-6.2e-02	IQI	[-8.3e-02 - -3.4e-02]

Notes:
This item `vdexf6` is a renaming of `h1rafnumincorr`. Also, if the checkpoint item (`h1rafincorr` *IWER: DID YOU RECORD ANY INCORRECT NAMES?*) has a value of 5 (no) then zero is imputed for the number of incorrection mentions. No accomodation for missing or other non-response codes has been used.

3.22 HRS Number Series

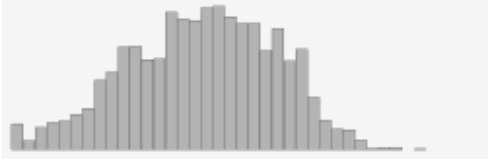
vdexf7 (Executive function)

Distinct values	29		
Missing N (%)	578 (17%)		
At max N (%)	100 (4%)		
At min N (%)	20 (1%)		
Corr(MMSE)	.45		
Mean (SD)	522.45 (31.40)	Range	[409.00 - 584.00]
skewness	-0.79	kurtosis	4.66
Range of correlation coefficients with other items			
max	.59	vdexf1 (Raven's progressive matrices)	
min	-.14	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.26	IQI	[.11 - .36]

Notes:
This is from the *2016 Harmonized Cognitive Assessment Protocol (HCAP) Study Protocol Summary*: Developed for the HRS, this section evaluates Respondents ability for numeric reasoning by presenting a series of 6 individual series of numbers, where one or two numbers in the series is missing. The Respondent is asked to take as much time as s/he needs, with the help of scrap paper and a pencil, to identify the missing number/s. This test is a block-adaptive test. Respondents are given a set of three number series questions of varying difficulty to first complete. Based on the number of correct responses in this first set of three (score Range = 0 to 4), Respondents are then assigned to a second set of three questions, for which the difficulty level is based on the number correct on the first set. The HRS uses two versions of the Number Series questions and respondents are assigned to the version that was not done in the previous wave. For HRS-HCAP, Respondents were assigned to the Number Series that was not assigned in the 2016 Core interview. If a Respondent was not able to do the Number Series section in the 2016 Core interview (not able to do practice questions, was too confused), then they were skipped out of this section. In creating `vdexf7`, missing codes (codes 996 and higher) on the source variable `h1rnsscore` are treated as system missing.

3.23 Symbol Digit Modalities Test score

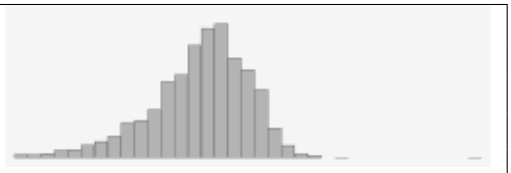
vdasp1 (Attention, speed)

Distinct values	68		
Missing N (%)	179 (5%)		
At max N (%)	1 (0%)		
At min N (%)	14 (0%)		
Corr(MMSE)	.59		
Mean (SD)	32.49 (12.52)	Range	[0.00 - 71.00]
skewness	-0.22	kurtosis	2.56
Range of correlation coefficients with other items			
max	.73	vdasp2 (Trails A)	
min	-.26	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.4	IQI	[.19 - .53]

Notes:
This item `vdasp1` is simply a renaming of h1rsdmscore. No accomodation for missing or other non-response codes has been used. Note that according to the *2016 Harmonized Cognitive Assessment Protocol (HCAP) Study Protocol Summary*, the SDMT score is the number of correct pairings minus any mistakes or skips. Watch out for logical dependency or local dependence with SDMT errors (in executive function domain).

3.24 Trails A

vdasp2 (Attention, speed)

Distinct values	190		
Missing N (%)	137 (4%)		
At max N (%)	1 (0%)		
At min N (%)	5 (0%)		
Corr(MMSE)	.56		
Mean (SD)	0.32 (0.09)	Range	[0.00 - 0.81]
skewness	-0.71	kurtosis	4.04
Range of correlation coefficients with other items			
max	.73	vdasp1 (Symbol Digit Modalities Test score)	
min	-.15	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.35	IQI	[.19 - .45]

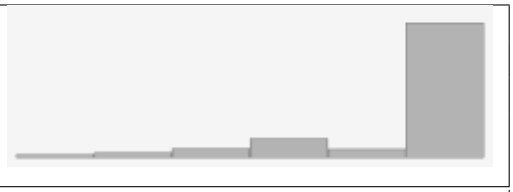
Notes:
`vdasp2` is

$$1 - \frac{\log(T_A)}{\log(300)}$$

where T_A is the number of seconds needed to complete the Trails A task, and 300 is the ceiling on the number of seconds allowed to complete the task. The resulting score is 0 when the participant took 300 seconds to complete the task (or did not complete the task in 300 seconds and was assigned a score of 300), and 1 when the task was completed in 0 seconds (unsurprisingly, we do not observe scores of 1). The *direction* of this log transformed score is such that higher scores (approaching 1) are better and indicate faster performance. Missing codes (i.e., not between 0 and 300 on the source variables) are treated as missing.

3.25 MMSE spell world backwards

vdasp3 (Attention, speed)

Distinct values	6		
Missing N (%)	171 (5%)		
At max N (%)	2390 (75%)		
At min N (%)	52 (2%)		
Corr(MMSE)	.69		
Range of correlation coefficients with other items			
max	.39	vdexf1 (Raven's progressive matrices)	
min	-.15	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.26	IQI	[.18 - .3]

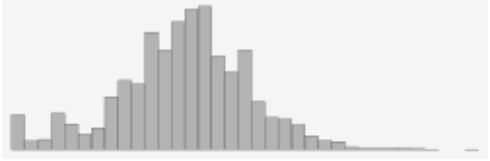
Notes:
vdasp3 is the sum of 5 recorded responses to the MMSE spell world backwards task, recored with five correct/incorrect indicators. Only correct responses are summed (code 1 on source variables). At least 1 of the five indicators must have a non-missing code (not missing or 96, 97, 98, 99) to get the 0-5 score on vdasp3.

Cautionary statement on distribution. This categorical variable (vdasp3) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating vdasp3 as a categorical variable.

vdasp3	Count	Propor~n
0	52	.0163728
1	87	.0273929
2	159	.050063
3	338	.1064232
4	150	.0472292
5	2,390	.7525189

3.26 Backwards counting

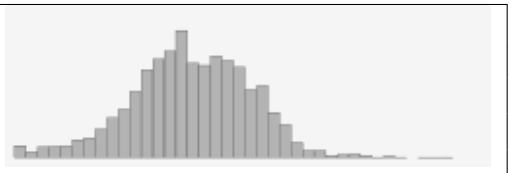
vdasp4 (Attention, speed)

Distinct values	70		
Missing N (%)	47 (1%)		
At max N (%)	1 (0%)		
At min N (%)	62 (2%)		
Corr(MMSE)	.56		
Mean (SD)	29.31 (11.40)	Range	[0.00 - 80.00]
skewness	-0.20	kurtosis	3.52
Range of correlation coefficients with other items			
max	.61	vdasp1 (Symbol Digit Modalities Test score)	
min	-.16	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.33	IQI	[.21 - .42]

Notes:
This is from the *2016 Harmonized Cognitive Assessment Protocol (HCAP) Study Protocol Summary*: This test assesses speed and attention and is derived from the Backward Count measure in the MIDUS Study. Respondents are asked to begin at 100 and to count backwards as fast as possible. They are given 30 seconds and the number they reach and number of errors are recorded.

3.27 Letter cancellation

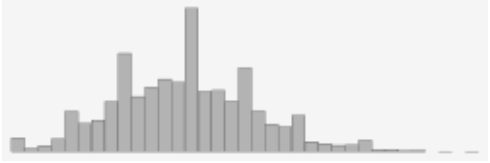
vdasp5 (Attention, speed)

Distinct values	37		
Missing N (%)	150 (4%)		
At max N (%)	1 (0%)		
At min N (%)	27 (1%)		
Corr(MMSE)	.5		
Mean (SD)	14.78 (5.27)	Range	[0.00 - 37.00]
skewness	-0.14	kurtosis	3.38
Range of correlation coefficients with other items			
max	.68	vdasp1 (Symbol Digit Modalities Test score)	
min	-.22	vdexf4 (Errors, Cancellation number of incorrectly marked letters)	
median	.31	IQI	[.18 - .42]

Notes:
This is from the *2016 Harmonized Cognitive Assessment Protocol (HCAP) Study Protocol Summary*: This test has been included in ELSA and assesses attention and speed. Respondents are given a paper with a large grid of letters and are asked to scan the grid as quickly as possible in a minute and to cross out as many *P* and *W* letters as they can in that time. This variable (`vdasp5`, renamed and otherwise unmolested version of `h1rlcscore`) is the number of correctly crossed-out letters.

3.28 Category fluency (animals)

vdlfl1 (Language, fluency)

Distinct values	41		
Missing N (%)	2 (0%)		
At max N (%)	1 (0%)		
At min N (%)	28 (1%)		
Corr(MMSE)	.51		
Mean (SD)	15.97 (6.57)	Range	[0.00 - 43.00]
skewness	0.26	kurtosis	3.12
Range of correlation coefficients with other items			
max	.54	vdasp1 (Symbol Digit Modalities Test score)	
min	-.1	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.38	IQI	[.2 - .48]

Notes:
The created variable `vdlfl1` is simply a copied or renamed version of `h1rafscore`. No handling of missing response codes was implemented (none were observed).

3.29 Naming 2 items HRS TICS scissors, cactus

vdlfl2 (Language, fluency)

Distinct values	3		
Missing N (%)	13 (0%)		
At max N (%)	3047 (91%)		
At min N (%)	21 (1%)		
Corr(MMSE)	.46		
Range of correlation coefficients with other items			
max	.36	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	-8.7e-02	vdexf5 (Errors, Symbol Digit Modalities Test)	
median	.23	IQI	[.17 - .28]

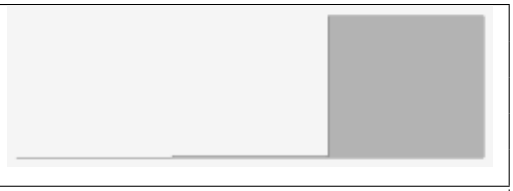
Notes:
This is the number of correct responses to the HRS TICS items name two objects (scisssor, cactus). Respondents must have at least 1 non-missing (not system missing, not 7, 8, 9) to get a score.

Cautionary statement on distribution. This categorical variable (`vdlfl2`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdlfl2` as a categorical variable.

vdlfl2	Count	Propor~n
0	21	.0062987
1	266	.079784
2	3,047	.9139172

3.30 Naming 2 items MMSE

vdlfl3 (Language, fluency)

Distinct values	3		
Missing N (%)	9 (0%)		
At max N (%)	3298 (99%)		
At min N (%)	5 (0%)		
Corr(MMSE)	.31		
Range of correlation coefficients with other items			
max	.24	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	-4.9e-02	vdexf6 (Errors, fluency)	
median	.12	IQI	[8.2e-02 - .14]

Notes:
This is the number of correct responses to the two MMSE name objects questions. Respondents must have at least 1 non-missing (not system missing, not 97, 98, 99) to get a score.

Cautionary statement on distribution. This categorical variable (`vdlfl3`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdlfl3` as a categorical variable.

vdlfl3	Count	Propor~n
0	5	.0014979
1	35	.0104853
2	3,298	.9880168

3.31 MMSE write a sentence

vdlfl4 (Language, fluency)

Distinct values	2		
Missing N (%)	111 (3%)		
At max N (%)	3023 (93%)		
At min N (%)	213 (7%)		
Corr(MMSE)	.39		
Range of correlation coefficients with other items			
max	.24	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	-.13	vdexf4 (Errors, Cancellation number of incorrectly marked letters)	
median	.17	IQI	[.13 - .19]

Notes:
The variable vdlfl4 is an indicator as to whether h1rmse21 is scored as correct (value 1). Missing codes (any value coded 96 or higher) are treated as missing

3.32 MMSE read and follow command

vdlfl5 (Language, fluency)

Distinct values	2		
Missing N (%)	23 (1%)		
At max N (%)	3195 (96%)		
At min N (%)	129 (4%)		
Corr(MMSE)	.34		
Range of correlation coefficients with other items			
max	.22	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	-.11	vdexf4 (Errors, Cancellation number of incorrectly marked letters)	
median	.12	IQI	[9.0e-02 - .16]

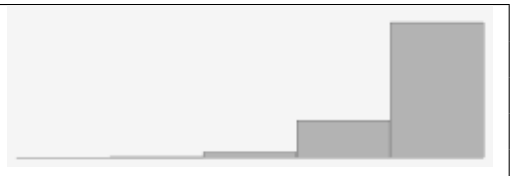
Notes:
The variable vdlfl5 is an indicator as to whether h1rmse17 is scored as correct (value 1). Missing codes (any value coded 96 or higher) are treated as missing

Cautionary statement on distribution. This categorical variable (`vdlfl5`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdlfl5` as a categorical variable.

```
vdlfl5   Count   Propor~n
     0     129   .0388087
     1   3,195   .9611914
```

3.33 1066 object naming

vdlfl6 (Language, fluency)

Distinct values	5		
Missing N (%)	6 (0%)		
At max N (%)	2522 (75%)		
At min N (%)	7 (0%)		
Corr(MMSE)	.46		
Range of correlation coefficients with other items			
max	.35	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	-.12	vdexf4 (Errors, Cancellation number of incorrectly marked letters)	
median	.23	IQI	[.18 - .26]

Notes:
The created variable `vdlfl1` is simply a copied or renamed version of `h1r1066score`. No handling of missing response codes was implemented (none were observed).

Cautionary statement on distribution. This categorical variable (`vdlfl6`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdlfl6` as a categorical variable.

vdlfl6	Count	Propor~n
0	7	.0020952
1	12	.0035917
2	102	.0305298
3	698	.2089195
4	2,522	.7548638

4 Refine variables

4.1 Drop Errors

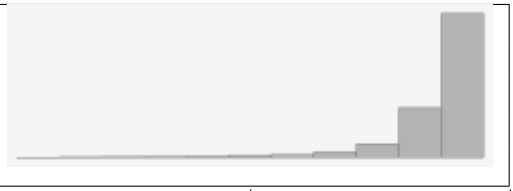
- Errors items have low correlations with each other and do not likely measure a single trait
- Some errors items have logically-induced correlations with correct items, violating local indendence assumptions
- Therefore, they are dropped from consideration in psychometric models

4.2 Recode categorical items with sparse cells

5 Information about analytic variables - Updated following analytic variable recoding

5.1 MMSE 10 items (number of correct, 0-10)

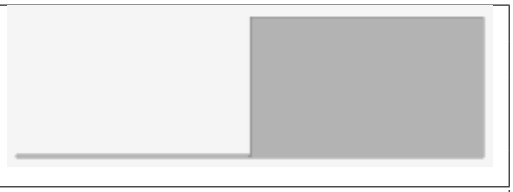
vdori1 (Orientation)

Distinct values	11		
Missing N (%)	7 (0%)		
At max N (%)	2156 (65%)		
At min N (%)	2 (0%)		
Corr(MMSE)	.78		
Mean (SD)	9.32 (1.35)	Range	[0.00 - 10.00]
skewness	-3.24	kurtosis	15.66
Range of correlation coefficients with other items			
max	.55	vdmre1 (CERAD word list recognition task (0-20))	
min	.21	vdvis2 (MMSE copy polygons)	
median	.35	IQI	[.28 - .4]

Notes:
`vdori1` captures orientation to time and place using 10 items from the MMSE. It is coded as the sum of the number of `h1rmse1-h1rmse10` that have a value of 1, with 97, 98, and 99 responses treated as missing values. Persons who do not have at least 1 item in the list that has a response of 1 or 5 are treated as missing. This sum has a Cronbach's alpha of 0.632.

5.2 TICS name president correct (0,1)

vdori2 (Orientation)

Distinct values	2		
Missing N (%)	128 (4%)		
At max N (%)	3157 (98%)		
At min N (%)	62 (2%)		
Corr(MMSE)	.32		
Range of correlation coefficients with other items			
max	.32	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	6.6e-02	vdexf2 (Trails B time (observed 32-300 seconds))	
median	.14	IQI	[.11 - .17]

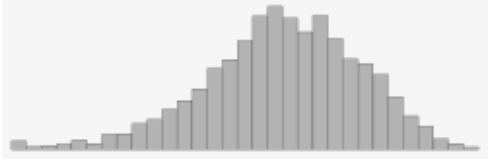
Notes:
`vdori2` identifies whether the respondent can correctly identify the President. It is a simple recode of the TICS name the President item. Responses of 7, 8 , 9 are treated as missing.

Cautionary statement on distribution. This categorical variable (`vdori2`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdori2` as a categorical variable.

vdori2	Count	Propor~n
0	62	.0192606
1	3,157	.9807394

5.3 CERAD word list immediate sum of 3 trials (0-30)

vdmie1 (Memory, immediate episodic)

Distinct values	31		
Missing N (%)	9 (0%)		
At max N (%)	5 (0%)		
At min N (%)	17 (1%)		
Corr(MMSE)	.62		
Mean (SD)	17.42 (5.23)	Range	[0.00 - 30.00]
skewness	-0.47	kurtosis	3.31
Range of correlation coefficients with other items			
max	.8	vdmde1 (CERAD word list delayed (0-10))	
min	.15	vdlfl5 (MMSE read and follow command)	
median	.43	IQI	[.28 - .51]

Notes:

`vdmie1` is the sum of three learning trials on the CERAD 10 item word list. Coded values of 97, 98, and 99 are treated as missing values. Persons who do not have at least 1 item in the list that has a response between 0 and 10 are treated as missing. This sum has a Cronbach's alpha of 0.892.

5.4 MMSE 3 word recognition (0-3)

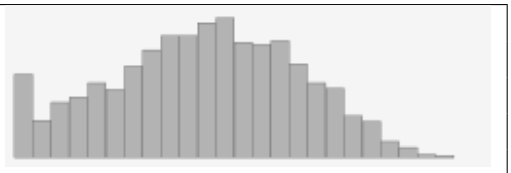
vdmie2 (Memory, immediate episodic)

Distinct values	2		
Missing N (%)	13 (0%)		
At max N (%)	3036 (91%)		
At min N (%)	298 (9%)		
Corr(MMSE)	.4		
Range of correlation coefficients with other items			
max	.26	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	8.8e-02	vdexf7 (HRS Number Series)	
median	.17	IQI	[.14 - .2]

Notes:
`vdmie2` represents the number of words immediately recalled on a 3 word list. It is the first registration trial of the MMSE. It is simply a recoded version of the original variable h1rmse11t1, with responses of 97, 98 , 99 treated as missing. To address maldistribution issues, observed values of 0, 1 and 2 are collapsed, so the analytic variable vdmie2 is 1 if all are correct, otherwise 0 or missing. (Note that the histogram above does not reflect this recoding.)

5.5 Logical memory immediate (0-25)

vdmie3 (Memory, immediate episodic)

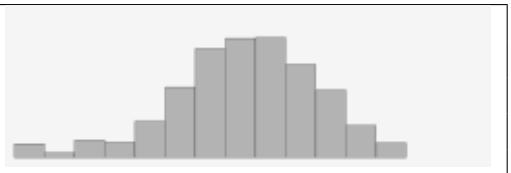
Distinct values	24		
Missing N (%)	41 (1%)		
At max N (%)	4 (0%)		
At min N (%)	154 (5%)		
Corr(MMSE)	.52		
Mean (SD)	9.83 (5.10)	Range	[0.00 - 23.00]
skewness	-0.08	kurtosis	2.33
Range of correlation coefficients with other items			
max	.84	vdmde2 (Logical memory delayed (0-25))	
min	.13	vdlfl3 (Naming 2 items MMSE)	
median	.38	IQI	[.28 - .47]

Notes:

`vdmie3` is the number correct on the WMS-IV Logical Memory I immediate story recall task. It is simply a renaming of ‘.

5.6 Brave man immediate (0-12)

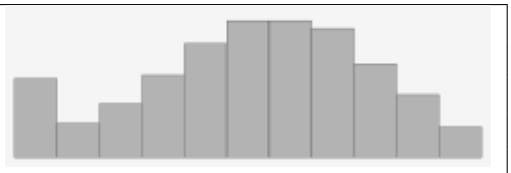
vdmie4 (Memory, immediate episodic)

Distinct values	13		
Missing N (%)	15 (0%)		
At max N (%)	69 (2%)		
At min N (%)	65 (2%)		
Corr(MMSE)	.5		
Mean (SD)	7.11 (2.44)	Range	[0.00 - 12.00]
skewness	-0.53	kurtosis	3.40
Range of correlation coefficients with other items			
max	.59	vdmde5 (Brave man delayed score (0-12))	
min	.15	vdlfl3 (Naming 2 items MMSE)	
median	.32	IQI	[.23 - .39]

Notes:
This item `vdmie4` is simply a renaming of h1rbmimmscore. No accomodation for missing or other non-response codes has been used.

5.7 CERAD word list delayed (0-10)

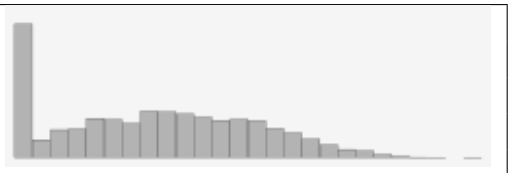
vdmde1 (Memory, delayed episodic)

Distinct values	11		
Missing N (%)	16 (0%)		
At max N (%)	107 (3%)		
At min N (%)	276 (8%)		
Corr(MMSE)	.57		
Mean (SD)	5.11 (2.65)	Range	[0.00 - 10.00]
skewness	-0.28	kurtosis	2.35
Range of correlation coefficients with other items			
max	.8	vdmie1 (CERAD word list immediate sum of 3 trials (0-30))	
min	.12	vdlfl5 (MMSE read and follow command)	
median	.42	IQI	[.26 - .51]

Notes:
`vdmde1` is the number correct on the CERAD delayed 10 word recall task. It is simply a renaming of h1rwldelscore.

5.8 Logical memory delayed (0-25)

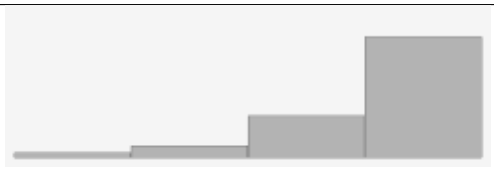
vdmde2 (Memory, delayed episodic)

Distinct values	25		
Missing N (%)	238 (7%)		
At max N (%)	1 (0%)		
At min N (%)	580 (19%)		
Corr(MMSE)	.48		
Mean (SD)	7.34 (5.44)	Range	[0.00 - 25.00]
skewness	0.22	kurtosis	2.09
Range of correlation coefficients with other items			
max	.84	vdmie3 (Logical memory immediate (0-25))	
min	9.8e-02	vdlfl3 (Naming 2 items MMSE)	
median	.37	IQI	[.23 - .49]

Notes:
`vdmde2` is the number correct on the WMS-IV Logical Memory I delayed story recall task. There are 25 story points to be recalled, and the source variable is the sum of these that are recalled. `'var` is basically a renaming of h1rlmdelscore. **Special handling:** if the HRS variable `h1rlmdeltest` has a value of 9 (imputed) the created variable `vdmde2` is set to missing.

5.9 MMSE 3 word delayed recall (0-3)

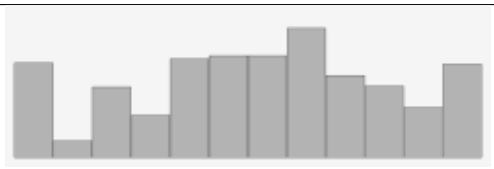
vdmde3 (Memory, delayed episodic)

Distinct values	2		
Missing N (%)	60 (2%)		
At max N (%)	2983 (91%)		
At min N (%)	304 (9%)		
Corr(MMSE)	.47		
Range of correlation coefficients with other items			
max	.43	vdmre1 (CERAD word list recognition task (0-20))	
min	7.7e-02	vdlfl4 (MMSE write a sentence)	
median	.26	IQI	[.18 - .3]

Notes:
`vdmde3` represents the number of words recalled after a delay on the MMSE 3 word list. It is simply a recoded version of the original variable h1rmse13, with responses of 97, 98 , 99 treated as missing. To address maldistribtion, observed values of 0 and 1 are scored 0, observed values of 2 are scored 1, and observed values of 3 are scored 2. (Note that the histogram above does not reflect this recoding.)

5.10 CERAD constructional praxis delayed (0-11)

vdmde4 (Memory, delayed episodic)

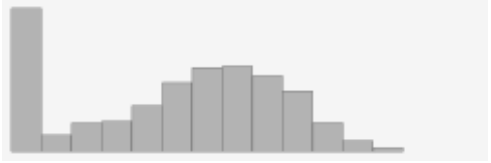
Distinct values	12		
Missing N (%)	42 (1%)		
At max N (%)	324 (10%)		
At min N (%)	328 (10%)		
Corr(MMSE)	.52		
Mean (SD)	5.81 (3.25)	Range	[0.00 - 11.00]
skewness	-0.17	kurtosis	2.16
Range of correlation coefficients with other items			
max	.59	vdvis1 (CERAD Constructional praxis)	
min	.12	vdlfl5 (MMSE read and follow command)	
median	.4	IQI	[.27 - .48]

Notes:

`vdmde4` is the number correct shapes drawn from memory after a delay on the CERAD Constructional Praxis task. This is a delayed recall of the geometric shapes drawn in the test of CERAD Constructional Praxis (immediate) task. Respondents are asked to draw the shapes from earlier in the interview to the best of their memory. It is simply a renaming of h1rcpdelscore.

5.11 Brave man delayed score (0-12)

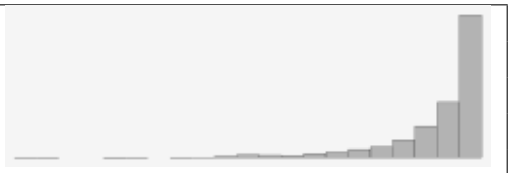
vdmde5 (Memory, delayed episodic)

Distinct values	13		
Missing N (%)	15 (0%)		
At max N (%)	19 (1%)		
At min N (%)	698 (21%)		
Corr(MMSE)	.41		
Mean (SD)	4.98 (3.35)	Range	[0.00 - 12.00]
skewness	-0.22	kurtosis	1.88
Range of correlation coefficients with other items			
max	.59	vdmie4 (Brave man immediate (0-12))	
min	8.2e-02	vdlfl5 (MMSE read and follow command)	
median	.31	IQI	[.2 - .41]

Notes:
This item `vdmde5` is simply a renaming of h1rbmdelscore. No accomodation for missing or other non-response codes has been used.

5.12 CERAD word list recognition task (0-20)

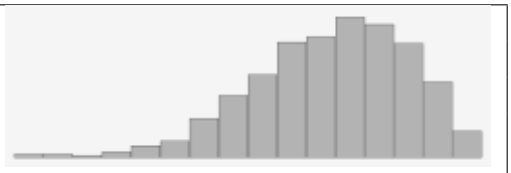
vdmre1 (Memory, recognition)

Distinct values	18		
Missing N (%)	24 (1%)		
At max N (%)	1654 (50%)		
At min N (%)	2 (0%)		
Corr(MMSE)	.58		
Mean (SD)	18.53 (2.36)	Range	[0.00 - 20.00]
skewness	-2.54	kurtosis	11.51
Range of correlation coefficients with other items			
max	.62	vdmde1 (CERAD word list delayed (0-10))	
min	.12	vdlfl5 (MMSE read and follow command)	
median	.35	IQI	[.24 - .43]

Notes:
`vdmre1` is the number correct *yes* and number correct *no* on the CERAD delayed recognition task. This two item sum has an internal consistency reliability (alpha) coefficient of 0.36.

5.13 Logical memory recognition (0-15)

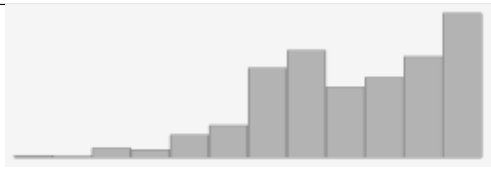
vdmre2 (Memory, recognition)

Distinct values	16		
Missing N (%)	108 (3%)		
At max N (%)	90 (3%)		
At min N (%)	12 (0%)		
Corr(MMSE)	.45		
Mean (SD)	10.29 (2.72)	Range	[0.00 - 15.00]
skewness	-0.66	kurtosis	3.52
Range of correlation coefficients with other items			
max	.62	vdmie3 (Logical memory immediate (0-25))	
min	.12	vdlfl5 (MMSE read and follow command)	
median	.32	IQI	[.22 - .38]

Notes:
`vdmre2` is the number correct on the WMS-IV Logical Memory I story recognition task. It is simply a renaming of `h1rlmrecscore` but missing codes (97, 98, 99) are treated as missing.

5.14 CERAD Constructional praxis

vdvis1 (Visuospatial)

Distinct values	12		
Missing N (%)	39 (1%)		
At max N (%)	715 (22%)		
At min N (%)	11 (0%)		
Corr(MMSE)	.48		
Mean (SD)	8.18 (2.33)	Range	[0.00 - 11.00]
skewness	-0.59	kurtosis	2.84
Range of correlation coefficients with other items			
max	.59	vdmde4 (CERAD constructional praxis delayed (0-11))	
min	.11	vdlfl3 (Naming 2 items MMSE)	
median	.3	IQI	[.25 - .38]

Notes:
`vdvis1` is CERAD constructional praxis immediate. The summary variable is a simple recode (for missing, other non-response codes as system missing) version of `h1rcpimmscore`

5.15 MMSE copy polygons

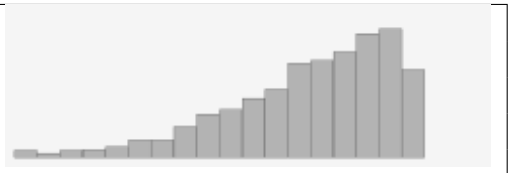
vdvis2 (Visuospatial)

Distinct values	2		
Missing N (%)	63 (2%)		
At max N (%)	1752 (53%)		
At min N (%)	1532 (47%)		
Corr(MMSE)	.42		
Range of correlation coefficients with other items			
max	.39	vdvis1 (CERAD Constructional praxis)	
min	5.8e-02	vdlfl3 (Naming 2 items MMSE)	
median	.21	IQI	[.16 - .25]

Notes:
`vdvis2` is the copy polygons item from the MMSE. It is based only on `h1rmse22`, with missing codes excluded (97, 98, 99).

5.16 Raven's progressive matrices

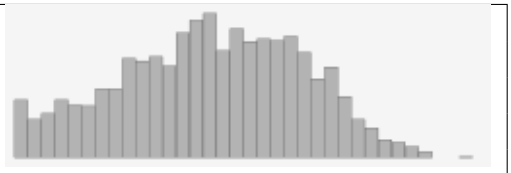
vdexf1 (Executive function)

Distinct values	18		
Missing N (%)	60 (2%)		
At max N (%)	301 (9%)		
At min N (%)	25 (1%)		
Corr(MMSE)	.57		
Mean (SD)	12.40 (3.69)	Range	[0.00 - 17.00]
skewness	-0.98	kurtosis	3.63
Range of correlation coefficients with other items			
max	.61	vdasp1 (Symbol Digit Modalities Test score)	
min	.15	vdori2 (TICS name president correct (0,1))	
median	.38	IQI	[.31 - .49]

Notes:
`vdexf1` is the score from Raven's progressive matrices. It is based only on `h1rrvscore`

5.17 Trails B time (observed 32-300 seconds)

vdexf2 (Executive function)

Distinct values	259		
Missing N (%)	520 (16%)		
At max N (%)	0 (0%)		
At min N (%)	29 (1%)		
Corr(MMSE)	.42		
Mean (SD)	0.17 (0.08)	Range	[0.00 - 0.39]
skewness	-0.14	kurtosis	2.36
Range of correlation coefficients with other items			
max	.67	vdasp1 (Symbol Digit Modalities Test score)	
min	6.4e-02	vdlfl5 (MMSE read and follow command)	
median	.31	IQI	[.2 - .42]

Notes:
`vdexf2` is

$$1 - \frac{\log(T_B)}{\log(300)}$$

where T_B is the number of seconds needed to complete the Trails B task, and 300 is the ceiling on the number of seconds allowed to complete the task. The resulting score is 0 when the participant took 300 seconds to complete the task (or did not complete the task in 300 seconds and was assigned a score of 300), and 1 when the task was completed in 0 seconds (unsurprisingly, we do not observe scores of 1). The *direction* of this log transformed score is such that higher scores (approaching 1) are better and indicate faster performance. Missing codes (i.e., not between 0 and 300 on the source variable(s)) are treated as missing. NB the reverse transformation is $300^{(1-B)}$ where B is the log transformed, log-normalized complement number of seconds to complete the Trails B task.

5.18 HRS Number Series

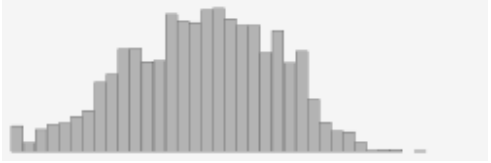
vdexf7 (Executive function)

Distinct values	29		
Missing N (%)	578 (17%)		
At max N (%)	100 (4%)		
At min N (%)	20 (1%)		
Corr(MMSE)	.45		
Mean (SD)	522.45 (31.40)	Range	[409.00 - 584.00]
skewness	-0.79	kurtosis	4.66
Range of correlation coefficients with other items			
max	.59	vdexf1 (Raven's progressive matrices)	
min	8.2e-02	vdlfl3 (Naming 2 items MMSE)	
median	.28	IQI	[.18 - .37]

Notes:
This is from the *2016 Harmonized Cognitive Assessment Protocol (HCAP) Study Protocol Summary*: Developed for the HRS, this section evaluates Respondents ability for numeric reasoning by presenting a series of 6 individual series of numbers, where one or two numbers in the series is missing. The Respondent is asked to take as much time as s/he needs, with the help of scrap paper and a pencil, to identify the missing number/s. This test is a block-adaptive test. Respondents are given a set of three number series questions of varying difficulty to first complete. Based on the number of correct responses in this first set of three (score Range = 0 to 4), Respondents are then assigned to a second set of three questions, for which the difficulty level is based on the number correct on the first set. The HRS uses two versions of the Number Series questions and respondents are assigned to the version that was not done in the previous wave. For HRS-HCAP, Respondents were assigned to the Number Series that was not assigned in the 2016 Core interview. If a Respondent was not able to do the Number Series section in the 2016 Core interview (not able to do practice questions, was too confused), then they were skipped out of this section. In creating `vdexf7`, missing codes (codes 996 and higher) on the source variable `h1rnsscore` are treated as system missing.

5.19 Symbol Digit Modalities Test score

vdasp1 (Attention, speed)

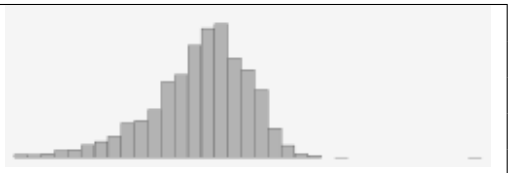
Distinct values	68		
Missing N (%)	179 (5%)		
At max N (%)	1 (0%)		
At min N (%)	14 (0%)		
Corr(MMSE)	.59		
Mean (SD)	32.49 (12.52)	Range	[0.00 - 71.00]
skewness	-0.22	kurtosis	2.56
Range of correlation coefficients with other items			
max	.73	vdasp2 (Trails A)	
min	8.9e-02	vdlfl3 (Naming 2 items MMSE)	
median	.4	IQI	[.3 - .53]

Notes:

This item `vdasp1` is simply a renaming of h1rsdmscore. No accomodation for missing or other non-response codes has been used. Note that according to the *2016 Harmonized Cognitive Assessment Protocol (HCAP) Study Protocol Summary*, the SDMT score is the number of correct pairings minus any mistakes or skips. Watch out for logical dependency or local dependence with SDMT errors (in executive function domain).

5.20 Trails A

vdasp2 (Attention, speed)

Distinct values	190		
Missing N (%)	137 (4%)		
At max N (%)	1 (0%)		
At min N (%)	5 (0%)		
Corr(MMSE)	.56		
Mean (SD)	0.32 (0.09)	Range	[0.00 - 0.81]
skewness	-0.71	kurtosis	4.04
Range of correlation coefficients with other items			
max	.73	vdasp1 (Symbol Digit Modalities Test score)	
min	.12	vdlfl3 (Naming 2 items MMSE)	
median	.37	IQI	[.28 - .47]

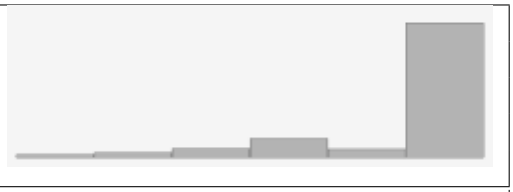
Notes:
`vdasp2` is

$$1 - \frac{\log(T_A)}{\log(300)}$$

where T_A is the number of seconds needed to complete the Trails A task, and 300 is the ceiling on the number of seconds allowed to complete the task. The resulting score is 0 when the participant took 300 seconds to complete the task (or did not complete the task in 300 seconds and was assigned a score of 300), and 1 when the task was completed in 0 seconds (unsurprisingly, we do not observe scores of 1). The *direction* of this log transformed score is such that higher scores (approaching 1) are better and indicate faster performance. Missing codes (i.e., not between 0 and 300 on the source variables) are treated as missing.

5.21 MMSE spell world backwards

vdasp3 (Attention, speed)

Distinct values	6		
Missing N (%)	171 (5%)		
At max N (%)	2390 (75%)		
At min N (%)	52 (2%)		
Corr(MMSE)	.69		
Range of correlation coefficients with other items			
max	.39	vdexf1 (Raven's progressive matrices)	
min	9.2e-02	vdlfl5 (MMSE read and follow command)	
median	.27	IQI	[.21 - .31]

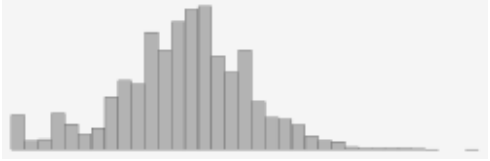
Notes:
vdasp3 is the sum of 5 recorded responses to the MMSE spell world backwards task, recored with five correct/incorrect indicators. Only correct responses are summed (code 1 on source variables). At least 1 of the five indicators must have a non-missing code (not missing or 96, 97, 98, 99) to get the 0-5 score on vdasp3.

Cautionary statement on distribution. This categorical variable (vdasp3) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating vdasp3 as a categorical variable.

vdasp3	Count	Propor~n
0	52	.0163728
1	87	.0273929
2	159	.050063
3	338	.1064232
4	150	.0472292
5	2,390	.7525189

5.22 Backwards counting

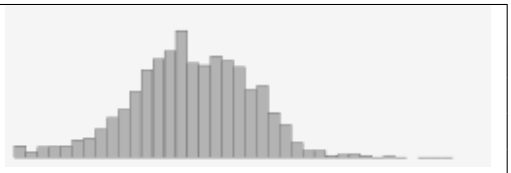
vdasp4 (Attention, speed)

Distinct values	70		
Missing N (%)	47 (1%)		
At max N (%)	1 (0%)		
At min N (%)	62 (2%)		
Corr(MMSE)	.56		
Mean (SD)	29.31 (11.40)	Range	[0.00 - 80.00]
skewness	-0.20	kurtosis	3.52
Range of correlation coefficients with other items			
max	.61	vdasp1 (Symbol Digit Modalities Test score)	
min	8.6e-02	vdlfl3 (Naming 2 items MMSE)	
median	.38	IQI	[.25 - .45]

Notes:
This is from the *2016 Harmonized Cognitive Assessment Protocol (HCAP) Study Protocol Summary*: This test assesses speed and attention and is derived from the Backward Count measure in the MIDUS Study. Respondents are asked to begin at 100 and to count backwards as fast as possible. They are given 30 seconds and the number they reach and number of errors are recorded.

5.23 Letter cancellation

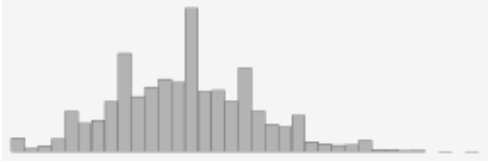
vdasp5 (Attention, speed)

Distinct values	37		
Missing N (%)	150 (4%)		
At max N (%)	1 (0%)		
At min N (%)	27 (1%)		
Corr(MMSE)	.5		
Mean (SD)	14.78 (5.27)	Range	[0.00 - 37.00]
skewness	-0.14	kurtosis	3.38
Range of correlation coefficients with other items			
max	.68	vdasp1 (Symbol Digit Modalities Test score)	
min	9.1e-02	vdlfl3 (Naming 2 items MMSE)	
median	.33	IQI	[.24 - .43]

Notes:
This is from the *2016 Harmonized Cognitive Assessment Protocol (HCAP) Study Protocol Summary*: This test has been included in ELSA and assesses attention and speed. Respondents are given a paper with a large grid of letters and are asked to scan the grid as quickly as possible in a minute and to cross out as many *P* and *W* letters as they can in that time. This variable (`vdasp5`, renamed and otherwise unmolested version of `h1rlcscore`) is the number of correctly crossed-out letters.

5.24 Category fluency (animals)

vdlfl1 (Language, fluency)

Distinct values	41		
Missing N (%)	2 (0%)		
At max N (%)	1 (0%)		
At min N (%)	28 (1%)		
Corr(MMSE)	.51		
Mean (SD)	15.97 (6.57)	Range	[0.00 - 43.00]
skewness	0.26	kurtosis	3.12
Range of correlation coefficients with other items			
max	.54	vdasp1 (Symbol Digit Modalities Test score)	
min	.12	vdlfl5 (MMSE read and follow command)	
median	.4	IQI	[.28 - .48]

Notes:
The created variable `vdlfl1` is simply a copied or renamed version of `h1rafscore`. No handling of missing response codes was implemented (none were observed).

5.25 Naming 2 items HRS TICS scissors, cactus

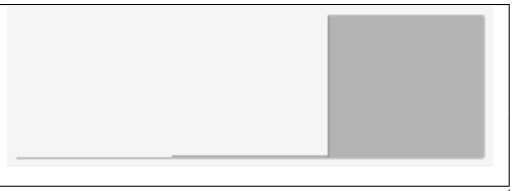
vdlfl2 (Language, fluency)

Distinct values	2		
Missing N (%)	13 (0%)		
At max N (%)	3047 (91%)		
At min N (%)	287 (9%)		
Corr(MMSE)	.44		
Range of correlation coefficients with other items			
max	.36	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	.11	vdori2 (TICS name president correct (0,1))	
median	.25	IQI	[.2 - .28]

Notes:
This is the number of correct responses to the HRS TICS items name two objects (scisssor, cactus). Respondents must have at least 1 non-missing (not system missing, not 7, 8, 9) to get a score. To address maldistribtion, observed values of 0 and 1 are scored 0, observed values of 2 are scored 1. (Note that the histogram above does not reflect this recoding.)

5.26 Naming 2 items MMSE

vdlfl3 (Language, fluency)

Distinct values	2		
Missing N (%)	9 (0%)		
At max N (%)	3298 (99%)		
At min N (%)	40 (1%)		
Corr(MMSE)	.31		
Range of correlation coefficients with other items			
max	.25	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	5.8e-02	vdvis2 (MMSE copy polygons)	
median	.12	IQI	[9.3e-02 - .13]

Notes:
The created variable `vdlfl1` is simply a copied or renamed version of `h1r1066score`. No handling of missing response codes was implemented (none were observed). To address maldistribtion, observed values of 0-2 are scored 0, observed values of 2 are scored 1, and observed values of 4 are scored 2. (Note that the histogram above does not reflect this recoding.)

Cautionary statement on distribution. This categorical variable (`vdlfl3`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdlfl3` as a categorical variable.

```
vdlfl3   Count   Propor~n
   0-1      40   .0119832
     2   3,298   .9880168
```

5.27 MMSE write a sentence

vdlfl4 (Language, fluency)

Distinct values	2		
Missing N (%)	111 (3%)		
At max N (%)	3023 (93%)		
At min N (%)	213 (7%)		
Corr(MMSE)	.39		
Range of correlation coefficients with other items			
max	.24	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	7.7e-02	vdmde3 (MMSE 3 word delayed recall (0-3))	
median	.18	IQI	[.15 - .19]

Notes:
The variable vdlfl4 is an indicator as to whether h1rmse21 is scored as correct (value 1). Missing codes (any value coded 96 or higher) are treated as missing

5.28 MMSE read and follow command

vdlfl5 (Language, fluency)

Distinct values	2		
Missing N (%)	23 (1%)		
At max N (%)	3195 (96%)		
At min N (%)	129 (4%)		
Corr(MMSE)	.34		
Range of correlation coefficients with other items			
max	.22	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	6.4e-02	vdexf2 (Trails B time (observed 32-300 seconds))	
median	.13	IQI	[.12 - .15]

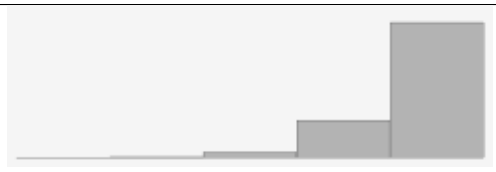
Notes:
The variable vdlfl5 is an indicator as to whether h1rmse17 is scored as correct (value 1). Missing codes (any value coded 96 or higher) are treated as missing

Cautionary statement on distribution. This categorical variable (`vdlfl5`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdlfl5` as a categorical variable.

```
vdlfl5   Count   Propor~n
     0     129   .0388087
     1   3,195   .9611914
```

5.29 1066 object naming

vdlfl6 (Language, fluency)

Distinct values	3		
Missing N (%)	6 (0%)		
At max N (%)	2522 (75%)		
At min N (%)	121 (4%)		
Corr(MMSE)	.41		
Range of correlation coefficients with other items			
max	.33	vdori1 (MMSE 10 items (number of correct, 0-10))	
min	.15	vdori2 (TICS name president correct (0,1))	
median	.23	IQI	[.17 - .25]

Notes:
The created variable `vdlfl1` is simply a copied or renamed version of `h1r1066score`. No handling of missing response codes was implemented (none were observed).

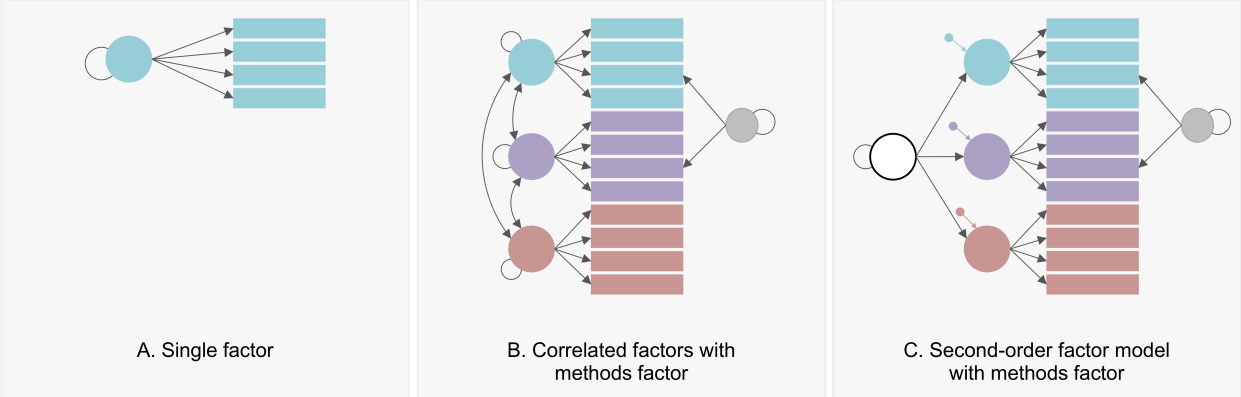
Cautionary statement on distribution. This categorical variable (`vdlfl6`) has at least one sparsely populated response level. There is a response category that has fewer than 5% of the responding sample in the category. This maldistribution is *likely* to cause problems when using least squares estimators and it might be worth considering addressing before analysis. Ways to address include collapsing categories or not treating `vdlfl6` as a categorical variable.

vdlfl6	Count	Propor~n
0-2	121	.0362167
3	698	.2089195
4	2,522	.7548638

6 Psychometric modeling - unidimensional models

6.1 Types of models

I will be running a variety of types of confirmatory factor analysis models. Here is a quick overview:



Single factor models examine the fit of a single domain of functioning independent of other domains. The single factor models are an end in and of themselves. One product we would like to generate are estimates of domain-specific performance. For these, all that are required are well-fitting and reasonably constructed single factor models. All other more complicated models serve other purposes (e.g., obtaining an estimate of general cognitive performance, summarizing across domains, demonstrating the extent to which the domains measure distinct constructs, taking advantage of the multi-domain structure and non-independent measurements to obtain estimates of individual domain performance from a reduced set of items, etc.).

Correlated factors with a methods factor. The Correlated factors models examine the fit of a model with multiple domains simultaneosly, and no structure is imposed on the domain specific factors but they are allowed to correlate with one another freely. We include a specific factor that links items across domains that share stimulus material. For example, the immediate and delayed recall of the same word list.

Second order factor models include specific domains, but attempt to account for the correlation among domain specific factors with a single general and second order factor.

6.2 Assessing model fit

Latent variable measurement models (CFA) were estimated using Mplus software and the weighted least squares estimator with mean and variance standardization (WLSMV) and theta parameterization. We only moved to multi-dimensional models after a satisfactorily fitting unidimensional models within an a priori specified domain was achieved. Model fit was evaluated with the standardized root mean square residual (SRMR), confirmatory fit index (CFI), and root mean squared error of approximation. Greatest weight was afforded the SRMR and an examination of model residuals.

Guide to model fit Model fit is good, adequate or poor according to the following criteria:

Descriptor	CFI		RMSEA		SRMR
perfect	1.00	AND	0.00	AND	0.00
good	≥ 0.95	AND	≤ 0.05	AND	≤ 0.05
adequate	≥ 0.90	AND	≤ 0.08	AND	≤ 0.08
poor	< 0.90	OR	> 0.08	OR	> 0.08

Note: Perfectly fitting models will arise when a common factor model is fit to less than four indicators.

The **SRMR** is an *absolute fit measure* based on residuals and is not penalized for model complexity, and ideal values approach 0.

The **RMSEA** is an *absolute fit measure* can be viewed as an index of model discrepancy per degree of freedom. It is computed as $\frac{\sqrt{\chi^2 - df}}{\sqrt{df(n-1)}}$ where χ^2 is the model chi-square (higher values indicate greater discrepancy between observed mean and covariance matrix and model-implied mean and covariance matrix), df is the model degrees of freedom (a function of the number of variables and number of parameters estimated) and n is the sample size. This fit index is sensitive to the number of parameters and sample size. Ideal values approach 0 and when the computation is less than 0 the RMSEA is set to 0.

the **CFI** is an *incremental fit measure* and compares the fit of the target model to a null model. It is computed as $1 - d_0/d_1$ where $d = \chi^2 - df$ and the subscript 0 indicates a null model and subscript 1 indicates a target model.

If SRMR indicates good fit but CFI and/or RMSEA do not, it could be that there extraneous parameters being estimated (e.g., regressions or factor loadings that are not important).

Mean weighted fit index
In this report, I will summarize model fit using a novel heuristic index that I am calling the *mean weighted fit index* that is computed as

$$\text{MWFI} = 0.9 + \tfrac{1}{3}\left[(CFI - 0.9) + 1.25(0.08 - RMSEA) + 1.25(0.08 - SRMR)\right]$$

The MWFI will take on values up to 1, and will be 0.9 when all three fit indices are at bare adequate levels (CFI = 0.9, RMSEA = .08, SRMR = .08), will be 0.94 when all three criteria are equal to the "good" criteria detailed below, and will approach 1 as these three fit indices approach their ideal points (CFI $\rightarrow$ 1, RMSEA $\rightarrow$ 0, SRMR $\rightarrow$ 0). The utility of this MWFI is to judge fit taking into account the three indices and to allow ranking of models within the same verbal descriptor level.

Factor reliability (Omega)
For single factor models, I will also show the omega coefficient, which is a measure of internal consistency reliability and interpreted as one would a coefficient alpha. It is computed as

$$\omega_t = \frac{(\Sigma\lambda_j)^2}{\left[(\Sigma\lambda_j)^2 + \Sigma(1-\lambda_j^2)\right]}$$

where λ_j is the standardized measurement slope (factor loading) for indicator j.

6.3 Data notes

In the psychometric data analysis, variables that have 10 or fewer discrete values are treated as categorical variables. All other variables are treated as continuous. Continuous variables are transformed to a 0-1 scale before modeling. Variables so transformed have a `"z"` appended to their name.

6.4 Model I: Specific factor model, Orientation

Parameter)	Estimate	Standard error
Standardized measurement slopes (factor loadings)		
MMSE 10 items (number of correct, 0-10) (vdori1z)	1.82	(0.06)
TICS name president correct (0,1) (vdori2)	0.25	(0.01)
Variances and residual variances (not standardized)		
general factor	0.06	
MMSE 10 items (number of correct, 0-10) (vdori1z)	-0.04	

Model fit summary	
N	3342 *(evaluable sample size, $>$99 % of 3347)*
$\chi^2(df)$	0(0)
Omega	1.47
CFI	1
RMSEA	0
SRMR	0
Fit (MWFI)	perfect (1.00)

Comment:
This model fits perfectly, but the standardized measurement slope greater than 1, negative residual variance, and reliability greater than 1 indicate that the two items in this scale are redundant. We are not getting unique information from the TICS name the president item and the other MMSE derived orientation to time and place questions. The TICS item should be dropped because it contains less information. **Therefore this cannot be considered a final model.**

DECISION
Since there are only two indicators for the *orientation* domain, we have no choice but to consider a single indicator for our best measure of this domain. So, **the proposed measure of the orientation domain is the 10-item sum of orientation to time and place questions in the MMSE.**

6.5 Model IIA: Specific factor model, Memory, immediate episodic

Parameter)	Estimate	Standard error
Standardized measurement slopes (factor loadings)		
CERAD word list immediate sum of 3 trials (0-30) (vdmie1z)	0.76	(0.01)
MMSE 3 word recognition (0-3) (vdmie2)	0.46	(0.03)
Logical memory immediate (0-25) (vdmie3z)	0.76	(0.01)
Brave man immediate (0-12) (vdmie4z)	0.66	(0.01)
Variances and residual variances (not standardized)		
general factor	0.02	
CERAD word list immediate sum of 3 trials (0-30) (vdmie1z)	0.01	
Logical memory immediate (0-25) (vdmie3z)	0.02	
Brave man immediate (0-12) (vdmie4z)	0.02	

Model fit summary	
N	3344 *(evaluable sample size, $>$99 % of 3347)*
$\chi^2(df)$	34.768(2)
Omega	0.76
CFI	.981
RMSEA	.07
SRMR	.021
Fit (MWFI)	adequate (0.96)

Comment:
This model fits well overall, but the RMSEA is too high for comfort. The SRMR is good, which implies that the high RMSE might indicate the model is over parameterized. Since this is a single factor model, there are not a lot of places for having included too many parameters. It could be that misfit arises due to local dependence of the MMSE 3 word registration task and the CERAD word list task. **Because of the high RMSEA this cannot be considered a final model.**

This model will require some further exploration to determine if fit can be improved.

6.6 Model IIB: Specific factor model, Memory, delayed episodic

Parameter)	Estimate	Standard error
Standardized measurement slopes (factor loadings)		
CERAD word list delayed (0-10) (vdmde1z)	0.80	(0.01)
Logical memory delayed (0-25) (vdmde2z)	0.77	(0.01)
MMSE 3 word delayed recall (0-3) (vdmde3)	0.79	(0.02)
CERAD constructional praxis delayed (0-11) (vdmde4z)	0.65	(0.01)
Brave man delayed score (0-12) (vdmde5z)	0.66	(0.01)
Variances and residual variances (not standardized)		
general factor	0.04	
CERAD word list delayed (0-10) (vdmde1z)	0.03	
Logical memory delayed (0-25) (vdmde2z)	0.02	
CERAD constructional praxis delayed (0-11) (vdmde4z)	0.05	
Brave man delayed score (0-12) (vdmde5z)	0.04	

Model fit summary	
N	3345 *(evaluable sample size, $>$99 % of 3347)*
$\chi^2(df)$	43.885(5)
Omega	0.85
CFI	.985
RMSEA	.048
SRMR	.017
Fit (MWFI)	good (0.97)

Comment:
This is a good model.

6.7 Model IIC: Specific factor model, Memory, recognition

Parameter)	Estimate	Standard error
Standardized measurement slopes (factor loadings)		
CERAD word list recognition task (0-20) (vdmre1z)	0.83	(0.02)
Logical memory recognition (0-15) (vdmre2z)	0.53	(0.01)
Variances and residual variances (not standardized)		
general factor	0.01	
CERAD word list recognition task (0-20) (vdmre1z)	0.00	
Logical memory recognition (0-15) (vdmre2z)	0.02	

Model fit summary	
N	3330 *(evaluable sample size, 99 % of 3347)*
$\chi^2(df)$	0(0)
Omega	0.64
CFI	1
RMSEA	0
SRMR	0
Fit (MWFI)	perfect (1.00)

Comment:
This is a good model (if we can call a model with only two indicators a good model). The items are reasonably highly correlated (implied about .4) and are not logically dependent upon each other.

6.8 Model III: Specific factor model, Set shifting

Parameter)	Estimate	Standard error
Standardized measurement slopes (factor loadings)		
Raven's progressive matrices (vdexf1z)	0.80	(0.01)
Trails B time (observed 32-300 seconds) (vdexf2z)	0.68	(0.01)
HRS Number Series (vdexf7z)	0.81	(0.01)
Variances and residual variances (not standardized)		
general factor	0.03	
Raven's progressive matrices (vdexf1z)	0.02	
Trails B time (observed 32-300 seconds) (vdexf2z)	0.02	
HRS Number Series (vdexf7z)	0.01	

Model fit summary	
N	3298 *(evaluable sample size, 99 % of 3347)*
$\chi^2(df)$	0(0)
Omega	0.81
CFI	1
RMSEA	0
SRMR	0
Fit (MWFI)	perfect (1.00)

Comment:
This is a good model. A three indicator model with all continuous factor indicators is just-identified (zero degrees of freedom) and will fit perfectly. The reliability coefficient indicates the factor is sufficiently reliable for group differences research.

However, a more detailed analysis of the impact of excluding the errors indicators will be pursued in the next section. As noted in the section describing data handling, I dropped the items encoding *errors* on various tests from consideration of inclusion in the factor models. The rationale was low correlations of these items with other items and logical dependencies among some error counts and component scores. But it would be nice to have some additional evidence that those items are not worth including.

6.9 Model IV: Specific factor model, Attention, speed

Parameter)		Estimate	Standard error
Standardized measurement slopes (factor loadings)			
	Symbol Digit Modalities Test score (vdasp1z)	0.90	(0.01)
	Trails A (vdasp2z)	0.81	(0.01)
	MMSE spell world backwards (vdasp3)	0.58	(0.02)
	Backwards counting (vdasp4z)	0.69	(0.01)
	Letter cancellation (vdasp5z)	0.75	(0.01)
Variances and residual variances (not standardized)			
	general factor	0.03	
	Symbol Digit Modalities Test score (vdasp1z)	0.01	
	Trails A (vdasp2z)	0.00	
	Backwards counting (vdasp4z)	0.01	
	Letter cancellation (vdasp5z)	0.01	
Model fit summary			
N	3339 *(evaluable sample size, $>$99 % of 3347)*		
$\chi^2(df)$	137.299(5)		
Omega	0.87		
CFI	.972		
RMSEA	.089		
SRMR	.021		
Fit (MWFI)	poor (0.94)		

Comment:
This model fits well overall, but the RMSEA is too high for comfort. The SRMR is good, which implies that the high RMSE might indicate the model is over parameterized. Since this is a single factor model, there are not a lot of places for having included too many parameters. **Because of the high RMSEA this cannot be considered a final model.**

This model will require some futher exploration to determine if fit can be improved.

6.10 Model V: Specific factor model, Language, fluency

Parameter)		Estimate	Standard error
Standardized measurement slopes (factor loadings)			
	Category fluency (animals) (vdlfl1z)	0.67	(0.02)
	Naming 2 items HRS TICS scissors, cactus (vdlfl2)	0.76	(0.03)
	Naming 2 items MMSE (vdlfl3)	0.77	(0.06)
	MMSE write a sentence (vdlfl4)	0.59	(0.04)
	MMSE read and follow command (vdlfl5)	0.53	(0.04)
	1066 object naming (vdlfl6)	0.58	(0.02)
Variances and residual variances (not standardized)			
	general factor	0.01	
	Category fluency (animals) (vdlfl1z)	0.01	
Model fit summary			
N	3347 *(evaluable sample size, 100 % of 3347)*		
$\chi^2(df)$	43.863(9)		
Omega	0.82		
CFI	.978		
RMSEA	.034		
SRMR	.051		
Fit (MWFI)	good (0.96)		

Comment:
This is a good model.

6.11 Model VI: Specific factor model, Visuospatial

Parameter)		Estimate	Standard error
Standardized measurement slopes (factor loadings)			
	CERAD Constructional praxis (vdvis1z)	1.51	(0.03)
	MMSE copy polygons (vdvis2)	0.32	(0.01)
Variances and residual variances (not standardized)			
	general factor	0.10	
	CERAD Constructional praxis (vdvis1z)	-0.06	
Model fit summary			
N	3318 *(evaluable sample size, 99 % of 3347)*		
$\chi^2(df)$	0(0)		
Omega	1.13		
CFI	1		
RMSEA	0		
SRMR	0		
Fit (MWFI)	perfect (1.00)		

Comment:
This model fits perfectly, but the standardized measurement slope greater than 1, negative residual variance, and reliability greater than 1 indicate that the two items in this scale are redundant. We are not getting unique information from the copy polygons and CERAD constructional praxis. The MMSE item should be dropped because it contains less information. **Therefore this cannot be considered a final model.**

DECISION
Since there are only two indicators for the *visuospatial* domain, we have no choice but to consider a single indicator for our best measure of this domain. So, **the proposed measure of the visuospatial domain is the CERAD constructional praxis score, and we omit the draw polygons task from the MMSE.**

6.12 Summary model fit of all initial single factor mdoels

6.13 Summary of factor models 1 - 8

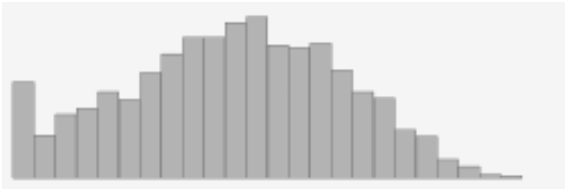
Model	Description	Items	CFI	RMSEA	SRMR	Fit Assessment	NRV
1. I	Orientation single factor	2	1.000	0.000	0.000	perfect (1.00)	•
2. IIA	Memory, immediate episodic single factor	4	0.981	0.070	0.021	adequate (0.96)	
3. IIB	Memory, delayed episodic single factor	5	0.985	0.048	0.017	good (0.97)	
4. IIC	Memory, recognition single factor	2	1.000	0.000	0.000	perfect (1.00)	
5. III	Set shifting single factor	3	1.000	0.000	0.000	perfect (1.00)	
6. IV	Attention, speed single factor	5	0.972	0.089	0.021	poor (0.94)	
7. V	Language, fluency single factor	6	0.978	0.034	0.051	good (0.96)	
8. VI	Visuospatial single factor	2	1.000	0.000	0.000	perfect (1.00)	•

Notes: Items indicates the number of dependent variables; a •under the NRV column indicates the presence of a negative residual variance, or a standardized factor loading that is greater than 1.0, or a standardized covariance parameter greater than 1.0.

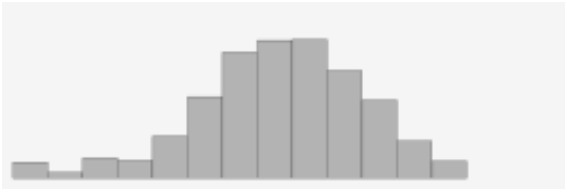
6.14 Exploring misfit in Model IIA

I examined the modification indices from Model IIA. Modification indices are computed for parameters in the model that are constrained to some value (either a fixed value of fixed to be equal to some other parameter). The largest modification index for model IIA was for the correlation of *Brave man immediate (0-12)* and *Logical memory immediate (0-25)*. This source of residual covariance could be that the observed data are not consistent with a unidimensional model, and this could be due to item content (i.e., story immediate recall and word list immediate recall tap an additional ability or a separate ability from that required to respond to the word list recall items) or something induced by the data.

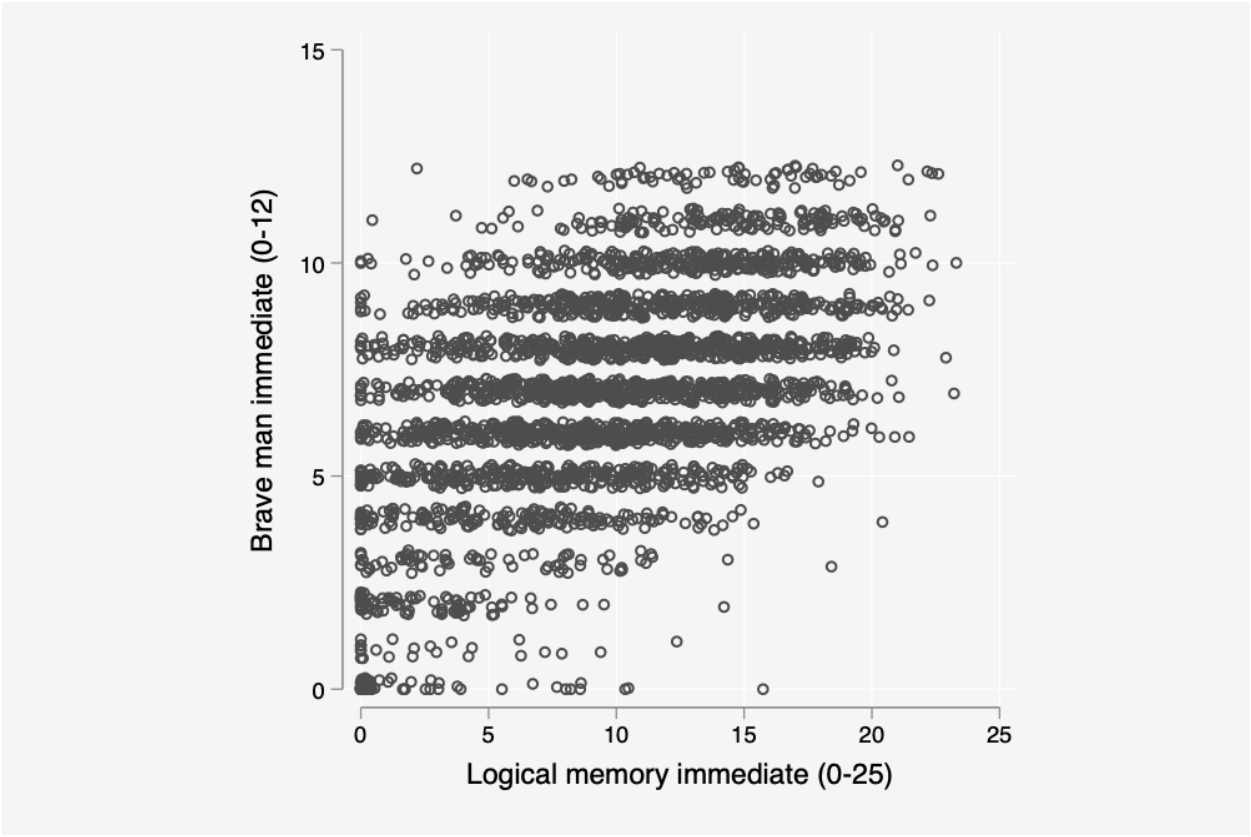
The way the data could produce a strong residual correlation is through the pronounced floor effect on logical memory immediate seems like a likely candidate for an induced residual correlation due to non-normal distribution:



Logical memory immediate (0-25)



Brave man immediate (0-12)



This floor effect can induce a non-linear relationship between `vdmie3` and `vdmie4`. We can handle

this floor effect a couple of different ways:

1. Treat observations at the floor of `vdmie3` as missing values
2. Transform `vdmie3`, we could try either:
    - a rank-based transformation (e.g., Blom transformation), or
    - a discretized version (treating 0 as it's own category, and performance levels beyond 0 as separate ordered categories).

Treating observations at the floor as missing is rejected because this results in loss of information. My preference is for discretizing, as while this also results in loss of information the magnitude is minimal relative to treating observations at the floor as missing. A percentile rank based transformation (e.g., Blom transformation) might also work well, but these are sample dependent and may not translate across settings and therefore not preferred.

6.14.1 Blom transformation to vdmie3

Using a blom transformation on `vdmie3` decreases the RMSEA to 0.069.

6.14.2 Discretization of vdmie3

Using a discretized version of `vdmie3` results in a RMSEA to 0.070.

The above results suggest that it is **not the distribution of the data** that is perturbing the fit of model IIA. Neither of these two approaches are dealing with the poor RMSEA of this model. This last model still has a large, unestimated, residual covariance between Brave man immediate (0-12) and Logical memory immediate (0-25). The source of misfit is more likely a violation of the linearity assumption that is implicit in the factor analysis model. This is also a manifestation of the violation of the assumption of local independence.

Important note: In the analyses to follow I return to a continuous normal variable for logical memory performance (`vdmie4z`).

6.14.3 Add residual covariance of vdmie3z and vdmie4z

This produces a model with a RMSEA of 0.000.

The implication is this selection of items that are intended to measure immediate episodic memory are not unidimensional. The immediate registration of story information (capured with `vdmie3z` and `vdmie4z`) are more highly correlated with each other than what is captured by their correlation with the common factor defined by all four variables. The other two items being word list registration items.

Problem is, I can acheive similarly good fit by introducing a residual covariance between CERAD word list immediate sum of 3 trials (0-30) (`vdmmie1z`) and MMSE 3 word recognition (0-3) (`vdmie2z`). Such a model produces a RMSEA of 0.000.

6.14.4 Decision on Model Memory, immediate episodic single factor: Memory, immediate episodic revision

The only information we can use to adjust the Memory, immediate episodic soultion are the factor loadings. We have ruled out maldistribution of the indicators as a source of misfit. There is some evidence that the unidimensionality assumption of these two word list registration tasks and two story registration tasks is violated. We know that removing one of the four items will result in a three indicator model that will fit near perfectly and provide only 1 degree of freedom. The only reasonable item to pick is the MMSE three word registration task (`vdmie2`) as this indicator has the lowest factor loading and result in the least loss of information.

This means **I will also drop the MMSE three word delayed recall task** from the Memory, delayed episodic model (`vdmde3`).

6.15 Model Memory, immediate episodic single factor: REVISED Specific factor model, Memory, immediate episodic

Parameter)	Estimate	Standard error
Standardized measurement slopes (factor loadings)		
CERAD word list immediate sum of 3 trials (0-30) (vdmie1z)	0.72	(0.01)
Logical memory immediate (0-25) (vdmie3z)	0.78	(0.01)
Brave man immediate (0-12) (vdmie4z)	0.68	(0.01)
Variances and residual variances (not standardized)		
general factor	0.02	
CERAD word list immediate sum of 3 trials (0-30) (vdmie1z)	0.01	
Logical memory immediate (0-25) (vdmie3z)	0.02	
Brave man immediate (0-12) (vdmie4z)	0.02	

Model fit summary	
N	3343 *(evaluable sample size, $>$99 % of 3347)*
$\chi^2(df)$	0(0)
Omega	0.77
CFI	1
RMSEA	0
SRMR	0
Fit (MWFI)	perfect (1.00)

Comment:
This model fits well. But as is discussed on the next page, **This model is ultimately rejected.** The reason why is the cascading decision to remove the MMSE three word delayed recall task as well blows up the MDE model (next page). I decided the least bad of the options was to retain the original MIE model.

6.16 Model Memory, delayed episodic single factor: REVISED Specific factor model, Memory, delayed episodic

Parameter)	Estimate	Standard error
Standardized measurement slopes (factor loadings)		
CERAD word list delayed (0-10) (vdmde1z)	0.80	(0.01)
Logical memory delayed (0-25) (vdmde2z)	0.77	(0.01)
CERAD constructional praxis delayed (0-11) (vdmde4z)	0.66	(0.01)
Brave man delayed score (0-12) (vdmde5z)	0.68	(0.01)
Variances and residual variances (not standardized)		
general factor	0.04	
CERAD word list delayed (0-10) (vdmde1z)	0.03	
Logical memory delayed (0-25) (vdmde2z)	0.02	
CERAD constructional praxis delayed (0-11) (vdmde4z)	0.05	
Brave man delayed score (0-12) (vdmde5z)	0.04	

Model fit summary	
N	3341 *(evaluable sample size, >99 % of 3347)*
$\chi^2(df)$	65.479(2)
Omega	0.82
CFI	.985
RMSEA	.097
SRMR	.019
Fit (MWFI)	poor (0.95)

Comment:
This model fits poorly (RMSEA), whereas the previous version of the MDE unidimensional model fit well. Now we have to drill down on poor fit in the MDE domain. Here is what we can do:

- Drop any 1 item and the model will fit perfectly. Logical choice is CERAD constructional praxis, but not satisfactory because that would imply we'd want to drop CERAD constructional praxis from the battery, but it is our preferred measure of visuospatial function.
- Add a residual covariance (e.g., logical memory and brave man are obvious choices).
  - If we allow this then we could allow it for the MIE domain and not have to drop the MMSE immediate and delayed three word recall items.
  - And if we allow residual covariances, then we would have allowed the residual covariance in the MIE model and would never have recognized the need for a residual covariance in this MDE model.

It's not ideal to accept models with poor fit.

It is not ideal to propose models that only acheive good fit with the inclusion of residual covariances that were not hypothesized a priori (as in methods effects).

DECISION

I decided that the least bad of the options presented is to accept the original MIE model even though the RMSEA for that model is higher than what would be considered ideal.

6.17 Exploring misfit in Model IV (Attention, Speed)

I examined the modification indices from Model IV. The largest modification index for model IV was for the correlation of *MMSE spell world backwards* and *Backwards counting*. These two items contain a clear source of methods-related covariance (keyword backwards). It could be that there is a specific set shifting function relating to backwardsness that drives this correlation (remember, this is supposed to be an attention and speed factor). Or it might be some participants misunderstand the directions, or turn around instead of doing the task backwards.

Adding a residual covariance for these two items resolves the high RMSEA issue, nominally (RMSEA = 0.047) but not impressively. This residual correlation is of small magnitude (0.181).

DECISION
I decided to keep the original model for Attention, speed as proposed even though the model fit statitics are not ideal. I would say that there is a pretty good indication that this domain is not exclusively measuring one area of cognitive functioning, and perhaps that is not surprising given the domain name mentions two abilities: Attention *and* speed.

6.18 Check that errors don't belong in Set Shifting domain

In this section we'll run a version of the Set shifting model that includes the errors indicators. These items were all highly skewed so we'll include discretized versions (i.e., binned into up to 9 levels and treated as a categorical variable) of the errors variables.

Parameter)	**Estimate**	**Standard error**
Standardized measurement slopes (factor loadings)		
Raven's progressive matrices (vdexf1z)	0.80	(0.01)
Trails B time (observed 32-300 seconds) (vdexf2z)	0.65	(0.01)
HRS Number Series (vdexf7z)	0.75	(0.01)
Errors, Cancellation number of missed letters (vdexf3c)	-0.20	(0.02)
Errors, Cancellation number of incorrectly marked letters (vdexf4c)	-0.40	(0.05)
Errors, Symbol Digit Modalities Test (vdexf5c)	-0.35	(0.03)
Errors, fluency (vdexf6c)	-0.11	(0.03)
Variances and residual variances (not standardized)		
general factor	1.00	
Raven's progressive matrices (vdexf1z)	0.02	
Trails B time (observed 32-300 seconds) (vdexf2z)	0.02	
HRS Number Series (vdexf7z)	0.01	
Model fit summary		
N	3338 *(evaluable sample size, $>$99 % of 3347)*	
$\chi^2(df)$	58.612(14)	
Omega	0.68	
CFI	.982	
RMSEA	.031	
SRMR	.033	
Fit (MWFI)	good (0.97)	

This model actually fits well. But, the *errors* items have very low loadings, and the factor reliability (omega, computed with absolute values of factor loadings) is actually higher without these items (compare to model III above).

DECISION The decision to eliminate the *errors* indicators from the modeling seems to have been reasonable.

7 Review of single factor models

- With the exception of Orientation (ORI), Set shifting (SSH), and Visuospatial (VIS), we have retained the original hypothesized model structure. Model fit is adequate for all of the remaining domains although not quite ideal for some (Memory, immediate episodic [MIE] and Attention, speed [ASP]).
- **Orientation** (ORI) we have dropped the TICS name president item and retained a single indicator, a sum on the 10 item orientation to time and place questions from the MMSE.
- **Set shifting** (SSH) we have affirmed a decision made prior to factor analysis models to omit the *errors* indicators.
- **Visuospatial** (VIS) we have dropped the MMSE copy polygons item and retained a single indicator, the CERAD constructional praxis test (immediate).

The following section, which looks at a multiple correlated factors model including all domains, will reflect these decisions on inclusion of indicators.

7.1 Additional Unidimensional Models

After estimating the correlated factors model (described in the following section), we decided to combine episodic memory delayed and recognition memory factors into a general memory factor, and we also decided to combine the set shifting and attention, speed factors into a single executive functioning factor. Rationale and details of these decisions are described in the next section. In this section of the report, I describe the fit of these new unidimensional models.

7.2 Model IID: Memory (delayed and recognition)

```
. fitsis `m´
CFI = 0.978
RMSEA = 0.055
SRMR = 0.022
matrix  element residual_variances_vdmde1z column 1 is -> 0.022 (returned as r(r1))
matrix  element residual_variances_vdmde2z column 1 is -> 0.015 (returned as r(r1))
matrix  element residual_variances_vdmde4z column 1 is -> 0.047 (returned as r(r1))
matrix  element residual_variances_vdmde5z column 1 is -> 0.045 (returned as r(r1))
matrix  element residual_variances_vdmre1z column 1 is -> 0.005 (returned as r(r1))
matrix  element residual_variances_vdmre2z column 1 is -> 0.015 (returned as r(r1))
matrix  element stdyx_mem_by_vdmde1z column 1 is -> 0.806 (returned as r(r1))
matrix  element stdyx_mem_by_vdmde2z column 1 is -> 0.740 (returned as r(r1))
matrix  element stdyx_mem_by_vdmde3 column 1 is -> 0.776 (returned as r(r1))
matrix  element stdyx_mem_by_vdmde4z column 1 is -> 0.678 (returned as r(r1))
matrix  element stdyx_mem_by_vdmde5z column 1 is -> 0.654 (returned as r(r1))
matrix  element stdyx_mem_by_vdmre1z column 1 is -> 0.656 (returned as r(r1))
matrix  element stdyx_mem_by_vdmre2z column 1 is -> 0.596 (returned as r(r1))
matrix  element stdyx_ceradwl_by_vdmde1z column 1 is -> 0.207 (returned as r(r1))
matrix  element stdyx_ceradwl_by_vdmre1z column 1 is -> 0.467 (returned as r(r1))
matrix  element stdyx_lm_by_vdmde2z column 1 is -> 0.359 (returned as r(r1))
matrix  element stdyx_lm_by_vdmre2z column 1 is -> 0.431 (returned as r(r1))
matrix  element stdyx_ceradwl_with_lm column 1 is -> 0.000 (returned as r(r1))
matrix  element stdyx_ceradwl_with_mem column 1 is -> 0.000 (returned as r(r1))
matrix  element stdyx_lm_with_mem column 1 is -> 0.000 (returned as r(r1))
. runmplus_show_output_segment model`m´.out "Number of observations" 1

  Number of observations                                        3345
. runmplus_show_output_segment model`m´.out "Number of dependent variables" 1

  Number of dependent variables                                    7
. runmplus_show_output_segment model`m´.out "Chi-Square Test of Model Fit" 5

  Chi-Square Test of Model Fit

          Value                            133.333*
          Degrees of Freedom                    12
          P-Value                           0.0000
```

Omega = 0.89
Comment: This model fits adequately. The SRMR and CFI indicate good fit, the RMSEA is not as low as would be desired. The loadings in the general domain are greater than the loadings in the specific domains for the bifactor model part, which supports the inclusion of these indicators in the general model.

7.3 Model IIIA: Executive function (set shifting and attention, speed)

```
. fitsis `m´
CFI = 0.915
RMSEA = 0.107
SRMR = 0.039
matrix  element residual_variances_vdexf1z column 1 is -> 0.021 (returned as r(r1))
matrix  element residual_variances_vdexf2z column 1 is -> 0.018 (returned as r(r1))
matrix  element residual_variances_vdexf7z column 1 is -> 0.019 (returned as r(r1))
matrix  element residual_variances_vdasp1z column 1 is -> 0.006 (returned as r(r1))
matrix  element residual_variances_vdasp2z column 1 is -> 0.004 (returned as r(r1))
matrix  element residual_variances_vdasp4z column 1 is -> 0.010 (returned as r(r1))
matrix  element residual_variances_vdasp5z column 1 is -> 0.011 (returned as r(r1))
matrix  element stdyx_exf_by_vdexf1z column 1 is -> 0.743 (returned as r(r1))
matrix  element stdyx_exf_by_vdexf2z column 1 is -> 0.745 (returned as r(r1))
matrix  element stdyx_exf_by_vdexf7z column 1 is -> 0.637 (returned as r(r1))
matrix  element stdyx_exf_by_vdasp1z column 1 is -> 0.892 (returned as r(r1))
matrix  element stdyx_exf_by_vdasp2z column 1 is -> 0.809 (returned as r(r1))
matrix  element stdyx_exf_by_vdasp3 column 1 is -> 0.590 (returned as r(r1))
matrix  element stdyx_exf_by_vdasp4z column 1 is -> 0.712 (returned as r(r1))
matrix  element stdyx_exf_by_vdasp5z column 1 is -> 0.692 (returned as r(r1))
. runmplus_show_output_segment model`m´.out "Number of observations" 1

  Number of observations                                        3343

. runmplus_show_output_segment model`m´.out "Number of dependent variables" 1

  Number of dependent variables                                    8

. runmplus_show_output_segment model`m´.out "Chi-Square Test of Model Fit" 5

  Chi-Square Test of Model Fit

            Value                            779.246*
            Degrees of Freedom                   20
            P-Value                           0.0000
```

Omega = 0.94
Comment: This model fits poorly.

8 Psychometric modeling - multidimensional models

This model includes all indicators and their specific factors (orientation and visuspatial with single indicators) and no methods factors. Specific factors are allowed to correlate freely.

8.1 Model VII: Correlated factors model

8.2 Summary of factor models 11 - 11

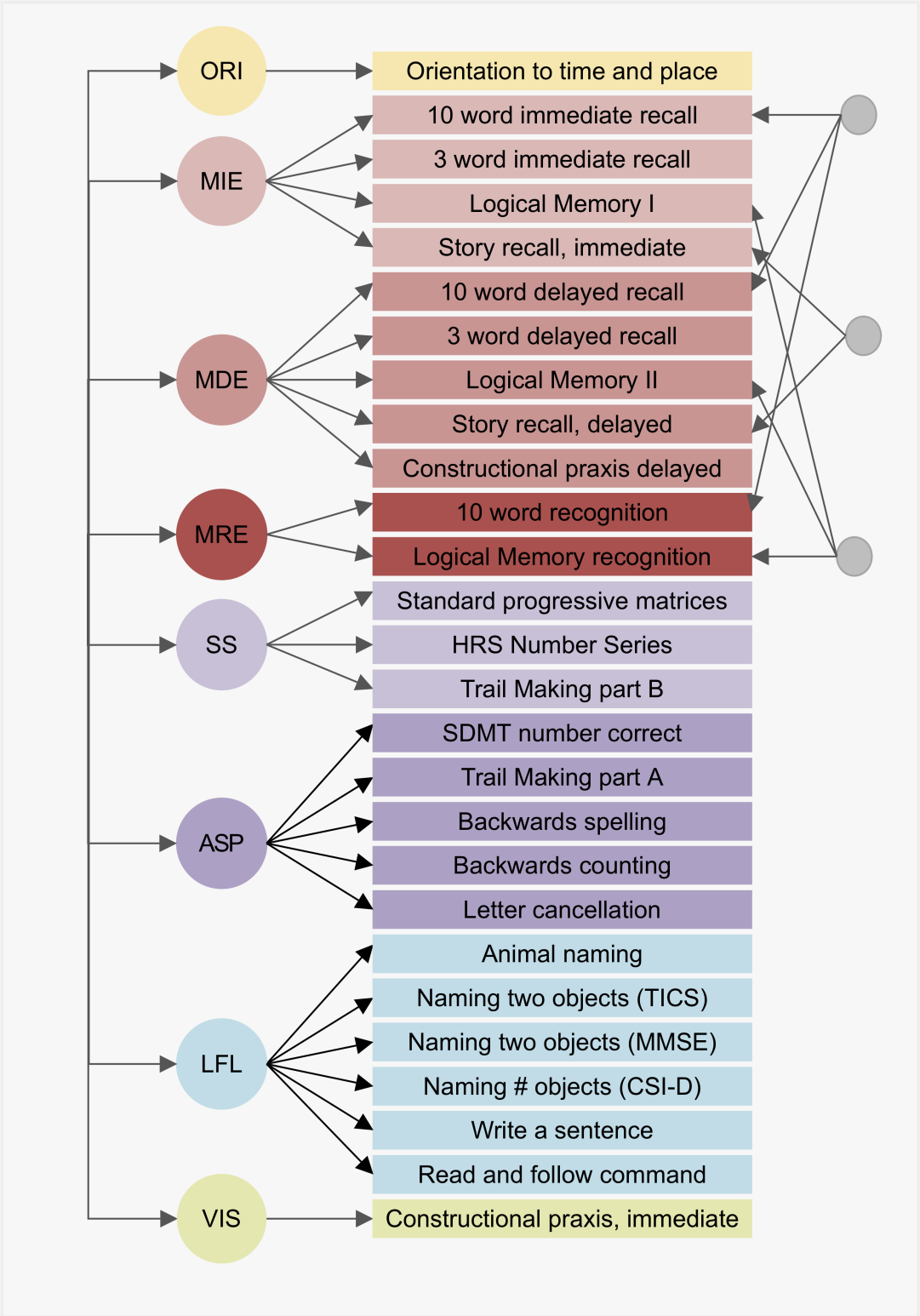
Model	Description	Items	CFI	RMSEA	SRMR	Fit Assessment	NRV
11. VII	Correlated factors model	27	0.858	0.078	0.055	poor (0.90)	•

Notes: Items indicates the number of dependent variables; a •under the NRV column indicates the presence of a negative residual variance, or a standardized factor loading that is greater than 1.0, or a standardized covariance parameter greater than 1.0.

Comment: Problems with the correlated factors model are standardized covariances among the memory factors greater than 1. This could be due to the fact that the tests are not measuring something distinct, or are due to the fact that some of the indicators in these domains share stimulus material. I think it's that shared material and will attempt to address with methods factors.

8.3 Model VIII: Correlated factors (with methods factors)

Specific factors are included for the CERAD word list, Brave man text, and Logical Memory text. Here's a picture:



Note: I considered a MMSE word list residual, but the variance wanted to be negative. A a residual covariances was included, but this was not significant and not retained in the model displayed

(residual correlation = -.01).

8.4 Summary of factor models 11 - 12

Model	Description	Items	CFI	RMSEA	SRMR	Fit Assessment	NRV
11. VII	Correlated factors model	27	0.858	0.078	0.055	poor (0.90)	•
12. VIII	Correlated factors (with methods factors)	27	0.932	0.054	0.044	adequate (0.94)	

Notes: Items indicates the number of dependent variables; a •under the NRV column indicates the presence of a negative residual variance, or a standardized factor loading that is greater than 1.0, or a standardized covariance parameter greater than 1.0.

This last model, model 12, is a decent model to look at fits to see if there are further modifications to be made.

Table 1. Model 12 latent factor correlations, Correlated factors (with methods factors)

Factor 1	Factor 2	Corr
Memory, delayed episodic	Memory, immediate episodic	0.95
Attention, speed	Set shifting	0.94
Language, fluency	Memory, immediate episodic	0.93
Language, fluency	Set shifting	0.93
Memory, recognition	Memory, delayed episodic	0.92
Memory, recognition	Memory, immediate episodic	0.90
Language, fluency	Attention, speed	0.89
Language, fluency	Memory, delayed episodic	0.88
Language, fluency	Memory, recognition	0.84
Set shifting	Memory, immediate episodic	0.80
Attention, speed	Memory, immediate episodic	0.80
Attention, speed	Memory, delayed episodic	0.78
Set shifting	Memory, delayed episodic	0.78
Orientation	Memory, recognition	0.72
Attention, speed	Memory, recognition	0.70
Orientation	Language, fluency	0.70
Set shifting	Memory, recognition	0.67
Visuospatial	Set shifting	0.65
Orientation	Memory, immediate episodic	0.64
Visuospatial	Language, fluency	0.59
Orientation	Memory, delayed episodic	0.59
Visuospatial	Attention, speed	0.57
Orientation	Attention, speed	0.56
Orientation	Set shifting	0.51
Visuospatial	Memory, delayed episodic	0.51
Visuospatial	Memory, immediate episodic	0.50
Visuospatial	Memory, recognition	0.41
Visuospatial	Orientation	0.33

Note that this implies that 0.95×0.95 = 90% of the variance in MIE and MDE is shared between the two constructs. Similar for ASP and EXF, and LFL and MIE.

Table 2 Model 12 Standardized measurement slopes, Correlated factors (with methods factors)
(aka factor loadings)

	Specific factor		Methods factors	
Domain and item	Estimate	SE	Estimate	SE
Memory, immediate episodic (MIE)				
CERAD word list immediate sum of 3 trials (0-30) (vdmie1z)	0.79	(0.01)	0.55	(0.01)
MMSE 3 word recognition (0-3) (vdmie2)	0.34	(0.02)		
Logical memory immediate (0-25) (vdmie3z)	0.70	(0.01)	0.61	(0.01)
Brave man immediate (0-12) (vdmie4z)	0.63	(0.01)	0.56	(0.01)
Omega = 0.72				
Memory, delayed episodic (MDE)				
CERAD word list delayed (0-10) (vdmde1z)	0.80	(0.01)	0.37	(0.01)
Logical memory delayed (0-25) (vdmde2z)	0.69	(0.01)	0.61	(0.01)
MMSE 3 word delayed recall (0-3) (vdmde3)	0.51	(0.01)		
CERAD constructional praxis delayed (0-11) (vdmde4z)	0.72	(0.01)		
Brave man delayed score (0-12) (vdmde5z)	0.64	(0.01)	0.41	(0.01)
Omega = 0.81				
Memory, recognition (MRE)				
CERAD word list recognition task (0-20) (vdmre1z)	0.78	(0.01)	0.14	(0.02)
Logical memory recognition (0-15) (vdmre2z)	0.54	(0.01)	0.39	(0.02)
Omega = 0.61				
Set shifting (EXF)				
Raven's progressive matrices (vdexf1z)	0.79	(0.01)		
Trails B time (observed 32-300 seconds) (vdexf2z)	0.81	(0.01)		
HRS Number Series (vdexf7z)	0.76	(0.01)		
Omega = 0.83				
Attention, speed (ASP)				
Symbol Digit Modalities Test score (vdasp1z)	0.93	(0.00)		
Trails A (vdasp2z)	0.84	(0.01)		
MMSE spell world backwards (vdasp3)	0.52	(0.01)		
Backwards counting (vdasp4z)	0.72	(0.01)		
Letter cancellation (vdasp5z)	0.76	(0.01)		
Omega = 0.87				
Language, fluency (LFL)				
Category fluency (animals) (vdlfl1z)	0.68	(0.01)		
Naming 2 items HRS TICS scissors, cactus (vdlfl2)	0.47	(0.01)		
Naming 2 items MMSE (vdlfl3)	0.27	(0.02)		
MMSE write a sentence (vdlfl4)	0.34	(0.02)		
MMSE read and follow command (vdlfl5)	0.28	(0.02)		
1066 object naming (vdlfl6)	0.43	(0.02)		
Omega = 0.56				

Includes logical memory, brave man, and CERAD word list methods factors.

8.4.1 Issues listing

Here are the issues:

- Overall the model fit is not good
  - The RMSEA is greater than 0.05
  - The CFI is less than 0.95
  - **Proposed action:** We will have a look at the residuals and modification indices
- Lack of memory subdomain specificity
  - **Issue:** The memory specific factors are unconvincingly measuring distinct constructs.
  - **Proposed action:**
    - Drop immediate episodic memory because it is indistinct from multiple other domains, including delayed episodic memory and also language. The immediate episodic memory factor has other problems
      - The MMSE *3 word recognition (0-3) (vdmie2)* is a lousy indicator of MIE. We could drop the MMSE 3 word registration, which might imply dropping the 3 word recall items. We've been through this already in the single domain models. It is a dead end that ends up causing more problems than it fixes. That does not mean the approach couldn't be revisited in the correlated factors approach. But current decision is to leave it as is. More on MMSE below.
    - Combine delayed episodic memory and recognition memory into a single domain
- Lack of distinction between *Attention, speed* and *Executive Function*
  - **Issue:** The two factors share nearly 90% of their variance
  - **Proposed action:** Consider combining set shifting and attention, speed into a single factor
- MMSE items are poor all around (MIE, MDE, ASP, LFL domains)
  - **Issue:** For every domain that includes MMSE items, the MMSE items are the poorest indicators (lowest standardized measurement slope.) Why do we retain these items?
  - **Proposed solution:** Although we have already had some bad experiences dropping MMSE items from specific domains, we could reconsider the proposition in the correlated factors situation. The items may have some potential utility in linking and harmonization activities, but how much and a justification for their inclusion on that basis is unknown.

8.5 Model IX: Correlated factors with single memory and no immediate episodic

8.6 Summary of factor models 13 - 13

Model	Description	Items	CFI	RMSEA	SRMR	Fit Assessment	NRV
13. IX	Correlated factors model no MIE (MDE,MRE)	23	0.948	0.044	0.046	adequate (0.95)	

Notes: Items indicates the number of dependent variables; a •under the NRV column indicates the presence of a negative residual variance, or a standardized factor loading that is greater than 1.0, or a standardized covariance parameter greater than 1.0.

8.7 Model X: Correlated factors with single memory and no immediate episodic and single executive domain

8.8 Summary of factor models 14 - 14

Model	Description	Items	CFI	RMSEA	SRMR	Fit Assessment	NRV
14. X	Correlated factors model no MIE (MDE,MRE)	23	0.944	0.046	0.047	adequate (0.94)	

Notes: Items indicates the number of dependent variables; a •under the NRV column indicates the presence of a negative residual variance, or a standardized factor loading that is greater than 1.0, or a standardized covariance parameter greater than 1.0.

Difference between model IX and X

The DIFFTEST χ^2 is 146.904 on 5 degrees of freedom, with $P < .001$. So the model does not fit appreciably worse on the basis of fit statistics, but by difference testing of the model chi-square is statistically significant.

Table 3. Model 14 latent factor correlations, Correlated factors model no MIE (MDE,MRE)

Factor 1	Factor 2	Corr
Language, fluency	Memory, delayed episodic	0.82
Language, fluency	Set shifting	0.81
Set shifting	Memory, delayed episodic	0.75
Orientation	Memory, delayed episodic	0.63
Visuospatial	Set shifting	0.57
Visuospatial	Language, fluency	0.55
Orientation	Set shifting	0.53
Orientation	Language, fluency	0.53
Visuospatial	Memory, delayed episodic	0.46
Visuospatial	Orientation	0.32

Note that this implies that 0.95×0.95 = 90% of the variance in MIE and MDE is shared between the two constructs. Similar for ASP and EXF, and LFL and MIE.

Table 4 Model 14 Standardized measurement slopes, Correlated factors model no MIE (MDE,MRE)
(aka factor loadings)

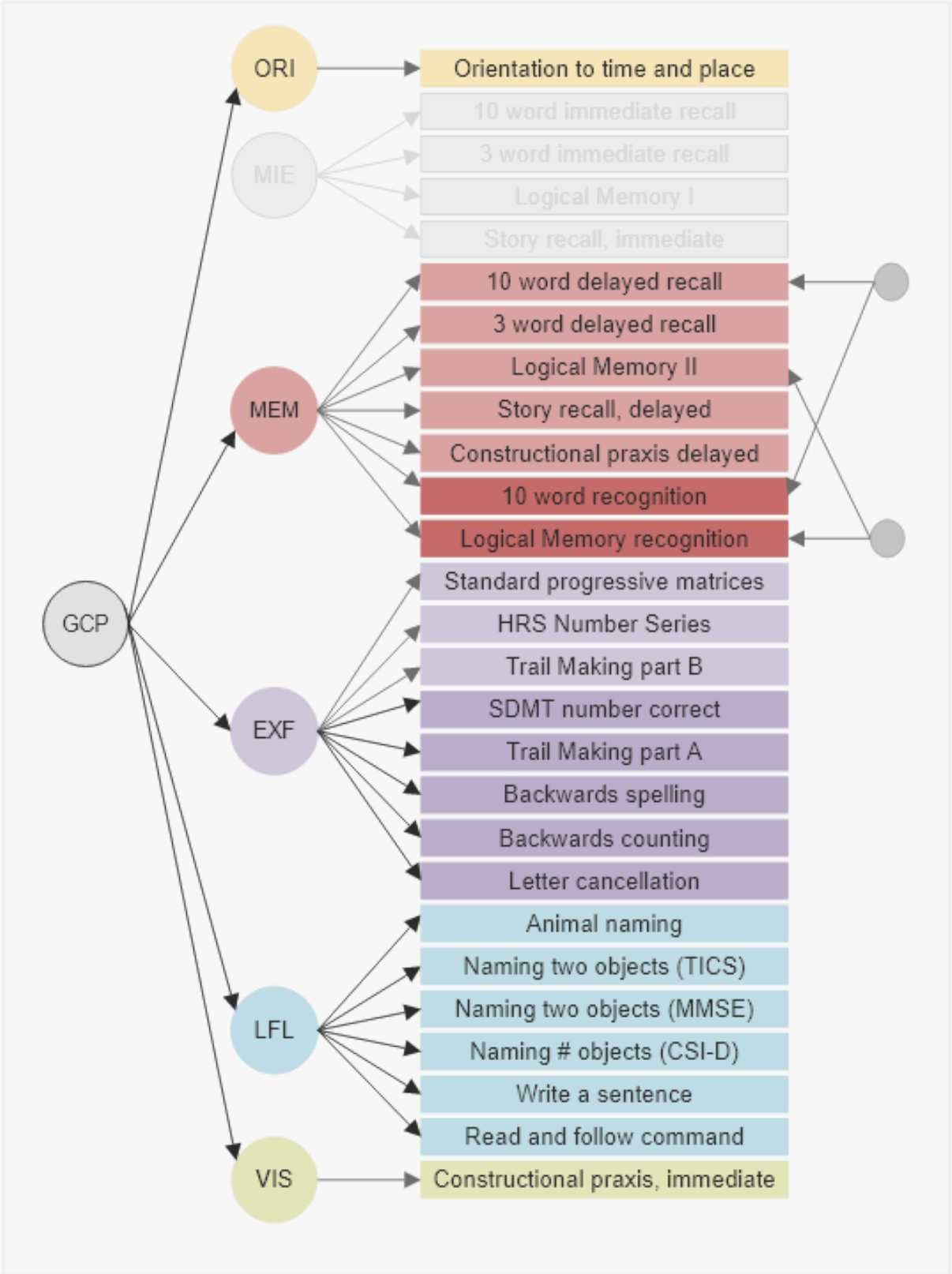
	Factor	
Domain and item	Estimate	SE
Memory, immediate episodic (MIE)		
Memory, delayed episodic (MDE)		
CERAD word list delayed (0-10) (vdmde1z)	0.78	(0.01)
Logical memory delayed (0-25) (vdmde2z)	0.72	(0.01)
MMSE 3 word delayed recall (0-3) (vdmde3)	0.75	(0.02)
CERAD constructional praxis delayed (0-11) (vdmde4z)	0.76	(0.01)
Brave man delayed score (0-12) (vdmde5z)	0.61	(0.01)
CERAD word list recognition task (0-20) (vdmre1z)	0.66	(0.01)
Logical memory recognition (0-15) (vdmre2z)	0.60	(0.01)
Omega = 0.87		
Memory, recognition (MRE)		
Set shifting (EXF)		
Raven's progressive matrices (vdexf1z)	0.78	(0.01)
Trails B time (observed 32-300 seconds) (vdexf2z)	0.70	(0.01)
HRS Number Series (vdexf7z)	0.62	(0.01)
Symbol Digit Modalities Test score (vdasp1z)	0.88	(0.01)
Trails A (vdasp2z)	0.79	(0.01)
MMSE spell world backwards (vdasp3)	0.62	(0.02)
Backwards counting (vdasp4z)	0.72	(0.01)
Letter cancellation (vdasp5z)	0.70	(0.01)
Omega = 0.90		
Attention, speed (ASP)		
Language, fluency (LFL)		
Category fluency (animals) (vdlfl1z)	0.77	(0.01)
Naming 2 items HRS TICS scissors, cactus (vdlfl2)	0.73	(0.02)
Naming 2 items MMSE (vdlfl3)	0.65	(0.05)
MMSE write a sentence (vdlfl4)	0.56	(0.03)
MMSE read and follow command (vdlfl5)	0.49	(0.04)
1066 object naming (vdlfl6)	0.52	(0.02)
Omega = 0.79		

The *Omega* entries in the table above are factor reliability estimates. Values can be interpreted as other internal consistency reliability coefficients (e.g., Cronbach's alpha). Values greater than 0.90 are considered reasonable for outcome measures, and may support individual level inference. Lower values may still be good for group differences research, down to about 0.6. Note that the common factors in this model are more aptly named **Memory**, **Executive functioning** and **Language, fluency**. Immediate episodic memory items are not included. Delayed episodic memory and recognition memory items are contained in a single factor (Memory). Set shifting and attention, speed items are in a single factor (executive functioning). Orientation and visuospatial are in the model as single factor indicators.

9 Specific alternative model 15: XI - Second order model

With orientation. No immediate recognition, no narrow domains.

Here's a picture of the model:


GCP
ORI
MIE
MEM
EXF
LFL
VIS
Orientation to time and place
10 word immediate recall
3 word immediate recall
Logical Memory I
Story recall, immediate
10 word delayed recall
3 word delayed recall
Logical Memory II
Story recall, delayed
Constructional praxis delayed
10 word recognition
Logical Memory recognition
Standard progressive matrices
HRS Number Series
Trail Making part B
SDMT number correct
Trail Making part A
Backwards spelling
Backwards counting
Letter cancellation
Animal naming
Naming two objects (TICS)
Naming two objects (MMSE)
Naming # objects (CSI-D)
Write a sentence
Read and follow command
Constructional praxis, immediate

9.1 Summary of factor models 15

Model	Description	Items	CFI	RMSEA	SRMR	Fit Assessment	NRV
15	Second order model	23	0.935	0.049	0.048	adequate (0.94)	

Notes: Items indicates the number of dependent variables; a •under the NRV column indicates the presence of a negative residual variance, or a standardized factor loading that is greater than 1.0, or a standardized covariance parameter greater than 1.0.

Table 5 Model 15 Standardized measurement slopes, Second order model
(aka factor loadings)

		Factor
Domain and item	Estimate	SE
General cognitive performance (G)		
CERAD Constructional praxis (vdvis1z)	0.60	(0.01)
Memory (gmem)	0.88	(0.01)
Executive functioning (gexf)	0.87	(0.01)
Language, fluency (lfl)	0.93	(0.01)
Omega = 0.90		
Memory (GMEM)		
CERAD word list delayed (0-10) (vdmde1z)	0.78	(0.01)
Logical memory delayed (0-25) (vdmde2z)	0.72	(0.01)
MMSE 3 word delayed recall (0-3) (vdmde3)	0.75	(0.02)
CERAD constructional praxis delayed (0-11) (vdmde4z)	0.76	(0.01)
Brave man delayed score (0-12) (vdmde5z)	0.61	(0.01)
CERAD word list recognition task (0-20) (vdmre1z)	0.66	(0.01)
Logical memory recognition (0-15) (vdmre2z)	0.60	(0.01)
Omega = 0.87		
Executive functioning (GEXF)		
Raven's progressive matrices (vdexf1z)	0.77	(0.01)
Trails B time (observed 32-300 seconds) (vdexf2z)	0.70	(0.01)
HRS Number Series (vdexf7z)	0.62	(0.01)
Symbol Digit Modalities Test score (vdasp1z)	0.88	(0.01)
Trails A (vdasp2z)	0.79	(0.01)
MMSE spell world backwards (vdasp3)	0.62	(0.02)
Backwards counting (vdasp4z)	0.72	(0.01)
Letter cancellation (vdasp5z)	0.70	(0.01)
Omega = 0.90		
Language, fluency (LFL)		
Category fluency (animals) (vdlfl1z)	0.78	(0.01)
Naming 2 items HRS TICS scissors, cactus (vdlfl2)	0.73	(0.02)
Naming 2 items MMSE (vdlfl3)	0.64	(0.05)
MMSE write a sentence (vdlfl4)	0.56	(0.03)
MMSE read and follow command (vdlfl5)	0.49	(0.04)
1066 object naming (vdlfl6)	0.52	(0.02)
Omega = 0.79		
CERAD word list methods factor (CERADWL)		
CERAD word list delayed (0-10) (vdmde1z)	0.23	(0.01)
CERAD word list recognition task (0-20) (vdmre1z)	0.51	(0.02)
Omega = 0.24		
Logical memory methods factor (LM)		

Logical memory delayed (0-25) (vdmde2z)	0.36	(0.01)
Logical memory recognition (0-15) (vdmre2z)	0.44	(0.02)
Omega = 0.28		

The *Omega* entries in the table above are factor reliability estimates. Values can be interpreted as other internal consistency reliability coefficients (e.g., Cronbach's alpha). Values greater than 0.90 are considered reasonable for outcome measures, and may support individual level inference. Lower values may still be good for group differences research, down to about 0.6.

10 Specific alternative model 16: XIA - Second order model-drop orientation

Without orientation. No immediate recognition, no narrow domains.

10.1 Summary of factor models 16

Model	Description	Items	CFI	RMSEA	SRMR	Fit Assessment	NRV
16	Second order model-drop orientation	22	0.949	0.043	0.047	adequate (0.95)	

Notes: Items indicates the number of dependent variables; a •under the NRV column indicates the presence of a negative residual variance, or a standardized factor loading that is greater than 1.0, or a standardized covariance parameter greater than 1.0.

Table 6 Model 16 Standardized measurement slopes, Second order model-drop orientation
(aka factor loadings)

	Factor	
Domain and item	Estimate	SE
General cognitive performance (G)		
CERAD Constructional praxis (vdvis1z)	0.60	(0.01)
Memory (gmem)	0.85	(0.01)
Executive functioning (gexf)	0.89	(0.01)
Language, fluency (lfl)	0.94	(0.01)
Omega = 0.90		
Memory (GMEM)		
CERAD word list delayed (0-10) (vdmde1z)	0.78	(0.01)
Logical memory delayed (0-25) (vdmde2z)	0.74	(0.01)
MMSE 3 word delayed recall (0-3) (vdmde3)	0.76	(0.02)
CERAD constructional praxis delayed (0-11) (vdmde4z)	0.77	(0.01)
Brave man delayed score (0-12) (vdmde5z)	0.62	(0.01)
CERAD word list recognition task (0-20) (vdmre1z)	0.63	(0.01)
Logical memory recognition (0-15) (vdmre2z)	0.60	(0.01)
Omega = 0.87		
Executive functioning (GEXF)		
Raven's progressive matrices (vdexf1z)	0.78	(0.01)
Trails B time (observed 32-300 seconds) (vdexf2z)	0.71	(0.01)
HRS Number Series (vdexf7z)	0.62	(0.01)
Symbol Digit Modalities Test score (vdasp1z)	0.89	(0.01)
Trails A (vdasp2z)	0.79	(0.01)
MMSE spell world backwards (vdasp3)	0.62	(0.02)
Backwards counting (vdasp4z)	0.72	(0.01)
Letter cancellation (vdasp5z)	0.70	(0.01)
Omega = 0.90		
Language, fluency (LFL)		
Category fluency (animals) (vdlfl1z)	0.77	(0.01)
Naming 2 items HRS TICS scissors, cactus (vdlfl2)	0.74	(0.02)
Naming 2 items MMSE (vdlfl3)	0.67	(0.05)
MMSE write a sentence (vdlfl4)	0.56	(0.03)
MMSE read and follow command (vdlfl5)	0.49	(0.04)
1066 object naming (vdlfl6)	0.52	(0.02)
Omega = 0.80		
CERAD word list methods factor (CERADWL)		
CERAD word list delayed (0-10) (vdmde1z)	0.25	(0.01)
CERAD word list recognition task (0-20) (vdmre1z)	0.56	(0.02)
Omega = 0.29		
Logical memory methods factor (LM)		

Logical memory delayed (0-25) (vdmde2z)	0.35	(0.02)
Logical memory recognition (0-15) (vdmre2z)	0.42	(0.02)
Omega = 0.26		

The *Omega* entries in the table above are factor reliability estimates. Values can be interpreted as other internal consistency reliability coefficients (e.g., Cronbach's alpha). Values greater than 0.90 are considered reasonable for outcome measures, and may support individual level inference. Lower values may still be good for group differences research, down to about 0.6.

11 Factor score estimation

Factor score estimation is conducted at the single domain level, meaning the factor scores are estimated separately for multiple indicator domains separately. We also estimate a general cognitive composite using all domains and the orientation and visual processing single indicators. Factor scores are generated using weighted least squares, maximum likelihood, and Bayes methods. These return, respectively, expected a posteriori, regression method, and plausible values as factor score estimates.

11.1 mem

11.2 exf

11.3 lfl

11.4 gcp