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ABSTRACT

Herzog and Wallace (A. Herzog and R. Wallace, 1997) discussed a measure designed to assess the cognitive functioning of older adults who participated in the study formerly known as the Asset and Health Dynamics among the Oldest Old (AHEAD). The measure derived from four well-known tests of cognitive functioning, but improves on them by combining elements of each emphasizing those aspects most relevant to the cognitive changes in the gerontological population. This measure promises to allow researchers to identify cognitive changes that may lead to dementia more effectively. While this measure has been used to assess large numbers of people, it has not been scrutinized empirically as an evaluative tool to assess the internal and external structural validity evidence of the scores produced. To understand this underlying factor structure of the instrument better, longitudinal congeneric, tau-equivalent, and parallel models were fit using five waves of the Health and Retirement study data (previously the AHEAD study) obtained from the University of Michigan. There were 2,681 male respondents and 3,841 females. The final three survey years provided surprisingly consistent models of the cognitive indicators. The first two survey years did not. Results indicate that the three measures used as indicators of cognition (immediate recall, delayed recall, and reverse 7s) are neither tau-equivalent nor parallel. Immediate and delayed recall, however, are equivalent measures of cognition when the word list contains 10 words, but are not parallel. (Contains 2 figures, 3 tables, and 9 references.) (Author/SLD)

Running Head: MEASURING COGNITIVE FUNCTION

Measuring cognitive function: An empirical investigation of the psychometric properties of a cognitive measure

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abstract

Herzog and Wallace (1997) discussed a measure designed to assess the cognitive functioning of older adults who participated in the study, formerly known as the Asset and Health Dynamics among the Oldest Old (AHEAD). The measure derives from four well-known tests of cognitive functioning but improves upon them by combining elements from each emphasizing those aspects most relevant to the cognitive changes in the gerontological population. This measure promises to allow researchers to more effectively identify the cognitive change that may lead to dementia. While this measure has been used to assess large numbers of people, it has not been empirically scrutinized as an evaluative tool to assess the internal and external structural validity evidence of the scores produced. To better understand the underlying factor structure of the instrument, longitudinal congeneric, tau-equivalent, and parallel models were fit using five waves of the Health and Retirement study data (previously called AHEAD) obtained from the University of Michigan. The final three survey years provided surprisingly consistent models of the cognitive indicators. The first two survey years did not. Results are presented and discussed.

As the baby boomers enter retirement age concern for gerontological issues is becoming more pervasive in multiple disciplines. In the fields of psychology and neurology heightened concern has been placed on the quality of life of older adults particularly with respect to their mental awareness. Specifically, psychological and neurological researchers have placed increasing emphasis on the development of evaluative methods focusing on declarative memory and mental status because of the need to detect the onset of dementia to slow its progress. However, for an instrument to be effective it must first be scrutinized with respect to its ability to truly measure what it purports to measure.

Recently, researchers at the University of Michigan participating in a study formerly know as the Asset and Health Dynamics among the Oldest Old (AHEAD) assembled an innovative measure emphasizing those aspects most relevant to the cognitive changes in the gerontological population. Herzog and Wallace (1997) discuss the composition of this measure, providing some evidence of the reliability and validity of the scores the measure produces. This study proposed a more rigorous examination of the cognitive measure used, specifically examining how well the constructs underlying the measure are sustained over time, and the manner in which they do so (i.e., congeneric, tau-equivalent, or parallel processes). The data was analyzed using LISREL 8.3, a program designed for structural equation modeling. Structural equation modeling is superior to traditional least squares statistical procedures because it allows researchers to better understand the latent constructs that underlie a test, while controlling for measurement error, a notorious problem resident in most social science measures. Structural equation modeling takes into consideration just how reliable a measure is when estimating variable relationships and underlying factor structures, and therefore leads to estimates far less biased than those produced by traditional, parametric statistics.

Congeneric Model

Measures are congeneric if their true values have "all pair-wise correlations equal to unity" (Jöreskog & Sörbom, 1996, p.125). Thus, in a congeneric model true scores are a linear function of the true scores of any other variable and the error variances are unequal. In the LISREL model this permits factor loadings and unique variances to vary across measures while sharing a single common factor (Millsap & Everson, 1991). In essence the congeneric model simply specifies that the variables are measuring the same construct.

Tau Equivalent Model

Measures are tau equivalent if true scores are identical, but have unequal variances. Thus if scores contribute equally to the latent construct, even though the means and standard deviations differ, the measures are tau equivalent. In the Lisrel model this requires that factor loadings are equal. Unique variances, however, are permitted to differ (Feldt, 2002; Hakistan & Barchard, 2000; Jöreskog & Sörbom, 1996; Millsap & Everson, 1991). Therefore the tau equivalent model requires that the variables measuring a construct contribute equally to measurement of that construct.

Parallel Model

Measures are parallel if the true scores and the unique variances are identical. Thus not only is it required that the factor loadings are identical, but also that the unique error variances are also identical (Feldt, 2002; Hakistan & Barchard, 2000; Jöreskog &

Sörbom, 1996; Millsap & Everson, 1991). Consequently, each model tested is a further restriction on the prior model.

Measures of Fit

Because each model (congeneric, tau-equivalent, and parallel) is build on the prior model, the models are considered to be hierarchical and can be tested for differences in fit. The difference chi-square ($\Delta\chi^2$) is distributed as a chi-square value with difference degrees of freedom (Δdf).

Method

Data for this study was obtained from the University of Michigan Health and Retirement Survey. This survey has been conducted since 1992 with the final data released in 2000. Although there was an additional release of data (AHEAD) in 1995, this study used only data from the 1992, 1994, 1996, 1998, and 2000 survey years. Data for this study was extracted from each year's database and merged using SPSS 10.0.

Of the 24,000 respondents to this survey, only 6,522 had completed the cognitive measures used in this study. There were 2681 male respondents and 3841 females. The racial composition was 5266 white/Caucasian, 714 black/African-American, 44 American Indian/Alaska Native, 73 Asian/Pacific Islanders, 416 Hispanic/Latino, and 1 Other. Age ranged from 23 to 80 years old in 1992 with an average age of 55.1 (SD 5.38). All respondents completing the cognitive measures for all 5 time periods were included.

Immediate Recall, Delayed Recall, and Reverse 7s were the three cognitive measures used in the current study. Immediate and Delayed Recall in 1992 and 1994 consisted of a list of 20 words read to the respondents. For immediate recall respondents were asked to recall the list of words. Thus they could have a total score of 20 correct words. Other questions were asked. Then for delayed recall, respondents were asked to again recall the words from the prior list. Reverse 7s was not used these years. In 1996 the format was changed. The word list consisted of 10 words read to the respondent. For immediate recall the respondent was asked to recall as many of the words as s/he could. Further questions were asked. Then the respondent was asked to remember the prior list and recall as many words as possible for delayed recall. The respondent was permitted 11 responses and could achieve a score of 11.

For the Reverse 7s test, respondents were asked to subtract seven from 100, then seven from that response, for a total of 5 subtractions. Thus the respondent could score a 5 for this test. There were also other items that could measure cognition in the database. However, most of these were asked of few respondents and were not consistently presented.

Our purpose in this study was two-fold: (1) to examine the structure of the cognitive measures each year specifically testing for tau-equivalence and parallel tests and (2) to examine the equivalence of the cognitive measures across years. To determine if the tests were congeneric, the correlation matrices, means, and standard deviations for each year were entered into LISREL 8.3. To test the tau-equivalence of the tests, factor loadings were then constrained to equivalence. To assess whether the tests were parallel, error variances were also constrained to equivalence. Figure 1 depicts the congeneric model.

Insert Figure 1 About here

In order to test the equivalence of the measures across years, the latent cognition variable in congeneric model for each year was permitted to correlate with the same variable for all other years. This provided an estimate or an omnibus congeneric model. Then all paths from cognition to immediate recall across the 5 survey years were constrained to equivalence. Similarly, all paths from cognition to delayed recall across survey years were constrained to equivalence, and all paths from cognition to reverse 7s across 3 survey years were constrained to equivalence. This provided a model of omnibus tau-equivalence of the measure across survey years. Finally, to test the parallel structure of the measures across survey years, the unique variance of immediate recall was constrained to equivalence across years. The unique variance of delayed recall and reverse 7s was constrained in a similar manner. This model is displayed in Figure 2.

Insert Figure 2 About here

Model fit criteria are based on differences between the observed and the model implied covariance matrix. A statistically significant χ^2 value suggests the observed and implied matrices are different. In addition, although the sample size of 6,522 is small compared to 24,000 in the original database, the value of chi-square (χ^2) is severely affected by sample size. Thus a small discrepancy between the observed and implied covariance matrices when the sample size is large can lead to a statistically significant $\chi 2$ and rejection of a good model. Consequently, other measures of fit were also used. Keith & Witta (1997) suggested the use of a Differential Fit Value (DFV) based on a still large sample size of 1000. For this study the DFV was calculated using χ^2 (6522-1)/(1000-1). The root mean square error of approximation (RMSEA) was used to provide a measure of model mis-specification and a measure of discrepancy between the sample and reproduced covariance matrices per degree of freedom (Browne & Cudeck, 1993). A value of 0.06 (Hu & Bentler, 1999), 0.05 (Browne & Cudeck, 1993) or less indicates one measure of adequate fit. The Tucker-Lewis coefficient or non-normed fit index (NNFI; Bentler & Bonnett, 1980) was used to provide a measure of incremental fit when compared to a null model. Values above 0.9 for this index suggest acceptable fit. The normed fit index (NFI) rescales χ^2 into a 0 (no fit) to 1 (perfect fit) range comparing the model to a null model. Models with an NFI value of .9 or higher represent a relatively good fit (Bentler & Bonnett, 1980). In addition, the adjusted goodness-of-fit index (AGFI) is based on a ratio of the sum of the squared differences between observed and implied matrices to the observed variances after adjusting for degrees of freedom for the model (Loehlin, 1987). The AGFI ranges from 1 representing perfect fit to 0 representing no fit but can have negative numbers. Thus large values (e.g. .8, .9) represent a good fit.

Results

When testing the fit of the congeneric, tau-equivalent, and parallel models for individual survey years, the congeneric model could not be tested. In 1992 and 1994 there were only two manifest measures of cognition, immediate and delayed recall. Thus the degrees of freedom (df) for the model were negative. With the addition of the reverse 7s test in 1996 the condition was changed. However, the model was a perfect fit with 0 df and a chi-square (χ^2) value of 0.

When individual survey year measures (immediate recall, delayed recall, reverse 7s) were constrained to tau-equivalence, the 1992 and 1994 data provided a perfect fit (or absolutely no fit) to the model with 0 df and a 0 χ^2 value. For the 1996, 1998, and 2000 survey years, however, the χ^2 values (>1400, 2 df) were statistically significant as shown in Table 1. In addition, the Root Mean Square Estimate of Approximation (RMSEA) ranged from 0.33 to 0.35. Because this fit was so poor, the data was again analyzed. However, only immediate and delayed recall were constrained to equivalence. Model fit as measured by χ^2 and RMSEA improved significantly with χ^2 values changing from 1422 to 9.89, from 1628 to 6.14, and from 1448 to 3.19 for a change of 1 degree of freedom in survey years 2000, 1998, and 1996, respectively. The RMSEA values changed to a range of 0.02 to 0.04, which also implied a better fit.

Insert Table 1 About here

When the tau-equivalent model was adjusted to a sample size of 1000, the χ^2 values produced by all models requiring equivalence of delayed recall, immediate recall, and reverse 7s indicated the models did not fit. However, when only delayed and immediate recall were constrained, the tau-equivalent model fit. When the parallel condition was added to the year models, there was a statistically significant χ^2 value under all conditions as shown in Table 1.

When testing the congeneric model of cognition over time (requiring the correlation of each latent cognition variable to every other to be 1), the initial model produced a χ^2 value of 13,308 (df=65, $p<.001$). All other fit measures were extremely poor. Thus, for this study a baseline model was used permitting the correlations between the latent cognition variables for each year to vary. This model was called the congeneric model. When testing the equivalence of specific measures across the 5 survey year time span, the χ^2 values for the initial congeneric model, the tau-equivalent models using each individual measure and their combination, and the parallel models using each individual measure and their combination were statistically significant under all conditions. In addition, the RMSEA value was never below a 0.09, and the NNFI and the AGFI were never 0.9. In three instances the NFI was 0.92: in the congeneric model, when reverse 7's only were constrained to equivalence, and when reverse 7s were parallel. In addition, the contrast of the tau equivalent and parallel models to the congeneric model was not statistically significant only when comparing the tau-equivalent reverse 7s or the parallel reverse 7s. When contrasting the parallel model to the tau-equivalent model, the χ^2 value was not statistically significant again when only the reverse 7s were constrained. These results are depicted in Table 2.

Insert Table 2 About here

Because reverse 7s were tau equivalent and parallel and were only collect for the 2000, 1998, and 1996 survey years and the format for delayed and immediate recall had changed after the 1994 survey, two further analyses were conducted. The tau-equivalent and parallel models of immediate and delayed recall was tested for the three final survey years (2000, 1998, 1996) and was again tested across the first two survey years (1994, 1992). These results were then converted to differential fit values.

The χ^2 value for the initial model was statistically significant under all conditions as depicted in Table 3. In addition, the fit values for RMSEA and AGFI were not acceptable. However, the smallest value for NFI under these conditions was 0.91 – an acceptable value. And, the lowest value for NNFI was 0.89 and exceeded 0.90 in two cases. When the congeneric model was contrasted with the tau-equivalent model, only delayed recall during the 2000, 1998, and 1996 survey years did not have a statistically significant increase (χ^2 =3.24, df=2). When the congeneric model was contrasted with the parallel model, all increases were statistically significant. When the tau-equivalent model was contrasted with the parallel model during the 2000, 1998, 1996 survey years, there was no statistically significant increase for immediate or delayed recall (χ^2 =1.46, df 2; χ^2 =7.34, df 2).

Insert Table 3 About here

When these values were adjusted to a sample size of 1000, initial χ^2 values were again statistically significant. However, when the congeneric model was contrasted with the tau equivalent model in the 2000, 1998, and 1996 survey years, there was no statistically significant increase in χ^2. However, when the same models were contrasted during the 1994 and 1992 survey years, all χ^2 changes were statistically significant. Similarly, when the congeneric model was contrasted with the parallel model during the 2000, 1998, and 1996 survey years, there was no significant increase. When the same model was tested during the 1994 and 1992 survey years, all χ^2 changes were significant.

When the tau-equivalent and parallel models were contrasted, there was no statistically significant χ^2 change during the 2000, 1998, and 1996 survey years. When contrasted during the 1994 and 1992 survey years, however, only delayed recall showed to significant change. These results are displayed in Table 4.

Discussion and Conclusion

Results from this study indicate that the three measures used as indicators of cognition (immediate recall, delayed recall, and reverse 7s) are neither tau-equivalent nor parallel. Immediate and delayed recall, however, are equivalent measures of cognition when the word list contained 10 words (2000, 1998, 1996) but are not parallel. The most interesting findings of this study, however, concerned the equivalence of measures across time. When the five survey years were included, the factor loadings of immediate and delayed recall were not equivalent to their other year counterparts. When only the most recent three survey years were included, the factor loadings of reverse 7s, and immediate and delayed recall were equivalent to the factor loadings of their other year counterparts. In addition, these measures were parallel. The reason for this is obviously the change in format of the tests. Thus, if researchers use this data in longitudinal models, they can be confident that the measures for the final three survey years are similar. More caution needs to be exercised when including the data from 1992 and 1994.

Further study using this data in a longitudinal model is needed. In this study delayed and immediate recall were constructed using the sum of the correct responses in any order. Any respondent completing all five survey years of data was included. It is suggested that further study into the order of recall and replicating this study only with older adults could provide additional information concerning cognition in the elderly.

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Table 1

Measures of Model Fit for Individual Years using Reverse 7s, Delayed and Immediate Recall with Original Sample and Original Adjusted to 1000

Year	Congeneric			Tau-Equivalent			Parallel		
	χ^2	df	RMSEA	χ^2	df	RMSEA	χ^2	df	RMSEA
2000[a]	0	0		1422**	2	.33	2805**	4	.33
2000[b]	0	0		9.89**	1	.04	535**	2	.20
1998[a]	0	0		1628**	2	.35	2949**	4	.34
1998[b]	0	0		6.14**	1	.03	635**	2	.22
1996[a]	0	0		1448**	2	.34	2744**	4	.33
1996[b]	0	0		3.19	1	.02	628**	2	.22
1994[c]	WNR			0	0		77.22**	1	.11
1992[c]	WNR			0	0		77.22**	1	.11
Adjusted to Sample Size of 1000									
2000[a]	0	0		217.85**	2		429.72**	4	
2000[b]	0	0		1.52	1		81.96**	2	
1998[a]	0	0		249.41**	2		451.78**	4	
1998[b]	0	0		0.94	1		97.27**	2	
1996[a]	0	0		221.83**	2		420.37**	4	
1996[b]	0	0		0.49	1		96.26**	2	
1994[c]	WNR			0	0		11.83**	1	
1992[c]	WNR			0	0		11.83**	1	

Note. RMSEA = Root Mean Square Error or Approximation. [a]All measures equivalent. [b]Only delayed and immediate recall equivalent. [c]Only two measures available. WNR = would not run (df were negative). *$p \leq .05$. **$p \leq .01$.

Table 2

Results under Model Conditions with Hierarchical Contrasts using initial Sample and Sample adjusted to size of 1000

Model	χ^2	df	RMSEA	NFI	NNFI	AGFI	Congeneric $\Delta\chi^2$	Congeneric Δdf	Tau Equivalent $\Delta\chi^2$	Tau Equivalent Δdf
Congeneric	3541.04**	55	.099	.92	.89	.88				
Tau Equivalent										
All Measures	6751.16**	65	.13	.83	.80	.81	3210.12**	10		
Immediate	5800.02**	59	.12	.86	.81	.81	2258.98**	4		
Delayed Recall	4797.84**	59	.11	.89	.85	.84	1256.8**	4		
Reverse 7s	3543.48**	57	.097	.92	.89	.88	2.44	2		
Parallel										
All Measures	10308.5**	75	.14	.72	.71	.76	6767.46**	20	3557.34**	10
Immediate	7584.06**	63	.14	.78	.73	.78	4043.02**	8	1784.04**	4
Delayed Recall	6700.01**	63	.13	.83	.79	.80	3158.97**	8	1902.17**	4
Reverse 7s	3543.18**	59	.095	.92	.89	.88	2.14	4	-0.30	2
<u>**Adjusted to Sample Size of 1000**</u>										
Congeneric	542.48**	55								
Tau Equivalent										
All Measures	1034.26**	65					491.78**	10		
Immediate	888.55**	59					346.07**	4		
Delayed Recall	735.02**	59					192.54**	4		
Reverse 7s	542.85**	57					0.37	2		
Parallel										
All Measures	1579.24**	75					1036.76**	20	544.98**	10
Immediate	1161.86**	63					619.38**	8	273.31**	4
Delayed Recall	1026.42**	63					483.94**	8	291.41**	4
Reverse 7s	542.81**	59					0.33	4	-0.05	2

Note. RMSEA= Root Mean Square Error of Approximation. NFI = Normed Fit Index. NNFI = NonNormed Fit Index. AGFI=Adjusted Goodness of Fit. Contrasts under Congeneric are contrasting the row condition versus congeneric. Contrasts under Tau Equivalent compare the condition under Parallel. *$p \leq .05$. **$p \leq .01$.

Table 3

Results under Model Conditions for Years with Comparable Tests

Model	χ^2	df	RMSEA	NFI	NNFI	AGFI	Congeneric $\Delta\chi^2$	Congeneric Δdf	Tau Equivalent $\Delta\chi^2$	Tau Equivalent Δdf
Congeneric	3541**	55	.099	.92	.89	.88				
Tau Equivalent										
Year 2000, 98, 96										
All Measures	3556**	61	.094	.92	.90	.88	14.58*	6		
Immediate Recall	3551**	57	.097	.92	.89	.88	10.50**	2		
Delayed Recall	3544**	57	.097	.92	.89	.88	3.24	2		
Year 1994, 92										
All Measures	3662**	57	.098	.92	.89	.87	121.39**	2		
Immediate Recal	3594**	56	.098	.92	.89	.87	52.85**	1		
Delayed Recall	3622**	56	.099	.92	.89	.87	81.44**	1		
Parallel										
Year 2000, 98, 96										
All Measures	3578**	67	.09	.92	.91	.89	36.66**	12	22.08**	6
Immediate Recall	3553**	59	.095	.92	.89	.88	11.96*	4	1.46	2
Delayed Recall	3552**	59	.095	.92	.89	.88	10.58*	4	7.34	2
Year 1994, 92										
All Measures	3722**	59	.098	.91	.89	.88	180.67**	4	59.28**	2
Immediate Recall	3696**	57	.099	.91	.89	.87	155.4**	2	102.55 **	1
Delayed Recall	3638**	57	.098	.92	.89	.87	96.59**	2	15.15**	1

Note. RMSEA= Root Mean Square Error of Approximation. NFI = Normed Fit Index. NNFI = NonNormed Fit Index. AGFI=Adjusted Goodness of Fit. Contrasts under Congeneric are contrasting the row condition versus congeneric. Contrasts under Tau Equivalent compare the condition under Parallel. *p≤.05. **p≤.01.

Table 4

Results under Model Conditions for Years with Comparable Tests: Sample Size of 1000

Model	χ^2	df	(Congeneric) $\Delta\chi^2$	Δdf	(Tau Equivalent) $\Delta\chi^2$	Δdf
Congeneric	542.48**	55				
Tau Equivalent						
Year 2000, 98, 96						
All Measures	544.71**	61	2.23	6		
Immediate Recall	544.09**	57	1.61	2		
Delayed Recall	542.97**	57	0.49	2		
Reverse 7s	542.85**	59	0.37	4		
Year 1994, 92						
All Measures	561.07**	57	18.59**	2		
Immediate Recall	550.57**	56	8.09**	1		
Delayed Recall	554.95**	56	12.47**	1		
Parallel						
Year 2000, 98, 96						
All Measures	548.09**	67	5.61	12	3.38	6
Immediate Recall	544.31**	59	1.83	4	0.22	2
Delayed Recall	544.10**	59	1.62	4	1.12	2
Reverse 7s	542.81**	59	0.33	4	-0.05	0
Year 1994, 92						
All Measures	570.16**	59	27.68**	4	9.08*	2
Immediate Recall	566.28**	57	23.80**	2	15.71**	1
Delayed Recall	557.28**	57	14.80**	2	2.32	1

Note. RMSEA= Root Mean Square Error of Approximation. NFI = Normed Fit Index. NNFI = NonNormed Fit Index. AGFI=Adjusted Goodness of Fit. Contrasts under Congeneric are contrasting the row condition versus congeneric. Contrasts under Tau Equivalent compare the condition under Parallel. *$p \leq .05$. **$p \leq .01$.

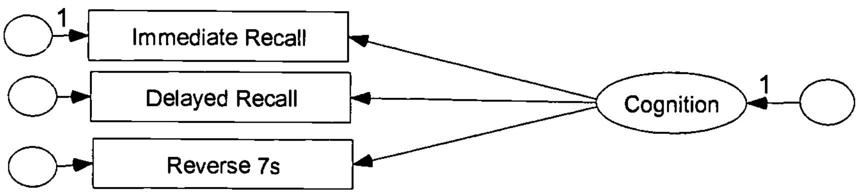

Figure 1

Individual Model of Cognition

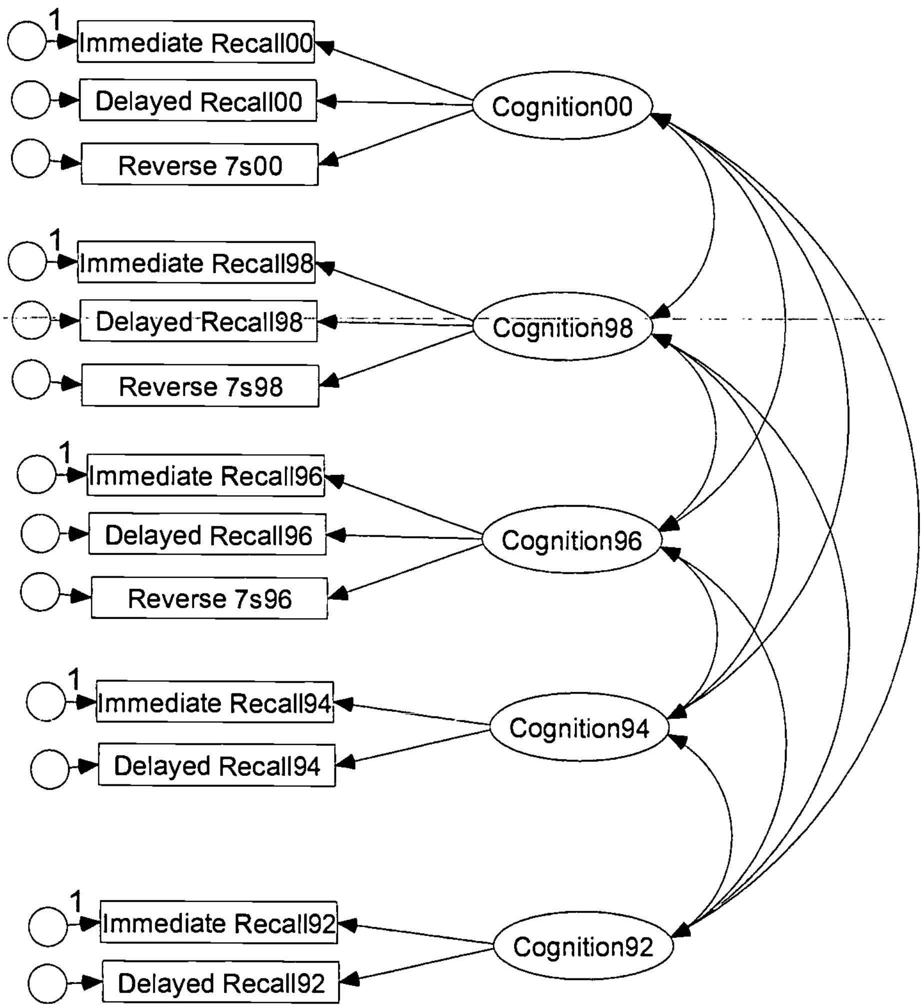

Figure 2

Cognition Across the Five Time Periods

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