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AUTHOR	Witta, E. Lea; Sivo, Stephen A.
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ABSTRACT

Cognition in the elderly has been widely investigated, but there has been some disagreement concerning this phenomenon fostered in part by differences in instruments used, in data collection methods, and in analytic methods used. This study used Immediate and Delayed Recall data collected by the Health and Retirement Survey housed at the University of Michigan. After excluding respondents not available for all 5 time periods over the span of 1992 through 2000, there was a final sample of 7,169. A latent growth curve model was used to estimate the mean and variability of scores over a 6-year time span. Results indicate there was a statistically significant decline in both immediate and delayed recall. However, there was substantial variability in both the change of scores and the starting values. (Contains 4 figures and 14 references.) (Author/SLD)

Latent Growth Modeling of Cognition In the Elderly

E. Lea Witta
Stephen A. Sivo

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Abstract

Cognition in the elderly has been widely investigated. There has, however, been some disagreement concerning this phenomenon fostered in part by differences in instruments used, in data collection methods, and in analytic methods used. This study used Immediate and Delayed Recall data collected by the Health and Retirement Survey housed at the University of Michigan. A latent growth curve model was used to estimate the mean and variability of scores over a six-year time span. Results indicated there was a statistically significant decline in both Immediate and Delayed Recall. However, there was substantial variability in both the change of scores and the starting values.

Latent Growth Modeling of Cognitive Decline in the Elderly

"If we live long enough, will we all become demented?" (Yankner, 2000, p125). Although most adults over 70 exhibit some degree of cognitive decline that accelerates with age, particularly in short-term memory, the theory of cognitive decline linked to the aging process has experienced a "…major upheaval in recent years." (Yankner, 2000, p125). Not all agree there is cognitive decline in the aging process. There is, however, general agreement that working memory does decline (Morra, Vigliocco, Penello, 2001). Changes in cognition during the aging process have been widely studied. Although cognitive decline is not an inevitable function of aging (Baltes & Willis, 1982; Christensen, Henderson, Griffiths, & Levings, 1999), most individuals associate a lack of cognitive functioning with age. And, indeed, it does occur in some individuals (Kaufman & Horn, 1996; Nelson & Dannefer, 1992). Barrett-Connor and Kritz-Silverstein (1999) found a significantly steeper decrement in cognitive function with age in men on the total recall and long-term memory tests ($p<.001$), on the immediate ($p<.01$) and delayed ($p<.05$) recall tasks of visual reproduction tests, and on category fluency ($p<.05$). Blackburn (1980), on the other hand, found no age differences in formal reasoning and suggested the impact of life experiences was more predictive of cognitive processes.

Using a cross-sectional sample, Wegesin, Jacobs, Zubin, Ventura, and Stern (2000) found a significant reduction in source memory with age. However, although memory loss was common in the elderly, not all domains were impacted equally. The aging process produced a marked decrease in encoding for acquisition and retention of memory. Similarly while studying how memory functions of the elderly deteriorate with aging, Yokota, Miyanaga, Yonemura, Watanabe, Nagashima, Naito, Yamada, Arai, & Neufeld (2000) found that the aging process affected memory functions differently. Short term working memory was more affected with aging than long term with short-term verbal memory declining first and then long-term memory.

Some, however, argue that because the response time is slower in the elderly, cognitive impairment is due to slowing of processing speed. In a cross-sectional study, Brébion (2001) found that accuracy was consistently greater for older adults than for younger while response time was slower. This led to the conclusion that older adults were more cautious in responding.

On the other hand, Christensen, Mackinnon, Korten, Jorm, Henderson, & Jacomb, (1999) content that most studies on cognition with the elderly are more on trajectory and less on the dispersion of changes in ability. In studying the dedifferentiation hypothesis[1] which would imply larger individual standard deviations with age, their results showed increased dispersion with age cross-sectionally. However, the increased dispersion longitudinally was no greater for the older cohorts than the younger. This would mean that although there is more variability with age, the increase is progressive. Instead, they found that higher variability was correlated with poorer activities of daily living – not age.

Clearly results vary depending upon which model of cognition is used for the investigation. Studies using cross-sectional data depict changes in cognition between age groups. Studies using longitudinal data do not describe these changes or describe changes with less severity during the aging process. These varying results lead

[1]Intellectual ability is integrated in early childhood, process differentiation in adolescent, exhibit invariance during adulthood, and re-integrate in old age (di-differentiate). For more information see Baltes, Cornelius, Spiro, Nesselroade, & Willis, (1980).

to the questions, does memory deteriorate over time and, if so, how does this occur. Specifically, does the trajectory for cognition decrease in the aging process and, if so, is the decrease similar for all respondents. The current study used a random coefficient model, latent growth curve modeling (LGM) in LISREL 8.3, to answer these questions.

Latent Growth Curve Modeling

Growth Curve Modeling is an extension of the regression process used to incorporate latent variables and random coefficients. The standard regression equation is written as:

$$\hat{Y} = a + bX$$

where Y is the respondent's predicted score, a is the intercept (value of Y when X is 0 – or starting point of the regression line), b is the slope of the line, and X represents the respondent's score on the predictor variable. If the individual has multiple or repeated measures of the Y variable, the latent model becomes:

$$y_t = a_t + b_t t + \varepsilon_t$$

where y_t represents the mean score at a particular time, a_t is the latent (estimated – value of group when t = 0) intercept, b_t is the latent (estimated value of change from a over time) slope, t is the time of measurement, and ε_t is error at time t. However, this model cannot account for the individual variances. In growth curve modeling the goal is not only to represent a group model, but also the individual variability or randomness of the individual differences. A respondent's score is a combination of the mean (intercept) for the group at time 1 plus the deviation of that score from the mean expressed as

$$a_i = \mu_a + \mu_{ai}.$$

In a similar manner, an individual respondent's change over time (slope) may be expressed as their deviation from the group change or

$$\beta_i = \mu_\beta + \mu_{\beta i}$$

By substituting these equations into the original model, the randomness of individuals scores becomes incorporated into the growth curve model so that

$$y_{it} = (\mu_a + \mu_{ai}) + (\mu_\beta + \mu_{\beta i})t_t + \varepsilon_{it}.$$

This yields

$$y_{it} = (\mu_a + \mu_{ai}) + (\mu_\beta t_t + \mu_{\beta i} t_t) + \varepsilon_{it}.$$

Then by re-arranging the data into fixed (or group) components and random (or individual) components the following equation is produced

$$y_{it} = (\mu_a + \mu_\beta t_t) + (\mu_{ai} + \mu_{\beta i} t_t + \varepsilon_{it}).$$

For fixed components of growth (e.g. $\mu_a + \mu_\beta t_t$) the estimates of the group mean intercept and group mean slope are used. For random components of growth ($\mu_{ai} + \mu_{\beta i} t_t + \varepsilon_{it}$) the individual deviations from the group means plus error are used. Consequently, when evaluating the growth curve model, fixed estimates (the mean intercept and the mean slope) are tested as well as random components (variability around the fixed estimates).

The use of this model permitted testing of the variability of individuals from their group means as well as difference in rate of change. Specifically, the following questions were answered:

(1) What are the characteristics of individual differences in the Age Trajectories of Immediate Recall?

(2) What are the characteristics of individual differences in the Age Trajectories of Delayed Recall?

(3) How are individual differences in developmental trajectories of immediate recall related to individual differences in developmental trajectories of delayed recall?

(4) Are earlier levels of immediate recall predictive of later developmental trajectories of delayed recall, and are earlier levels of delayed recall predictive of later developmental trajectories of immediate recall?

Method

Procedure

Data to answer the questions for this study were obtained from the Health & Retirement (HRS) database maintained by the University of Michigan. Data concerning cognitive ability (immediate and delayed recall) were accessed from the 1992, 1994, 1996, 1998, and 2000 databases. Immediate recall score was determined in each database by adding the number of correct responses following presentation of a list of words. Delayed recall was determined by the number of words that were recalled after a period of time. The two measures for each year were merged using person and household identification numbers resulting in a database of more than 11,000 subjects. The data was further refined by excluding any subjects not having responses for all 5 time periods. This resulted in a final sample size of 7169.

Measurement

In 1992 a list of 20 words was read to each respondent. For immediate recall, respondents were to immediately list as many words as they could. For delayed recall, another task was completed and respondents were asked to again list as many words as they could recall from the previous list. However, in 1996 the format changed - a list of 10 words was read to the respondents. Therefore, a perfect score for immediate or delayed recall in 1992 and 1994 was 20. In the remaining three years a perfect score was 10. In order to provide similar scales, data were transformed to the proportion correct. However, preliminary analyses indicated that respondents were improving in 1996, 1998, and 2000. Although this could be true, it could also indicate only the difference in difficulty level of the task and thus bias results produced by this study. Consequently, the 1992 and 1994 data were excluded from this analysis.

The means, standard deviations and correlation matrix of the 1996, 1998, and 2000 immediate and delayed recall scores were entered into LISREL 8.3 to determine if there was a change in cognitive functioning in the 6-year aging process using the mean structure procedure. Because the value of chi-square (χ^2) is inflated by large sample size and the sample size used in this analysis was 7169, other measures were also used to evaluate the fit of the model tested. The root mean square error of approximation (RMSEA), a measure of population discrepancy, was also used. Brown and Cudek (1993) suggested that a value of 0.05 or less represented a close fit, while a measure of 0.08 or less would indicate reasonable error. Three measures comparing the tested model to a baseline model were also used, the normed fit index (NFI), the Tucker-Lewis index (non-normed fit index – NNFI), and the comparative fit index (CFI). For these indices, a fit less than 0.9 needs improvement – measures close to 1.0 indicate a very good fit (Bentler & Bonett, 1980).

Subjects

Of the 7169 subjects, 2,430 were males and 4,329 were females. Age of the subjects in 1992 ranged from 23 to 80 years old (M=55.13, s =5.4) with an average educational level of 12.45 years (s = 3). There were 5,529 white/Caucasian, 954 black/African-American, 535 Hispanic/Latino, 139 other races, and 10 subjects not responding to the race question.

Results

Research Question 1

To answer research question 1, "What are the characteristics of individual differences in the age trajectories of Immediate Recall?", an unconditional growth curve model (Curran, 2000) was estimated. To estimate the model, the three repeated measures of immediate recall were defined to load on the latent intercept factor, Intercept Immediate, with loadings fixed to 1.0. The factor loadings relating the three immediate recall measures to the latent slope factor, Slope Immediate, were based on time and were fixed to 1.0 (Time 1 – 1996), 3.0 (Time 2 - 1998), and 5.0 (Time 3 - 2000). The means and variances of the two latent growth factors were freely estimated. The means of the observed repeated measures were not estimated – their variances, however, were.

Although the chi-square value was statistically significant ($p \leq 0.05$) and RMSEA was not less than 0.08, the NFI (0.98), the NNFI (0.94), and the CFI (0.98) were within acceptable limits Thus, the model provided an acceptable fit ($\chi^2_{1, N=7169}$=90.66, RMSEA = .11 with 90% CI = .093, .13) to the observed data. Indeed, with a sample size of 7169, it would be surprising if the chi-square value was not statistically significant.

Having determined an adequate overall fit, the estimated parameters were evaluated. The means for the intercept and slope factors were estimated to be 5.83 (μ_α) and -0.06 (μ_β) respectively. Both significantly differed from zero ($p<0.05$). This indicated the estimated mean starting point for immediate recall was 5.77 (5.83 - .06), and the estimated rate of true change was –0.06 words recalled per year. In addition, there were statistically significant variance estimates ($p<0.05$) for both the intercept ($\sigma_\alpha^2 = 1.11$) and the slope ($\sigma^2_\beta = 0.02$) indicating substantial individual variability around both the mean starting point and the mean rate of change over time. In addition there was a statistically significant ($p\leq0.05$), although relatively small, estimate of covariance between the intercept and slope factors ($\sigma_{\alpha\beta}= -0.04$) which was standardized to a correlation of $r = -0.28$. In summary, the unconditional linear growth model indicated that when this group was in the immediate recall condition they recalled significantly more words than zero, there were significant decreases in word recall over the 6 year time span, and there was significant variability in both the starting point and rates of change over time.

Research Question 2

Research question 2, "What are the characteristics of individual differences in the age trajectories of Delayed Recall?", was investigated in a similar manner as research question 1. The correlation matrix, means, and standard deviations for 1996, 1998, and 2000 delayed recall measures were entered into LISREL 8.3. An unconditional growth curve model was estimated as is depicted in Figure 2. To estimate the model, the three repeated measures of immediate recall were defined to load on the latent intercept factor, Intercept Delayed, with loadings fixed to 1.0. The factor loadings relating the three delayed recall measures to the latent slope factor, Slope Delayed, were again fixed to 1.0, 3.0, and 5.0. The means and variances of the two latent growth factors were freely estimated. The means of the observed repeated measures were not estimated – their variances, however, were.

Although the chi-square value was again statistically significant ($p\leq 0.05$) and RMSEA was not less than 0.08, the NFI (0.98), the NNFI (0.95), and the CFI (0.98) were within acceptable limits. Thus, the model provided an acceptable fit ($\chi^2_{1, N=7169} = 76.52$, RMSEA = .10 with 90% CI = .08, .12) to the observed data.

Having determined an adequate overall fit, the estimated parameters were evaluated. The means for the intercept and slope factors were estimated to be 4.95 (μ_α) and -0.04 (μ_β) respectively. Both significantly differed from zero ($p<0.05$). This indicated the estimated mean starting point for delayed recall was 4.91 (4.95 - .04), and the estimated rate of true change was –0.04 words recalled per year. In addition, there were statistically significant variance estimates for both the intercept ($\sigma_\alpha^2 = 1.61$) and the slope ($\sigma^2_\beta = 0.02$) indicating substantial individual variability around both the mean starting point and the mean rate of change over time. There was a small non-significant ($p\leq0.05$) estimate of covariance between the intercept and slope factors ($\sigma_{\alpha\beta}= -0.04$) which was standardized to a correlation of $r = -0.20$. In summary, the unconditional linear growth model indicated that when this group was in the delayed recall condition they recalled significantly more words than zero, there were significant decreases in word recall over the 6 year time span, and there was significant variability in both the starting point and rates of change over time.

Research Questions 3 and 4:

In order to answer research questions 3 and 4, a multivariate latent curve model was created by simultaneously estimating the two unconditional growth curves of immediate and delayed recall. In this model the previous two models of Immediate and Delayed Recall were combined by permitting the error estimates of the two intercept latent variables (Intercept Immediate and Intercept Delayed) and the two slope latent variables (Slope Immediate and Slope Delayed) to co-vary freely as shown in Figure 3. In addition, the time-constrained estimates of recall (Immediate and Delayed for each year) were free to co-vary. The model produced an acceptable fit ($\chi^2_{6, N=7169} = 122.84$) to the observed data. Although the chi-square value was statistically significant ($p \leq 0.05$), the NFI (0.99), the NNFI (0.99), CFI (0.99), and the RMSEA (0.052 with 90% CI = 0.044, 0.064) were within acceptable limits.

Research question 3, "How are individual differences in developmental trajectories of immediate recall related to individual differences in developmental trajectories of delayed recall?," was answered by the correlation between the two intercept measures and the correlation of the two slope measures. Approximately 90% of the variance in the intercept latent variables (r = 0.95) was shared. Approximately 98% of the variance in the slope latent variables (r = 0.99[2]) was shared. Thus, there was a statistically significant and practically important relationship between both the intercepts and the slopes of immediate and delayed recall. The change in each over time is practically identical.

Research question 4, "Are earlier levels of immediate recall predictive of later developmental trajectories of delayed recall, and are earlier levels of delayed recall predictive of later developmental trajectories of immediate recall?" required the addition of two new paths in Model 3. The path from Intercept Immediate to Slope Delayed and the path from Intercept Delayed to Slope Immediate were freed as depicted in Figure 4. The model provided an acceptable fit ($\chi^2_{4, N=7169} = 113.18$, NFI = 1.0, NNFI = .98, CFI = 1.0, RMSEA = 0.62 with 90% CI = .044, .084) to the observed data. Although the chi-square value was statistically significant ($p \leq 0.05$), the NFI (1.0), the NNFI (0.98), the CFI (1.0), and RMSEA (0.62 with 90% CI = 0.044, 0.84) were within acceptable limits.

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[2] Because an unacceptably high correlation was calculated for this estimate, the estimate was constrained to 0.99.

Having determined an adequate overall fit, the new estimated parameters were evaluated. The direct effect of Intercept Delay on Slope Immediate was –0.27. The direct effect of Intercept Immediate on Slope Delay was –0.33. Both of these regression parameters were found to significantly differ from zero ($p<.05$). The Intercept Delay factor negatively predicted the Slope Immediate factor indicating that higher initial levels of Delayed Recall were associated with a steeper slope (higher decline) in immediate recall. The Intercept Immediate factor also negatively predicted the Slope Delay factor in a similar fashion.

Summary

The decline in immediate recall was described by a negative linear trajectory over the six year time span (three time periods). There were large individual differences in the starting point of the trajectory and the rate of change over time. Decline in delayed recall was also described by a negative linear trajectory over the six-year time span with large individual differences in the starting point of the trajectory and the rate of change over time. Individual differences in developmental trajectories of immediate recall were closely related to those of delayed recall. And finally, higher initial levels of immediate recall were predictive of steeper slopes (higher decline) in delayed recall and higher initial levels of delayed recall were predictive of steeper slopes in immediate recall.

Because the data used in this study included age ranges from 23 to 80 and there was substantial variability in both the slope and intercept for both measures, conclusions concerning this study are limited. Rather, the current study provides a starting point for further research in testing this model by age groups, sex, and race and in using other explanatory variables, such as activities of daily living.

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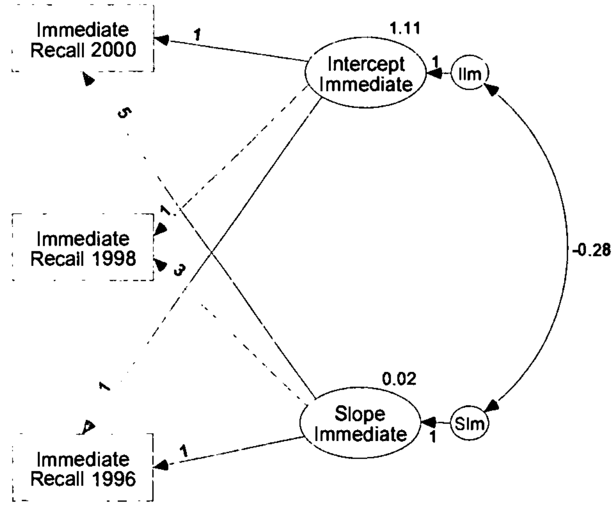
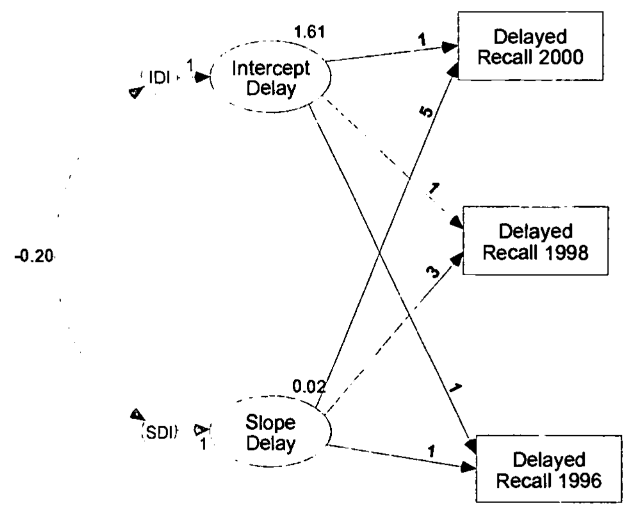
Figure 1: Latent Growth Curve
Immediate Recall - 2000, 1998, 1996



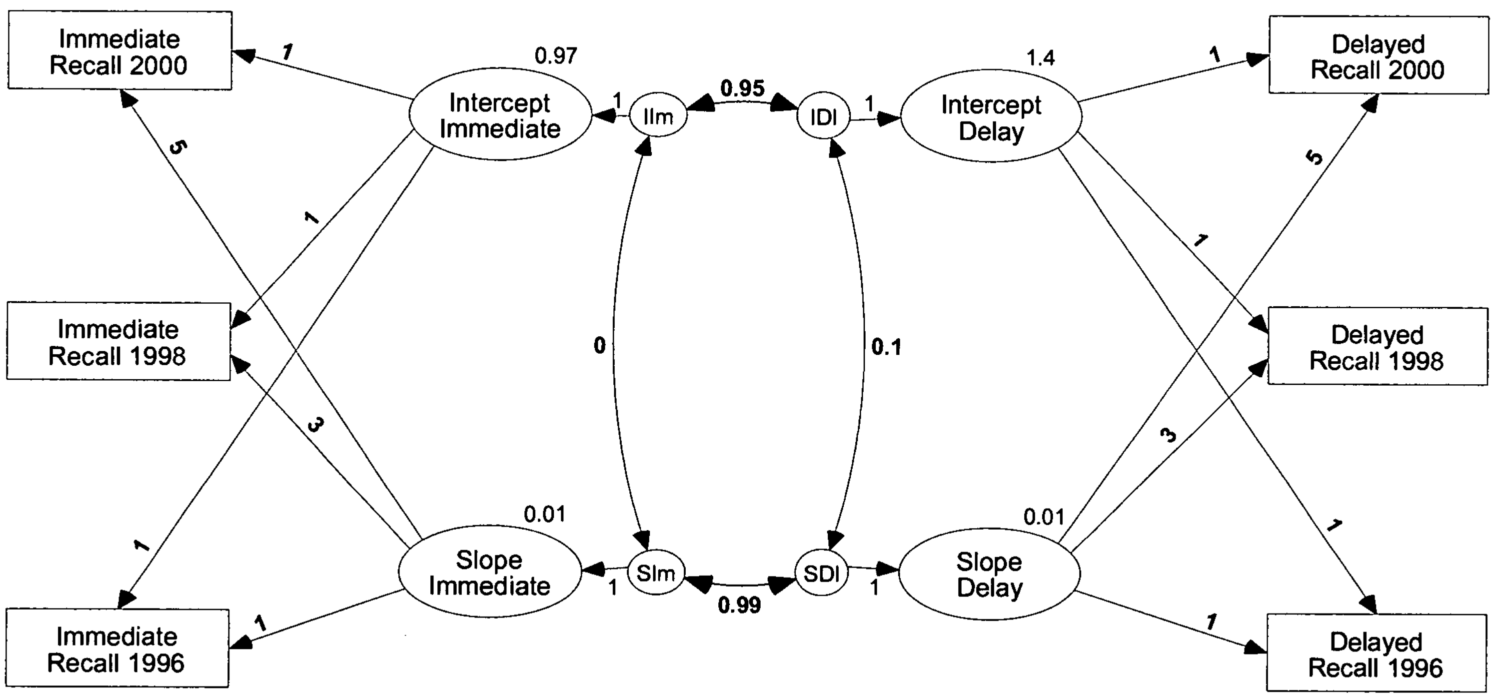
Chi-Square (1, N=7169) = 90.66, NFI=.98, NNFI=.94, CFI=.98, RMSEA = .11 (90% CI .093 - .13)
Variance of the Slope and Intercept Latent Variables is listed above the Variable

Figure 2: Latent Growth Curve
Delayed Recall for 1996, 1998, and 2000



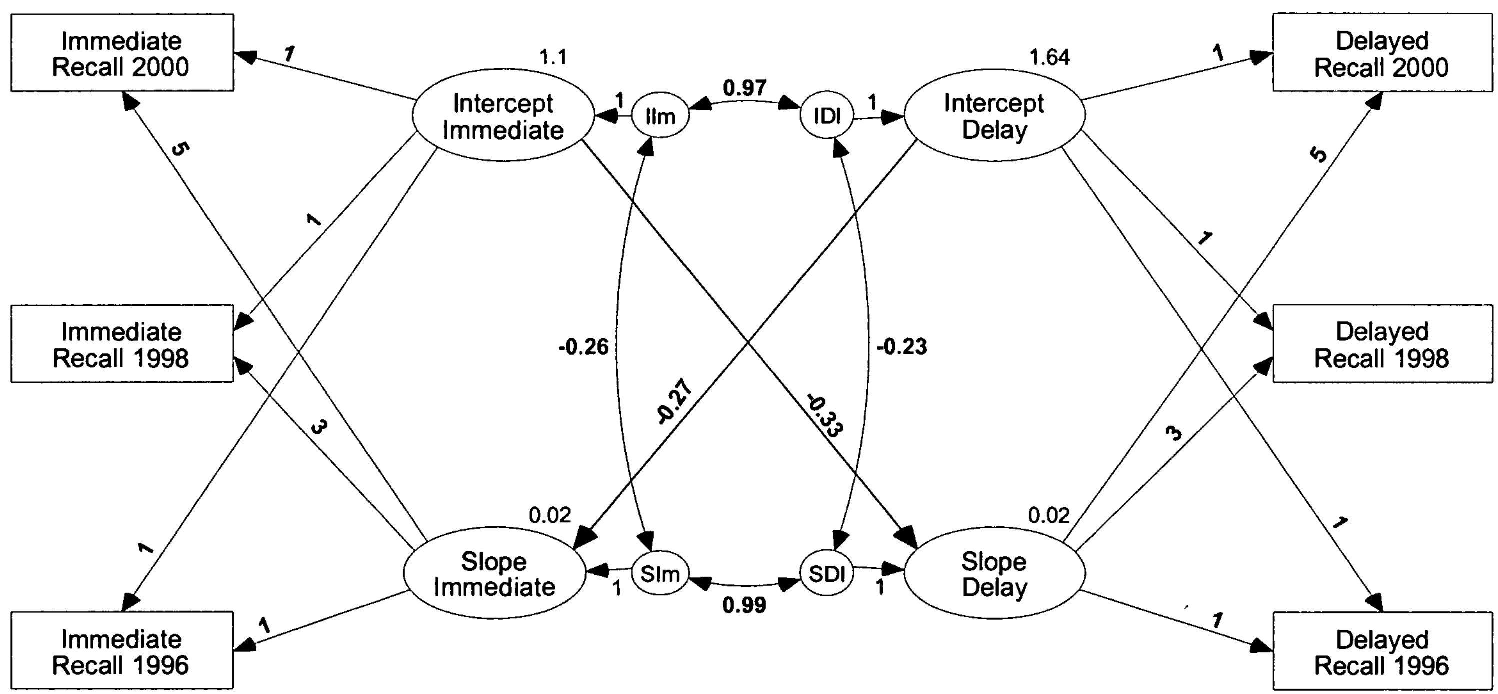
Chi-Square (1, N=7169) = 76.52, NFI=0.98, NNFI=0.95, CFI=0.98, RMSEA = 0.10 (90% CI, 0.08 - 0.12)
Variance of the Slope and Intercept is listed above the Variable

Figure 3: Latent Growth Curve
Combining Immediate and Delayed Recall



Chi-Square (6, N=7169) = 122.84, NFI=0.99, NNFI=0.99, CFI=0.99, RMSEA = .052 (90% CI .044 - .062)
Variances of Slope and Intercept are listed above the variable.
Correlation between time constrained repeated measures is not depicted.

Figure 4: Latent Growth Curve
Combining Immediate and Delayed Recall for Prediction



Chi-Square (4, N=7169) = 113.18, NFI=1.0, NNFI=.98, CFI=1, RMSEA = .062 (90% CI .04 - .08)
Variance of Slope and Intercept is listed above the variable.
Correlation between time constrained repeated measures is not depicted.

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Printed Name/Position/Title: E. Lea Witta, Assoc. Prof

Organization/Address: University of Central Florida
PO Box 161250
Orlando, Fl 32816-1250

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FAX: 407-823-4880

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