Verbal Learning and Everyday Functioning in Dementia: An Application of Latent Variable Growth Curve Modeling

Benjamin T. Mast\textsuperscript{1} and Jason C. Allaire\textsuperscript{2}

\textsuperscript{1}Psychological and Brain Sciences, University of Louisville, Kentucky. \textsuperscript{2}Department of Psychology, North Carolina State University, Raleigh.

This study used latent variable growth curve modeling to identify predictors and correlates of verbal learning over trials on a list-learning task in patients with dementia. Data from 116 patients evaluated at the Detroit satellite of the Michigan Alzheimer’s Disease Research Center were incorporated in the present analyses. Patients were administered the Fuld Object Memory Evaluation, examined independently by a geriatrician, and, if appropriate, given a diagnosis of probable Alzheimer’s disease according to criteria from the National Institute of Neurological and Communicative Disorders and Stroke/Alzheimer’s Disease and Related Disorders Association. The presence of dementia significantly predicted both the intercept (i.e., level of performance) and the slope (i.e., learning over trials), with dementia patients demonstrating lower overall levels of performance and less verbal learning over trials. Rate of verbal learning over trials was a significant predictor of everyday functioning (instrumental activities of daily living) above and beyond general cognitive impairment and demographics.

The evaluation of memory and learning in the assessment of older adults’ cognitive competency has grown over the past decades and now represents a central feature in geriatric and dementia assessments (LaRue, 1992; Nussbaum, 1998). Memory and learning is typically captured through the use of assessment tools. These tools are composed of multiple trials, which allow clinicians and researchers to examine not only the amount of information recalled at each trial (i.e., memory) but also the absolute magnitude or amount of learning that occurs over repeated trials. In the current study, we applied a specific statistical method (latent growth curve modeling) to the study of verbal recall and learning. Our goal was to examine differences between demented and nondemented elders in terms of initial recall and slope of performance (i.e., learning) over trials. In addition, we examined the extent to which initial recall and slope were uniquely related to individual differences in instrumental everyday functioning.

Latent variable growth curve modeling (LGM) is a latent variable approach to modeling change over time (Duncan, Duncan, Strycker, Li, & Alpert, 1999; Willett & Sayer, 1994). LGM is advantageous in the current context for two reasons. First, LGM estimates parameters representing the average or mean initial status and the average rate of change or slope (i.e., fixed effects), as well variance estimates for initial status and slope (i.e., random effects). Second, total change is not determined; instead, the actual shape of change (i.e., linear or quadratic) is estimated. With respect to verbal learning tasks, LGM allows for the estimation of both initial recall and the slope or rate of learning over trials. It is important to underscore that the LGM approach differs from traditional indices of learning used by neuropsychologists and clinicians, which are typically derived from trial-based measures. For example, the Fuld Object Memory Evaluation (FOME; Fuld, 1977), a learning and memory task that incorporates a selective-reminding procedure, typically has been incorporated in dementia research as a measure of overall recall over five trials (LaRue, Romero, Ortiz, Liang, & Lindeman, 1999; Loewenstein, Duara, Arguelles, & Arguelles, 1995; Marcopulos, Gripshover, Broshek, McLain, & Brashear, 1999; Mast, Fitzgerald, Steinberg, MacNeill, & Lichtenberg, 2001; Masur, Sliwinski, Lipton, Blau, & Crystal, 1994). In addition, for list-memory tests such as the Revised Hopkins Verbal Learning Test (Benedict, Schretlen, Groninger, & Brandt, 1998), the difference between the first and last recall trials is used as an absolute index of learning. Although these indices are intuitive and easy to calculate, they do not take into account the shape and rate of learning over repeated trials for each participant or patient. One exception is the California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 2000), which utilizes an ordinary least squares regression approach to estimate learning over trials. The LGM approach that we apply here is similar but adds considerable flexibility in simultaneously modeling both fixed and random effects as well as predictors and correlates of those effects.

Learning in Dementia Assessment and Research

The typical list-learning paradigm has allowed clinicians and researchers to separate different aspects of learning and recall into distinct components that are differentially affected by dementia syndromes. Not surprisingly, previous research has found that the performance of demented participants on initial trials and overall learning is significantly worse than that of individuals not diagnosed with dementia (Baltes, Kuhl, & Sowarka, 1992; Grober & Kawas, 1997; Lindenberger & Reischies, 1999; Royall, Palmer, Chiado, & Polk, 2003). Although both initial level of recall and amount of learning may be impaired in dementia, they likely involve different cognitive processes and may be differentially affected. For instance, immediate recall of words may reflect attention similar to that used for simple attention tasks such as digit or spatial span, whereas learning over trials has organizational, storage, and recall components (Delis et al., 2000).

Neuropsychological Prediction of Everyday Functioning in Dementia

Previous research has found that neuropsychological batteries (Cahn-Weiner, Ready, & Malloy, 2003; Searight, Dunn,
Of this outpatient sample, 75% of the participants were demented, and the majority of these individuals met the criteria for probable Alzheimer’s disease (AD; 63.6%). We determined dementia status (demented vs nondemented) on the basis of a board-certified geriatrician examination in accordance with criteria from the National Institute of Neurological and Communicative Disorders and Stroke/Alzheimer’s Disease and Related Disorders Association (McKhann et al., 1984). This was independent of the FOME, MMSE, and IADL scores, which were collected by a nurse practitioner, and was heavily based on patient history and interviews with the patient and caregivers. The mean MMSE score for the full sample was 21, with SD 4.4; it was significantly higher in the nondemented group, 23.5, SD 4.5, than in the demented group, 20.3, SD 4.0; t(114) = 3.75, p < .001. There were no significant differences (all comparisons at least p > .20) between demented and nondemented patients in terms of age (demented, M = 76.4 years; nondemented, M = 74.6 years), years of education (demented, M = 10.9 years; nondemented, M = 10.4 years), sex (demented group, 72.4% women; nondemented group, 65.5% women), or race (demented group, 66.3% African American; nondemented group, 58.6% African American).

**Measures**

The FOME (Fuld, 1977) assesses the storage and retrieval of information across five learning trials by means of a selective-reminding procedure. The participant is asked to recall the names of 10 objects that he or she has seen, held, and heard the name of (from the examiner). These objects include a ball, nail, scissors, cup, bottle, key, card, button, ring, and matches. After the patient has heard, seen, and heard the name of all 10 objects, they are hidden in a bag. The patient completes a distracter task and then is asked to recall the names of the 10 objects. The patient is then reminded of those items that he or she missed, and the procedure is repeated. Each of the retrieval trials has a potential score of from 0 to 10 words or objects recalled. The internal consistency of the five FOME trials in this sample was α = 0.96.

The MMSE (Folstein et al., 1975) is a standardized index of general cognitive functioning in geriatric patients. The MMSE contains items measuring several cognitive domains, including orientation, attention and calculation, immediate registration, short-term recall, language, and visual construction. Scores range from 0 to 30, with higher scores representing higher cognitive functioning. Twenty-four is the most commonly used cutoff score for detection of cognitive impairment; however, in this study we made the determination of dementia status independent of MMSE performance.

We measured IADLs by using both patient and caregiver report of the patient’s everyday functioning according to the Older Americans Resources and Services IADL index (Fillenbaum, 1988). This index measures ability in seven IADLs, including managing money, managing medication, doing housework, preparing meals, shopping, using the telephone, and leaving the home or traveling. Each item is scored as independent (2), needs assistance (1), or dependent (0). We calculated a composite score for both patient self-report and caregiver report of the patient’s ability, each ranging from 0 to 14, with higher scores indicating better everyday functioning (i.e., greater independence). Cronbach’s alpha reliability

**METHODS**

**Participants**

Clinicians evaluated 116 outpatients, with a mean age of 76 years (SD = 6.80, range 58–89 years), at the Detroit satellite of the Michigan Alzheimer’s Disease Research Center. These patients represent a consecutive series of patients referred for outpatient evaluation at this memory clinic, with the exception that those patients who were too impaired to be tested were not included. The sample consisted of 70% women and 30% men. Of the participants, 65% were African Americans and the remaining 35% were European Americans. Overall, the participants averaged less than a high school education (M = 10.84 years; SD = 3.32).

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estimates were $\alpha = 0.91$ and $\alpha = 0.89$ for the caregiver-reported and patient-reported IADLs, respectively.

**Statistical Analysis**

Our statistical analysis occurred in three steps. First, we estimated a latent variable growth curve model for the five FOME retrieval trials (see Figure 1). This measurement model contained two latent variables, one representing the level of performance (intercept) and the other representing the linear slope (change over trials). Consistent with LGM techniques, we set the error variances to equality and fixed the intercepts of the manifest variables to zero (Duncan et al., 1999). We fixed the factor loadings for the “level” latent variable to 1 and the factor loadings for the “slope” latent variable to 0, 1, 2, 3, and 4 for the five FOME trials, respectively. This pattern of fixed loadings allowed us to estimate a linear slope, and by setting the first loading to zero we scaled the intercept factor to represent initial status or Trial 1 performance. We freely estimated parameters representing the mean (i.e., fixed effects) and variance (i.e., random effects) of the level and slope factors. The mean parameters represent average performance at Trial 1 (level) and average intraindividual change (slope), whereas the variance parameters represent the magnitude of intraindividual differences in average level and intraindividual change.

The second step involved estimation of the structural equation model that included the two latent factors (level and slope) and a dichotomous exogenous variable representing dementia status (nondemented = 0, demented = 1). We used this exogenous variable as a predictor of level and slope of performance over trials. In subsequent analyses, we expanded the number of exogenous predictors to include the demographic variables of age, race (Black = 1; White = 2), gender (men = 1; women = 2), and years of formal education.

In the third step we expanded this structural equation model to examine (a) whether slope and intercept latent variables were predictive of IADL functioning, and (b) whether slope and intercept were predictive of IADL functioning independent of demographic variables and general levels of cognitive functioning (according to the MMSE). We estimated all models by using maximum likelihood estimation with AMOS 4 (Arbuckle & Wothke, 1999). The current sample size is relatively small for structural equation modeling, and therefore the results should be interpreted with caution, particularly in relation to global model fit and individual parameter estimates. We evaluated model fit through traditional fit indices, but given the sensitivity of the chi-square goodness-of-fit statistic to sample size, we also reported the Tucker Lewis Index (TLI), which is robust in small samples (e.g., Bentler & Chou, 1987; Marsh, Balla, & McDonald, 1988).

**RESULTS**

**Model Fitting**

Mean performance on each of the five trials for the full sample of participants as well as the nondemented and demented subsamples is provided in Table 1. In order to characterize the shape and rate of change over trials, we estimated a latent growth curve model that included a linear slope factor by using the full sample of participants. We also estimated an additional model that included a quadratic slope factor to account for any potential curvature; however, the mean and variance estimates for this additional factor were not significant, indicating an absence of any leveling off in the learning process. Consequently, we considered a linear growth model to best represent the pattern of change over the five trials, and the fit of this
Dementia and Initial Status and Linear Slope

Our analyses next turned to examining differences in initial status and rate of change between nondemented and demented participants. We estimated two growth models that included level and linear slope factors as well as the observed variables of dementia status (i.e., demented vs nondemented), age, education, and gender. In the first model (Model 1), we included dementia status as an exogenous predictor of both the initial status and linear slope factors; we did not estimate regression paths from the remaining covariates. The fit of this model was acceptable: $\chi^2(28) = 22.92, p > .05$; CFI = 1.00, TLI = 1.00, and RMSEA = 0.00. In Model 2 we added regression paths from each demographic characteristic to the initial status and linear slope factors. The fit of this model was also acceptable: $\chi^2(22) = 18.46, p > .05$; CFI = 1.00, TLI = 1.00, and RMSEA = 0.04. However, it did not significantly differ from the previous model, $\Delta \chi^2(6) = 4.46, p > .05$, which included only dementia status as a predictor of level and slope. As we can see in Table 2, dementia status was a significant and negative predictor of both the initial status and linear slope factors in Model 1, indicating that demented participants performed significantly lower on the first trial and had a significantly slower rate of learning over the five trials. In Model 2, dementia status remained a significant predictor of initial level and linear slope after we controlled for the demographic covariates, none of which were significant predictors of either the initial level or linear slope variables.

The results from the previous model indicated that demented participants differed from nondemented participants with respect to initial performance on the FOME as well as in rate of change (i.e., learning over trials). Given that initial status and linear slope differed as a function of dementia status, it is possible to obtain mean parameters as well as their corresponding tests of significance for the initial status and linear slope variables within each group of participants. The parameters for the nondemented group were already provided by Model 1, because the parameter estimates for initial status and linear slope variables take on values corresponding to when the dementia status variable equals zero or being nondemented. By changing the dummy coding of the dementia status variable so that zero represented being demented and then reestimating the model, we obtained the parameters for the demented group.

This approach is similar to interpreting the intercept and main effects in a regression equation that also includes an interaction, and it provides the same results that would have been obtained from doing a two-group growth model (Curran, Bauer, & Willoughby, 2003). Table 3 contains the mean estimates for the initial status and linear slope. At the first trial (i.e., initial status), nondemented participants were scoring, on average, two words higher than the demented participants. The linear slope for the nondemented participants was also significantly different from zero. More clearly, nondemented participants increased about one fourth of a word per trial for an average improvement of 0.53 words per trial, or a 0.48-word improvement over the five trials. The variance estimates (i.e., random effects) for the initial level was 0.12 ($SE = 0.04$) words per trial, or a 0.48-word improvement over the five trials. The variance estimates (i.e., random effects) for the initial level and linear slope factors were both significant ($p \leq .05$), indicating that performance at the first trial and the rate of learning over subsequent trials were significantly different from zero. Specifically, the mean for the linear slope factor was 0.12 ($SE = 0.04$) words per trial, or a 0.48-word improvement over the five trials. The variance estimates (i.e., random effects) for the initial level and linear slope factors were both significant ($p \leq .05$), indicating significant interindividual differences in initial level and in intraintividual change, respectively. In addition, the correlation between initial level and slope was significant ($r = .44$), suggesting that participants with a higher initial level exhibited a faster rate of learning.
Predicting Everyday Functioning

We examined the predictive utility of initial status and linear slope to account for individual differences in everyday functioning within the sample of demented participants. Although the LGM results indicated that learning over trials was not significant in the subsample of dementia patients, there are likely individual differences in intraindividual learning that may be important for predicting everyday functioning. Our analysis began with the specification of Model 1, which included the initial status and linear slope variables as well as observed variables representing patient report IADLs, caregiver report IADLs, age, education, gender, and MMSE score. We estimated direct regression paths from initial status and linear slope variables to the patient report IADLs and caregiver report IADLs, while we allowed the remaining observed variables to intercorrelate. The fit of this model was adequate: \( \chi^2(46) = 63.29, p = .05 \); CFI = 0.96, TLI = 0.95, and RMSEA = 0.07. Initial status was a significant predictor of only patient report IADLs; higher initial recall was associated with better patient IADL competency. However, this relationship fell just shy of statistical significance for caregiver reports (\( p < .10 \)).

Next, in Model 2 we estimated regression paths from the remaining observed variables (i.e., age, education, gender, and MMSE performance) to patient report IADLs and caregiver report IADLs (see Figure 2). The fit of this model was good: \( \chi^2(38) = 42.20, p > .05 \); CFI = 0.99, TLI = 0.98, and RMSEA = 0.04. It provided a better fit to the data than did Model 1, with \( \Delta \chi^2(8) = 21.09 \) and \( p > .05 \). As we can see in Table 4, age was a significant and negative predictor of patient report of IADL competency. In addition, higher MMSE scores were significantly associated with a higher patient report of IADL competency scores. Initial status remained a significant predictor for patient report of IADL functioning, whereas the unique effect of linear slope was still large but no longer uniquely significant. Interestingly, with the inclusion of the covariates, the linear slope variable was a significant and unique predictor of caregiver report; greater learning on the FOME was associated with better IADL functioning.

DISCUSSION

Our goal in this study was to demonstrate how LGM techniques can be applied to neuropsychological data that consider multiple learning trials, and to demonstrate how this methodology can be used to identify predictors and outcomes of initial performance as well as learning over repeated trials. Using this analytic approach, we sought not only to replicate the findings from previous research that learning is significantly reduced in demented older adults (Baltes et al., 1992; Grober & Kawas, 1997; Lindenberger & Reischnitz, 1999; Royall et al., 2003) but also to examine the extent to which individual differences in the rate of learning account for individual differences in everyday IADL functioning in a sample of demented older adults.

Our main findings were that latent variable growth curve models estimated with a single linear slope provided excellent fit to the data on a list-learning test in memory clinic outpatients, and that dementia status was a significant predictor of both the level and rate of verbal learning above and beyond that which could be accounted for by demographic variables, including age, education, sex, and years of formal education. Further modeling indicated that, as a group, dementia patients did not demonstrate significant learning over the five trials. Nonetheless, individual differences in learning over trials within the dementia group were important in the prediction of everyday functioning based on caregiver report, after we controlled for general cognitive and demographic variables.

The discrepancy between significant predictors of caregiver and patient reports of IADL functioning represents a challenge in interpreting these results. For example, in the full model (Table 4), the latent variable that represented initial status, age, and MMSE score predicted patient-reported IADL functioning, whereas only the latent variable that represented linear slope predicted caregiver-reported IADL functioning. In the current study, it is difficult for us to determine whether this is attributable to a relatively small sample size and less than optimal statistical power (see the subsequent discussion) or whether this...
reflects differences in the validity of caregiver reports and dementia patient self-reports. With regard to the latter, there exists a long literature suggesting that although dementia patients may offer reliable reports (as was the case in this study), their reports often differ from caregiver reports; these reports are considered by some investigators to be either less valid than caregiver reports or, at minimum, reflect slightly different constructs than caregiver reports on a number of clinical variables, including depression (Bedard et al., 2003), cognitive abilities (Kalbe et al., 2005), physical functioning (Kiyak, Teri, & Borson, 1994), quality of life (Logsdon, Gibbons, McCurry, & Teri, 2002), and IADL functioning (Tabert et al., 2002).

For example, Logsdon and colleagues (2002) found that, although cognitively impaired patients could reliably complete a self-report measure of quality of life, the measured construct appeared to differ slightly from that measured by caregiver reports as reflected by somewhat different patterns of associations with other tests between the patient and caregiver reports. Although the different predictors of patient- and caregiver-reported IADL function in the current study could also reflect the relatively small sample size and less than optimal power, prior dementia studies concerning caregiver reports and patient self-reports suggest that this type of discrepancy is not uncommon. Future studies with larger samples might further clarify whether discrepancies reflect true differences or low statistical power, particularly in light of the somewhat modest $R^2$ values. Despite this limitation, these findings provide further support for the link between cognitive performance and IADL functioning in cognitively impaired patients.

These findings extend the literature in two ways. First, from a clinical perspective, these findings highlight the utility of list-learning measures such as the FOME in the evaluation of dementia and more specifically demonstrate their value in considering patients’ learning over trials. In this study, learning over trials was affected by dementia, as was the initial level of recall. Learning over trials was a better predictor of everyday functioning (according to the caregiver reports) than was initial level of recall. The finding that dementia was associated with poorer learning over trials is consistent with prior literature concerning neuropsychological aspects of AD and basic research linking learning and memory changes to lesions in the hippocampus (Squire, 1992). In the context of AD, Stout and colleagues (1999) have demonstrated links between medial temporal lobe atrophy and learning over trials in AD patients. Learning over trials may be a key neuropsychological indicator of a patient’s ability to function effectively and adapt to her or his environment.

Second, from a methodological perspective, these findings suggest that LGM has valuable applications to neuropsychological data that concern learning over trials and its link to outcomes such as everyday functioning. LGM is advantageous in the context of neuropsychological measures of learning and memory in that both level and slope of learning can be modeled simultaneously and provide parameter estimates relating both to group averages and to individual differences. Moreover, in the current context, we took advantage of the flexibility of this approach by modeling predictors (e.g., dementia) and outcomes (e.g., IADL functioning) of individual differences in learning. This type of application is readily available in standard structural equation modeling packages (e.g., AMOS, LISREL, and Mplus) and can be used in conjunction with more traditional approaches to the evaluation of memory and learning.

One limitation of the current study was that the sample size could be considered small, which could have served to decrease the power of the parameter estimates. A larger sample of both demented and nondemented patients would have been advantageous, particularly when separate parameter estimates were obtained for each group. The primary concern regarding a small sample size centers on the lack of statistical power. Consequently, it is noteworthy that initial status and slope were both significant predictors of everyday functioning in a smaller subsample of elders with dementia. With that said, caution should be taken when interpreting the overall fit of our models and the stability of the parameter estimates.

A second limitation relates to the FOME as a measure of learning and memory. Although the FOME is advantageous in several ways (use of multiple sensory modalities for encoding, less dependence on processing speed, and availability of clinical utility data in diverse samples), it is limited in comparison with other list-learning measures such as the California Verbal Learning Test and Hopkins Verbal Learning Test because it does not lend itself to systematic evaluation of strategy use in the process of learning over trials. For example, the scoring system of the California Verbal Learning Test allows for examination of two specific strategies (semantic and serial clustering) that likely affect patients’ learning over trials. This information may be useful, particularly when considered in the context of prior literature that suggests that measures of frontal or executive functioning may be linked to IADLs (Boyle et al., 2003; Norton et al., 2001).

A third limitation is that, although these patients represent a consecutive series of patients evaluated at this clinic, our findings likely generalize only to those patients who are able to engage in neuropsychological testing; therefore, our findings may not generalize to patients with severe dementia. A final limitation is the possibility that a portion of the nondemented group actually had a milder form of cognitive impairment, such as Mild Cognitive Impairment (Petersen et al., 2001; Morris et al., 2001) or Cognitive Impairment, No Dementia (Unverzagt et al., 2001) syndromes. This milder form could serve to reduce the impact of the dementia status variable on the other study variables, including the initial status and linear growth variables derived from the latent variable growth curve models.

Despite these limitations, this study demonstrates an apparently novel application of LGM to learning in dementia patients. The findings indicate that verbal learning is significantly affected by dementia, and that verbal learning may be an important indicator of older adults’ ability to function independently in their everyday environment. Future research should incorporate large samples to confirm and replicate these findings, and to possibly clarify whether the different effects obtained for caregiver- and patient-reported indices reflect less than optimal statistical power or important differences that deserve further investigation. In addition, future studies with larger samples might investigate whether, with the use of this methodology, researchers find that patients with Mild Cognitive Impairment or Cognitive Impairment, No Dementia syndrome differ from dementia patients and those with normal aging in terms of level and slope of verbal learning, and whether individual differences on these indices are associated with poorer IADL functioning.