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Relations between Children's Metamemory and Strategic Performance: Time-Varying Covariates in Early Elementary School

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Abstract

Although much is known about the development of memory strategies and metamemory in childhood, evidence for linkages between these memory skills, either concurrently or over time, has been limited. Drawing from a longitudinal investigation of the development of memory, repeated assessments of children's (*N*=107) strategy use and declarative metamemory were made, in order to examine the development of these skills and the relations between them over time. Latent curve models were used first to estimate the trajectories of children's strategy use and metamemory and then to examine predictors of children's performance in each of these domains. Children's metamemory at the beginning of Grade 1 was linked to child- and home-level factors, whereas the development of both skills was related to maternal education level. Additional modeling of the longitudinal relations between strategic sorting and metacognitive knowledge indicated that metamemory at earlier time points was predictive of subsequent strategy use.

A salient feature of the cognitive development literature is the finding that with increases in age and experience in school, children undergo a systematic transition from the use of relatively inactive to more active techniques of remembering (Ornstein, Haden, & Elischberger, 2006; Schneider & Pressley, 1997). These changes in the deployment of a set of deliberate memory strategies – e.g. rehearsal and organization – are paralleled to some extent by corresponding changes in children's metamnemonic understanding of the processes involved in storing and retrieving information (Schneider & Pressley, 1997). Indeed, one assumption underlying much work in the area of metamemory is that what children (and adults, for that matter) know about the operation of memory is likely to be quite important for the deployment of various mnemonic techniques, as well as for developmental changes in the use of these strategies (Pressley & Hilden, 2006).

This assumption notwithstanding, evidence for conclusive linkages between children's strategy use and their metamnemonic understanding, either concurrently or over time, has been quite limited. For example, it is possible that: 1) strategy use and metamemory develop simultaneously, such that gains in one set of skills do not proceed in advance of the other, 2) strategic sorting ability develops in advance of, and contributes to, future increases in metacognitive knowledge, or 3) knowledge of declarative metamemory develops in advance

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of strategy use, and gains in metamemory contribute to future strategic success. Although subtle, the distinctions among these three models are meaningful when considering the development of these skills longitudinally. Indeed, whereas cross-sectional evidence has provided snap-shots of the relations between children's metamemory and strategic behavior at individual ages, the underlying development that occurs as children acquire these related skills remains uncharacterized. To explore these important developmental issues we make use of latent curve models (Bollen & Curran, 2006) to test these three equally plausible models of potential linkages between strategy use and metamemory using data drawn from a larger longitudinal investigation conducted in our laboratory of children's developing memory skills as they are followed across the first and second grades of elementary school.

Developmental Changes in the use of Mnemonic Strategies

Over the course of the elementary school years, children become increasingly skilled at using a group of deliberate strategies for remembering sets of words, objects, and pictures (Schneider & Pressley, 1997). Simply put, there are dramatic changes during this time period in what children do when confronted with tasks that involve remembering, as can be revealed in their use of organizational (e.g. Lange, 1978), rehearsal (e.g., Ornstein & Naus, 1978), and elaboration (e.g., Rohwer, 1973) strategies. Moreover, as can readily be illustrated with children's deployment of organizational techniques, to a considerable extent these changes involve learning to make deliberate use of information that is already known in the service of a memory goal. For example, within the context of a sort-recall task with categorically-related items, remembering is facilitated to the extent to which children form groups during the study period that reflect the taxonomic structure of the materials. In these situations, what seems to be changing with increases in age and experience is not so much the children's understanding of the taxonomic organization of the items, but rather their ability to make efficient use of that knowledge to establish a meaning-based grouping strategy. Indeed, for the most part, young children do not spontaneously organize to-be-remembered items on a semantic basis, but they can respond effectively to instructions to group according to meaning (Bjorklund, Ornstein, & Haig, 1977; Corsale & Ornstein, 1980). These findings indicate clearly that children in the early grades have the basic underlying knowledge to group semantically, but that they just do not use this knowledge to form strategies for remember. Yet, within a few years, these semantic grouping techniques are used spontaneously on a routine basis, and with increases in age and experience, children's organizational strategies become increasingly effective in mediating their recall performance (Ornstein et al., 2006; Schneider & Bjorklund, 1998).

Given these age differences in the use of organizational techniques, what can be said about the course of strategy development as children progress through the elementary school years? The impression derived from the literature is one of gradual acquisition of mnemonic skill, but it is difficult to make statements about developmental change within individual children on the basis of the cross-sectional research designs that have been used in the bulk of the published reports of children's memory. Although on average these studies may present a picture of relatively smooth trajectories over time, individual children often show fairly abrupt qualitative changes over short periods of time (Kron-Sperl, Schneider, & Hasselhorn, 2008). Indeed, the few longitudinal studies that have been reported suggest a more complicated picture of development, with some children making rapid transitions in organizational skill at different points in time (e.g., Schneider & Sodian, 1997; Schneider & Bullock, 2009), others never being able to master the strategy, and still others making use of the technique at one point, only to lose it at another (Schneider, Kron, Hunnerkopf, & Krajewski, 2004).

The Role of Developing Metamemory in the Development of Strategic Sorting

What may account for the variability observed in strategy acquisition across different children? Individual differences in developmental trajectories could be attributed, at least in part, to contextual factors such as interactions that children have at home or in school that have been identified as being important to the development of strategic sorting (Ornstein, Grammer, & Coffman, 2009). For example, recent evidence from an examination of teacher instructional style suggests that students of teachers who make more use of memory-rich metacognitive language in the classroom make greater gains in strategic sorting across the first grade than do their peers taught by teachers who use less use of this type of language (Coffman, Ornstein, McCall, & Curran, 2008).

As suggested above, paralleling the growth of children's strategy use are corresponding changes in their declarative metamemory or their knowledge of memory functioning and the range of factors that can influence remembering (Flavell & Wellman, 1977; Schneider, 1985). Indeed, a number of studies have documented substantial development in children's declarative metacognitive knowledge in childhood, revealing the extensive growth in children's knowledge of memory from the beginning of kindergarten through the third and fourth grades (Kreutzer, Leonard, & Flavell 1975; Schneider, 1999).

In contrast to more recent longitudinal investigations of children's strategy use that focus on predictors of children's performance, little is known about contextual or child-level factors that may be related to the development of metacognitive understanding. In one of the few investigations of the ways in which parents foster the development of metacognitive skills in their children during the elementary school years, Carr, Kurtz, Schneider, Turner, and Borkowski (1989) described differences between German and American parents' reports of strategy-related instruction. Moreover, Carr et al. also observed that greater amounts of such strategy instruction in the home are related to increased levels of children's metacognitive understanding and strategy use. Thus, it seems likely that the differences in children's metamemory that can be seen at the beginning of the first grade may be related to differences in aspects of the home environment that are experienced prior to school entry. Moreover, it is quite possible that individual child-level differences in other cognitive abilities may also contribute to the development of deliberate metacognitive understanding over time. For example, children's working memory, i.e., their ability to temporarily store information to be used for other tasks, may be predictive of their knowledge about remembering.

In addition, although it seems logical to assume that there would be clear linkages between strategy deployment and knowledge related to the use of mnemonic strategies, efforts to relate children's memory performance to their knowledge of memory processes have not always been successful (e.g., Salatas & Flavell, 1976). For example, in some instances children have been shown to possess knowledge of strategies that they fail to use subsequently (Sodian, Schneider, & Perlmutter, 1986). Alternatively, children who cannot articulate their knowledge of a specific mnemonic technique have nonetheless been found to be strategic (Bjorklund & Zeman, 1982). Despite these inconsistent findings, many researchers have proposed and tested theories about how the two constructs contribute to children's memory performance. For example, Pressley, Borkowski, and Schneider (1987, 1989) argued that the metamemory-memory relation was bidirectional, with gains in strategy sophistication increasing metamnemonic understanding, which in turn lead to further growth in strategic use.

More recent studies (e.g., Schneider, Schagmüller, & Vise, 1998) have provided evidence for linkages between metamemory and memory development by modeling children's performance. In general, models designed to characterize children's concurrent performance on memory strategy tasks have provided further evidence for the unique and important contribution of metamemory to recall, largely suggesting that metacognition relates to children's overall recall through its contributions to strategic behavior (Schneider & Pressley, 1997; DeMarie, Miller, Ferron, & Cunningham, 2004). Although these findings provide evidence concerning the relations between children's metamnemonic knowledge and strategic abilities at specific points in time, they do not provide insight into developmental changes that are occurring in each area separately or in the coordination of these skills as they grow over time.

Through the use of a microgenetic design that allowed near-weekly tracking of the acquisition of organizational strategies in elementary school children, Schlagmüller and Schneider (2002) came closer to capturing the role of metamemory knowledge in the development of strategic proficiency. When considering the role of metamemory in the development of strategic sorting, they found that children who came to develop the strategy during the investigation had knowledge of the utility of organized sorting in advance of implementing the technique. The metamnemonic understanding of these children was similar to that of children who had already acquired the strategy but greater than children who never came to sort proficiently during the investigation. These findings provide insight concerning matters of timing, indicating that the increases in declarative metamemory precede gains in strategy use. Importantly, however, although Schlagmüller and Schneider assessed children's strategic performance nine times, metamemory knowledge was only measured once before (5 months prior to the initial strategy task administration) and once after the repeated sort-recall trials were administered. As a result, it is difficult to draw conclusions about the timing of the relation between metamemory and memory behaviors.

The Current Investigation

Although each of the investigations described above was designed to describe linkages across different aspects of children's memory performance (e.g., DeMarie et al., 2004), for the most part they did not assess the same children over time. This focus on children's concurrent abilities may mask the underlying changes in the relations between strategy use and metamemory as they develop together over time. With repeated measures of both sorting strategy use and metamemory, competing hypotheses regarding the nature of the relations between the two over time can be tested.

In this investigation, we made use of data from a longitudinal study of the development of mnemonic skills to characterize the growth in individual children's metamemory and strategic sorting abilities across four assessments in the first- and second-grade years. In addition, potential predictors of these abilities and their growth were explored. Specifically, given the age-related changes in strategic performance and metamemory that have been observed in previous investigations, children's age at school entry was included as a predictor of performance. In addition, two measures related to the home environment that have been previously linked children's cognitive abilities at school entry – the home literacy environment and maternal education level (Griffin & Morrison, 1997; Christian, Morrison, & Bryant, 1998) – were also assessed. Further, children's working memory at the beginning of the first grade was also included as a predictor of both initial performance and growth. Finally, the nature of the relation between strategic sorting and metamemory as they develop together over time was assessed.

To make optimal use of the longitudinal data available and to better understand the growth in children's skills, a series of latent curve models (LCM) was fit to the data (Bollen & Curran, 2006). Although not commonly applied to memory-development data, this structural-equation based technique is uniquely suited to the analysis of multiple repeated measures that are thought to be developing simultaneously. LCM is based on the premise that a set of observed repeated measures collected from individuals over time can be used to estimate an unobserved underlying trajectory that gives rise to the observed repeated measures. The procedure allows for the estimation of both mean trajectories in children's performance over time and variability in individual trajectories. Moreover, LCM can be used to examine predictors of growth trajectories and, most importantly to the focal question of this project, relate the trajectories of one variable with those of another.

LCM models were first used to characterize the underlying individual growth trajectories of metamemory and strategic sorting that gave rise to the observed repeated measures collected in the child-level assessments across the first grade and into the beginning of the next school year. After identifying the best fitting model for the growth in strategy use and metacognitive understanding, potential time-invariant predictors of performance were then tested, with the goal of identifying factors that may contribute to children's mnemonic performance at the beginning of the first grade, as well as to changes in performance over time.

In addition to focusing on the independent trajectories of children's mnemonic skills, of greatest interest when considering the development of strategy use and metacognition is the ways in which one might be related to changes in the other over time. The use of latent curve models (Bollen & Curran, 2006; Curran, Obeidat, & Losardo, 2010) allows for the analysis of relations between variables that are developing concurrently. As such, a final set of analyses makes use of LCM models in an effort to better understand the linkages between metacognition and strategy use developmentally by testing three contrasting models to address the question of whether these skills grow simultaneously, or if one set precedes the other.

Method

Participants

The participants included 107 children, 49 boys and 58 girls, who were recruited from 14 first-grade classrooms in four schools across two districts and followed into the beginning of the second grade as a part of a larger longitudinal investigation of memory development in the classroom context. At the start of the investigation, the children were 6 years and 7 months old, on average. The diversity of the sample reflected the southern suburban/urban area from which the participants were drawn, with 47% of the families describing their ethnicity as Caucasian, 27% as African-American, 4% as Hispanic, 15% as Asian, and 7% as being of mixed ethnicity. For the purpose of the analyses presented here, data from the full sample of all children available at each time point are reported. In our analyses, direct maximum likelihood estimation was used, which enabled data from children who did not take part in all waves of data collection to remain in the models.

Design

As a part of the larger longitudinal investigation, the children participated in three assessments at their schools in the fall, winter, and spring of Grade 1 (Time Points 1, 2, and 3) and the fall of Grade 2 (Time Point 4). The fall and winter assessments were separated by 80 days, on average, with an additional 57 day delay between the winter and spring Time Points. Given the summer break between the spring assessment in Grade 1 and the fall assessment in Grade 2, 211 days separated Time Points3 and 4. At each Time Point the children engaged in a variety of memory tasks with an experienced research assistant. Individual assessments lasted between 45 and 60 minutes and included a range of deliberate memory, event memory, and working memory tasks. For the purposes of this report, we focus on three measures of children's mnemonic skill: Sort-Recall with Organizational Training (Moely et al., 1992), a Metamemory Scale (Schlagmüller, Vise, & Schneider, 2001), and Working Memory Sentence Completion (Siegel & Ryan, 1989). In addition, questionnaires were sent to the families of each participating child. Included in the questionnaire were measures of the home literacy environment (Griffin & Morrison, 1997) and maternal educational level.

Procedure

Sort-Recall with Organizational Training (SRT)—At each administration of this task, which was designed by Moely and colleagues (1992) to measure the use of organizational strategies for sorting and clustering, the children were presented with 16 cards with line drawings that were taken from four conceptual categories. In the fall of the first grade, at the first assessment (Time Point 1), each child was given an initial baseline trial of the Sort-Recall task. Immediately following this initial assessment, a second trial was administered, during which strategy training was provided. After a 15-minute delay, at the same assessment each child was also given an initial generalization trial. At Time Points 2, 3, and 4 the children were presented with a single non-instructed generalization trial.

On the baseline trial at Time Point 1, the picture cards were presented in a quasi-random order such that categorically-related items were not displayed alongside each other, and the children were told to do whatever they could to remember the pictures. On the subsequent training trial, the children were instructed in the use of categorization during study (sorting) and recall (clustering) as aids to remembering. To assess the children's ability to make use of sorting and clustering strategies in the absence of specific instructions to do so, a generalization trial was administered 15 minutes later with a new set of cards. Subsequent assessments of long-term generalization of the trained sorting strategy were obtained at Time Points 2, 3, and 4. Throughout the administration of the task, the experimenter the recorded the children's sorting patterns, the number of items recalled, and the order in which the items were reported. With this information, a standard index of categorical grouping, the Adjusted Ratio of Clustering (ARC) Score (Roenker, Thompson, & Brown, 1971), was calculated to characterize the children's sorting during the study period. The ARC scores could range from -1 (below chance organization), to 0 (chance), to 1 (complete categorization). Two coders independently scored all records, with any discrepancies being resolved through examination of the original videotapes.

The Metamemory Scale (MET)—At each assessment at Time Points 1, 2, 3 and 4 the children were engaged in a series of questions that were adapted from the Würzburg Metamemory Task (Schlagmüller et al., 2001). Two subscales from Schlagmüller et al.'s original task were administered to assess: 1) general declarative metamemory and 2) knowledge of semantic categorization strategies. For each subscale, the children were presented with a variety of scenarios designed to tap into their metamnemonic knowledge in these two areas. In preparation for the task, children were given a few sample items to ensure that they understood the instructions.

To assess general declarative metamemory, the children were asked to compare person variables (i.e., characteristics of individuals thought to affect remembering), task demands, and potential strategies that individuals could use to remember information. For example, the participants were presented with descriptions of three individuals who had been asked to remember a story about a town. One of these individuals was described only as having never been to the town, whereas the other two were portrayed as having visited either 2 years or 4 weeks ago. The children were then asked rank order individuals to reflect who would have the hardest to the easiest time remembering the story.

When presented with scenarios designed to capture understanding of semantic categorization, the children were asked to compare the ease of remembering contrasting groups of words that varied as a function of the type and strength of categorical grouping. For example, the participants were asked to compare three ways that one might go about remembering 12 cards with objects on them. They were presented with three possible strategies for remembering the items that included 1) arranging the objects by color and repeating the colors, 2) grouping the objects based semantically and then rehearsing them in their groups, or 3) repeating the names of the objects in no particular order. The children were then asked to compare the three sets of similar items based on the extent to which the grouping in each example would make the sets easier or harder to remember.

For each item on each subscale, these rank orderings were subsequently scored, with one point given for each correct paired comparison. For each question, the child could make up to 3 correct paired comparisons by ordering each of the three items correctly, or could obtain 1 or 2 points of credit for having successfully rank-ordered 1 or 2 of the pairs in the set. Thus, a maximum of 3 points could be earned for each item. Summing across both subscales, metamemory scores could range from 0 to 30.

Working Memory Sentence Completion—Following the procedure used by Siegel and Ryan (1989), at Time Point 1 the participants were read a set of sentences that lacked a final word and were asked to provide a word to complete each sentence. The experimenter instructed each child to repeat the words that he or she had provided in order after the last sentence in each set. Thus, the child was asked not only to nominate an appropriate word to complete each sentence, but also to remember the series of words that he or she provided in order. The number of sentences presented in a set increased systematically across trials from two to five, and three opportunities at each set length were given, so that the scores could range from 0 to 12 correctly recalled sets. The task was discontinued when the child failed all three trials in a set. The children's performance on the task was scored by two independent coders.

The Home Literacy Context—A questionnaire was sent to the parents of the participating children in order to gather general information about the family context. The questionnaire included items about maternal education, as well as reading in the family setting. To assess maternal education level, the families were asked to report whether or not the child's mother had completed high school, and, if so, to indicate the highest level of post-high school education achieved, ranging from no post high school education (0), to Vocational or Associate's degree (3), to PhD, JD, or MD (6). To assess the salience of reading in the family context, the Home Literacy Environment Index (Griffin & Morrison, 1997) was also included in the background questionnaire. This measure, which has been found to uniquely predict children's early language-based literacy skills in kindergarten and second grade, includes questions about the amount of reading material available in the home, the frequency of visits to the library, and parental reading practices. Family responses could result in scores ranging from 0 to 21.

Results

We first briefly present descriptive results for the children's mean levels of sorting and metamemory performance, as well as for additional time-invariant predictors of these aspects of children's mnemonic skills. Next, we describe a series of unconditional models that were designed to determine the optimal functional forms for both sorting and metamemory. We then describe time-invariant predictors of initial performance and growth on measures of both sorting and metamemory. Finally, comparisons of three hypothesized models linking strategic sorting and metamemory over time are presented.

Descriptive Results

At least 97% of the sample was seen at the first three Time Points in the fall, winter, and spring of the first grade, and 87% of the children continued to participate in the study as they entered the final Time Point in the second grade. At each Time Point, equipment failure led to the loss of only a few individual measures (range: 0 – 3). Comparisons conducted between children with and without missing data revealed no significant differences on any Time Point 1 variables, including metamemory and strategic sorting, or the time-invariant predictors, such as children's working memory and home literacy environment, as well as maternal education level. Model parameters were estimated using direct maximum likelihood estimation, which is suitable for use with datasets that include some missing data. Direct maximum likelihood estimation permits all available data to be included in an analysis and yields parameter estimates that tend to be less biased than those derived from other common missing data techniques (i.e., listwise deletion, pairwise deletion, mean imputation) (Collins, Schafer, & Kam, 2001; Schafer & Graham, 2002). Although the majority of children in the investigation were present at all Time Points, there were a few who were available for only two or three of the assessments, due to family moves out of the area. The use of direct maximum likelihood estimation allowed for the use of all data collected, even if a child did not have complete data for each Time Point. In addition, preliminary analyses indicated that there were no significant gender differences seen in performance on the variables of interest, and, as such, all analyses were collapsed across gender.

As can be seen in Table 1, prior to training in organizational sorting, the children's average sorting ARC scores at baseline were modest ($M = -.03$), reflecting near chance levels of sorting at the beginning of the first grade. After the training trial at Time Point 1, the mean ARC scores increased considerably at the generalization trials that were administered at Time Points 2, 3, and 4, with the values of .50, .64, and .62 reflecting the fact that children sorted at least 12 of the 16 cards according to their taxonomic groups. In addition, as indicated in Table 1, the participants' declarative metamemory scores also increased overall, although more gradually, with children gaining an average of 2 points on the scale from the beginning of the first grade to the start of the second grade.

As the investigation was launched, the children's mean working memory score, as assessed with the Working Memory Sentence Completion task, was 1.94 (range = 0 – 7) on a 12 point scale. The rate of return for the background questionnaires was 91%, and data drawn from these questionnaires yielded Home Literacy mean scores of 11.92 (range = 3 – 19) out of a potential 21 points. In addition, mother's mean reported education level was 3.76 (range = 0 – 6), indicating that, on average, the mothers of the children in the sample had obtained either an associate's or bachelor's degree.

Unconditional Models

Although descriptive analyses show increases in children's mean performance in sorting and metamemory, the use of LCM techniques allows us to examine more formally non-linear growth across time points. In order to identify the functional form that best describes the growth of sorting and metamemory across the first grade and the beginning of the second grade, we separately tested unconditional models of the individual trajectories of children's strategic sorting and metamemory scores. The goal of using these unconditional models is to determine the model that best approximates the observed change in our data across time; thus, no covariates or predictors are included. Specifically, we examined whether linear, quadratic, or free form parameterizations characterized the growth of these two skills, as indicated by measures of model fit, across the four data points.

Figures 1 and 2 represent the best fitting unconditional model for each construct. In these figures, there are two latent variables, alpha (α), which is the intercept or initial starting point and beta (β), which reflects the slope or growth over time. The arrows connecting each time point to the latent variables represent factor loadings and are labeled according to their numerical fixed value or to lambda (λ) to indicate the parameter is estimated instead of fixed. All factor loadings on the intercept are fixed to 1.0, so that each factor equally influences each time point. The factor loadings on the slope are fixed or estimated, depending on which functional form fits the data best. The four boxes represent the four time points at which each construct was measured. Thus, each repeated measure is a function of the intercept, the slope, and time-specific error. When evaluating model fit, we relied primarily on two measures, the root mean squared error of approximation (RMSEA), an absolute fit index, that assesses how well the specified model reproduces the sample data, and the confirmatory fit index (CFI), an incremental fit index that examines the improvement in fit in the specified model as compared to a more restricted baseline model (Hu & Bentler, 1999). Low values of RMSEA are desirable, with values less than .06 indicating good fit, and values between .6 and .10 indicating fair to mediocre model fit. When examining the CFI, values between .95 and 1 represent good fit, and values between .90 and .95 indicate moderate model fit (Hu & Bentler, 1999).

As illustrated in Figure 1, the free form model, that allows for non-linear change across time, best captured the growth in sorting scores, χ^2 (3) = 6.61, p=.09; RMSEA = .11, CFI = .96. Free form models require two time points to be fixed (for identification), but allow the other time points to be estimated freely from the data. Given the extreme changes in children's sorting ARC scores between the baseline and Time Point 2 generalization Trial, the free form model best reflects the patterns observed in children's changing sorting performance, from very little spontaneous sorting in the beginning of Grade 1 to high levels of sorting at the first and subsequent generalization trials after children were trained in the use of a sorting strategy. Additionally, fixing the first and last time points, as we have done, allows for the interpretation of freed factor loadings as the proportion of change between two time points relative to the total change seen in strategic sorting across all four time points. As shown in the bottom portion of the figure, model testing and comparisons of model fit indicate that a linear model optimally captured growth in metamemory across the four time points, χ^2 (5) = 8.23, p=.14; RMSEA = .08, CFI = .98, reflecting that the amount of growth shown in metamemory was similar across all time points.

LCM models provide both mean and variance estimates for intercepts (starting points) and slopes (change over time). Significant variances indicate that there is individual variability that could be potentially explained by other factors. The estimates of these parameters for the unconditional models are shown in Table 2. Whereas there was not significant variability in the children's initial sorting scores, there was significant variability observed in their declarative metamemory scores at Time Point 1, as reflected by significant variance in the intercepts. Importantly, results from both models indicated that variance in the growth of sorting and metamemory approached conventional levels of significance. In addition, for both models, the covariance between the intercept and slope was nonsignificant, suggesting that gains in metamemory and sorting were not linked to the children's initial starting performance on each task.

Predictors of Children's Strategy Use and Metamemory

Next, given the evidence from the unconditional models that there was significant variability left to predict in children's initial metamnemonic understanding at school entry, and in growth in both sorting and metamemory across the first and second grades, a series of conditional models including predictors of children's performance were tested. In these models, we assess the relations between predictors of the intercept of the metamemory scores, and the slope of both the metamemory and strategic sorting measures. Prior to carrying out these analyses, we predicted that factors related to the home and family environment, as assessed with the Home Literacy Index and maternal education level, might be important predictors of starting values in metamemory and trajectories of growth in both skills. Additionally, we hypothesized that child characteristics, such as age at school entry and initial working memory scores, may explain some of the variability seen in the initial levels of metamemory and in the growth of both skills.

Predictors of initial metamemory scores—Figures 2 and 3 portray the general conditional models in which time-invariant predictors are represented by the box labeled x_1, which predicts to both alpha (α), the intercept, and beta (β), the slope. First, we examined predictors of the initial metamemory scores; parallel models were not conducted for sorting, due to the lack of variability in the intercept of the unconditional model. Although maternal education level did not predict children's starting metacognitive knowledge, higher scores on the Home Literacy Environment Index were found to be significantly related to increased metacognitive understanding at the beginning of Grade 1 (γ = .27, SE = .13, p< .05; χ^2 (7) = 11.38, p=.12; RMSEA = .08, CFI = .97). In addition, children's age at school entry proved to be a significant predictor of children's metacognitive knowledge (γ = .04, SE = .01, p< .00; χ^2 (7) = 11.31, p=.13; RMSEA = .08, CFI = .97), with older children exhibiting higher initial metamemory scores than their younger peers. Finally, higher levels of working memory were also found to be related to higher initial metamemory scores (γ = .54, SE = .26, p< .04; χ^2 (7) = 8.41, p= .30; RMSEA = .04, CFI = .99).

Predictors of growth in strategy use and metamemory over time—Next, we tested the role of the home literacy environment and maternal education level on initial metamemory scores and growth in both sorting and metamemory. Results from separate models of each predictor indicated that maternal education level, but not the home literacy environment or children's working memory scores and age at school entry, was a significant predictor of the slope factor for both outcomes. Although the model fit for strategic sorting was adequate (χ^2 (8) = 17.74, p=.02; RMSEA = .11, CFI = .91), the model including maternal education level as a time-invariant predictor of metacognitive growth fit the data well (γ = .08, SE = .03, p< .01; χ^2 (7) = 9.40, p=.23; RMSEA = .06, CFI = .98). In both cases, the results indicated that there were significant differences in the rates of change in declarative metamemory as a function of the education level attained by the mothers of the participating children.

Finally, the interaction between maternal education level and children's metamnemonic growth was explored. The use of an online calculator (Preacher, Curran, & Bauer 2006) allowed us to examine precisely the levels of maternal education at which children show increases in metamemory over time. In particular, estimation of the region of significance of the slope factor indicated the levels of maternal education at which the slope of metamnemonic growth was significantly different from zero. The results revealed that children whose mothers reported having less than a college degree did not evidence significant increases in metamemory over the year, whereas the scores of children whose mothers reported having at least a college degree did increase across first grade (region of significance ≥ 1.7).

Linking Strategic Sorting and Metamemory Over Time—After fitting models that included time-invariant predictors of children's strategy use and metacognition, we tested multiple LCM models in order to investigate the relations between concurrent measures of metamemory and sorting across all four time points. To do this, we examined three different models that included metamemory and sorting ARC scores as time-varying covariates to test the following hypotheses: 1) strategy use and metamemory develop simultaneously, and gains in one set of skills do not proceed in advance of the other but instead are related to each other within individual time points, 2) strategic sorting ability develops in advance of, and contributes to, future increases in metacognitive knowledge, or 3) knowledge of declarative metamemory develops in advance of strategy use, and gains in metamemory contribute to strategy deployment at subsequent time points. Comparing the model fit indices and individual relations between the two constructs at different time points across these three models provides important information about the ordering and interconnections of the development of these two skills across the four time points. In each of these three models, time-specific influences of one skill are estimated on the time-specific performance of the other, above and beyond the growth process. In other words, the underlying growth estimated by the slope is controlled for in these models.

In the first of these models, the concurrent relations between metamemory and sorting were examined by including metamemory scores as a time-varying covariate in the prediction of sorting performance. The model fit reasonably well (χ^2 (10) = 19.77, p= .03; RMSEA = .10, CFI = .91), and is represented in Figure 4 by vertical arrows drawn from metamemory at each time point to sorting at the same time point. However, no time-specific influences of metamemory on sorting were found, indicating that above and beyond the estimated growth process of sorting, at each time-point there were no concurrent relations between metamemory and strategic sorting over time. Thus it seems unlikely that strategy use and metamemory develop in parallel, related to each other only when measured concurrently. Moreover, results of this initial model suggest the need to look for more than simultaneous relations between metamemory and sorting.

Next, we tested two lagged regression models to determine whether there were time-lagged relations between sorting and metamemory, hypothesizing that gains in one set of mnemonic skills would be related to gains in the other at a subsequent time point. Specifically, we assessed the fit of a lagged regression model of sorting performance on metamemory and compared those results to an alternative a lagged regression model of metamemory on sorting performance. Examinations of model fit indicated clearly that the model depicted in Figure 5, which shows time lagged influences of metamemory scores on later sorting performance (χ^2 (7) = 10.23, p= .18; RMSEA = .07, CFI = .97), more accurately described the data, than the alternative model, in which sorting performance influenced later metamemory scores (χ^2 (9) = 32.03, p= .00; RMSEA = .15, CFI = .85). Moreover, there were no significant time-specific effects identified in the model in which strategic sorting preceded metamemory, indicating further that it did not describe the data well. Conversely, in the model where metamemory precedes strategic behavior, metamemory at Time Point 2 was found to significantly predict sorting at Time Point 3 above and beyond the impact of metamemory within the same measurement point at Time Point 3. The same pattern was found between Time Points 3 and 4. These results suggest that metamemory develops in conjunction with, but in advance of, children's strategic sorting.

Discussion

In this longitudinal investigation, the trajectories of children's strategy sorting skills and declarative metacognitive knowledge across Grade 1 and into Grade 2 were modeled. In addition, predictors of both children's initial performance in metamemory and individual growth over time were explored. After identifying predictors of children's skills on each of these tasks, competing models of the relations between strategy use and metacognitive knowledge across this period of time were tested.

Variability in children's metamemory scores at the beginning of the first grade was predicted by a range of child-level and home variables. Indeed, indicators of children's initial mnemonic abilities, such as working memory scores, were related to children's initial metamemory performance, providing additional evidence for the interdependence of these related memory-related skills. The children's age and home literacy environment were also associated with initial metamemory scores, suggesting that there are aspects of the home environment and additional age-related experiences that may be impacting this important skill.

In addition, growth in metamemory and strategy use were both linked to maternal education level. When considering the interaction between maternal education and the development of metamemory, it appears likely that there is something unique about the context created by mothers who have had at least some experience in college that has implications for children's basic understanding of declarative metamemory. Although maternal education does not capture all aspects of socioeconomic status, it nonetheless correlates well with traditional measures of SES. The interaction between maternal education and metamemory is consistent with other reports of family-level effects on children's remembering. Indeed, previous research has illustrated linkages between variations in maternal conversational style in mother-child conversations about the past and children's independent autobiographical memory reports (Fivush, Haden, & Reese, 2006). Moreover, working- and middle-class families have been shown to differ in other components of mother-child reminiscing (e.g., Burger & Miller, 1999). Whereas broad measures such as maternal education level and SES do not provide information regarding the specific contextual factors that may be relevant for the development of metacognition, this interaction between maternal education level and metamnemonic growth highlights the importance of further investigation of specific aspects of the home context. Indeed, factors including maternal conversational style (e.g., Fivush et al., 2006) and opportunities for other memory-related activities that vary across children's home environments may contribute to the development of metacognitive knowledge and strategy use. Given that the origins of metamnemonic skills have not been explored extensively but that linkages between other aspects of children's memory performance and their experiences have been identified, future research should focus directly on determining those aspects of the home environment that may be linked to children's metacognition.

Interestingly, an examination of the covariance of the intercept with the slope of the individual unconditional models of both metamemory and sorting indicated that children's initial performance on each of these tasks was not systematically related to their growth in these skills across the first and into the second grade. This finding suggests that the trajectories of children's performance on either of these tasks are not predetermined when children enter the first grade. Indeed, it does not seem to be the case that children's performance simply levels off, with those who performed better initially then continuing to do so at each subsequent time point. The models also did not provide evidence for a catch up effect, which would have been identified if children who were lower performing at the beginning of the investigation were the only ones to show gains in metamnemonic understanding and strategic sophistication over time. This finding suggests that there are many other factors, including aspects of the school and home environments that may continue to impact children's skills in these areas.

In addition to predictors of these skills, the relations between sorting strategy use and metacognitive understanding over time were tested. The results of a series of LCM models indicated that the linkages between the development of strategic sorting and metamemory at early ages are best characterized by time lagged associations, not concurrent ones. Comparisons of concurrent and time-lagged models confirm the reports of Schlagmüller and Schneider (2002), and suggest that the acquisition of metamnemonic knowledge precedes strategic sorting and influences the amount of sorting that children exhibit at subsequent time points. The findings that we have identified with the use of LCM are exciting because they not only provide additional evidence for Schlagmüller and Schneider's earlier work, but they also allow us to make more specific statements about the developmental process underlying the development of these skills. In addition, they speak to the nature of the relations between these two abilities as they are developing over time. Although the results do not provide information about the specific mechanisms by which metacognitive knowledge might influence strategy use, it is clear that metacognition is important for the development of mnemonic strategies.

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When considered along with the predictors that were identified from the conditional model of metamemory, the results presented here suggest that metamemory may serve a mediating role between children's contextual experiences (e.g., home, school, or in the context of direct strategy training) and the development of strategy use during this period of time. As evidenced by marked increases in children's mean sorting ARC scores after training at Time Point 1 (see Table 1), it is clear that training in the use of sorting strategies was effective. Although the inclusion of strategy training in the longitudinal study prevents direct comparison with investigations of natural strategy development, it nonetheless enables a consideration of the relations between metamemory and strategy use under conditions in which children minimal instruction. For example, it is possible that children with higher metamemory skills at one point in time are better able to pick up on contextual cues, such as the training that we provided at the initial time point of the investigation, which then could result in more sophisticated strategic sorting at later assessments. Moreover, these findings offer hints about the relations between these two skills over time, as well as the predictors that might influence further the development of metamemory or strategy use, but many potentially interesting predictors at both the level of the child and the social environment remain to be explored.

In addition to these more theoretical contributions to our understanding of memory development, we have been able to draw upon statistical techniques that allow us to overcome a number of methodological limitations that have previously restricted researchers' abilities to characterize developmental change over time. Most importantly, the data presented here include repeated, concurrent measures of children's skills in both strategic sorting and metamemory across the first grade and into the beginning of the second grade. With our repeated assessments, it was possible not only to look within individual time points at the ways in which sorting and metamemory are related, but also to consider linkages between the two that might exist over time. In addition, the application of LCM techniques has allowed for the characterization of individual trajectories of growth in these two mnemonic abilities as they are related over the first grade and the beginning of the second grade.

Clearly there are a number of additional factors – some of which were included here as predictors of children's initial performance and growth – that must be accounted for in order to capture the full picture of children's mnemonic development. The measures of the home context described here, although informative for this initial investigation, are very limited in the amount of detail that they provide about specific aspects of the home environment that might matter for children's memory development. Another limitation of this work can be seen in the limited measures of metamemory that were employed. Future investigations could consider additional measures of procedural or task-specific metamemory in order to provide a more comprehensive understanding of the relations between metamemory and strategy use over time. Despite these limitations, the findings reported here capture some of the complexities of the processes underlying the development of memory by increasing our understanding of the temporal associations between the development of metamemory and strategy use.

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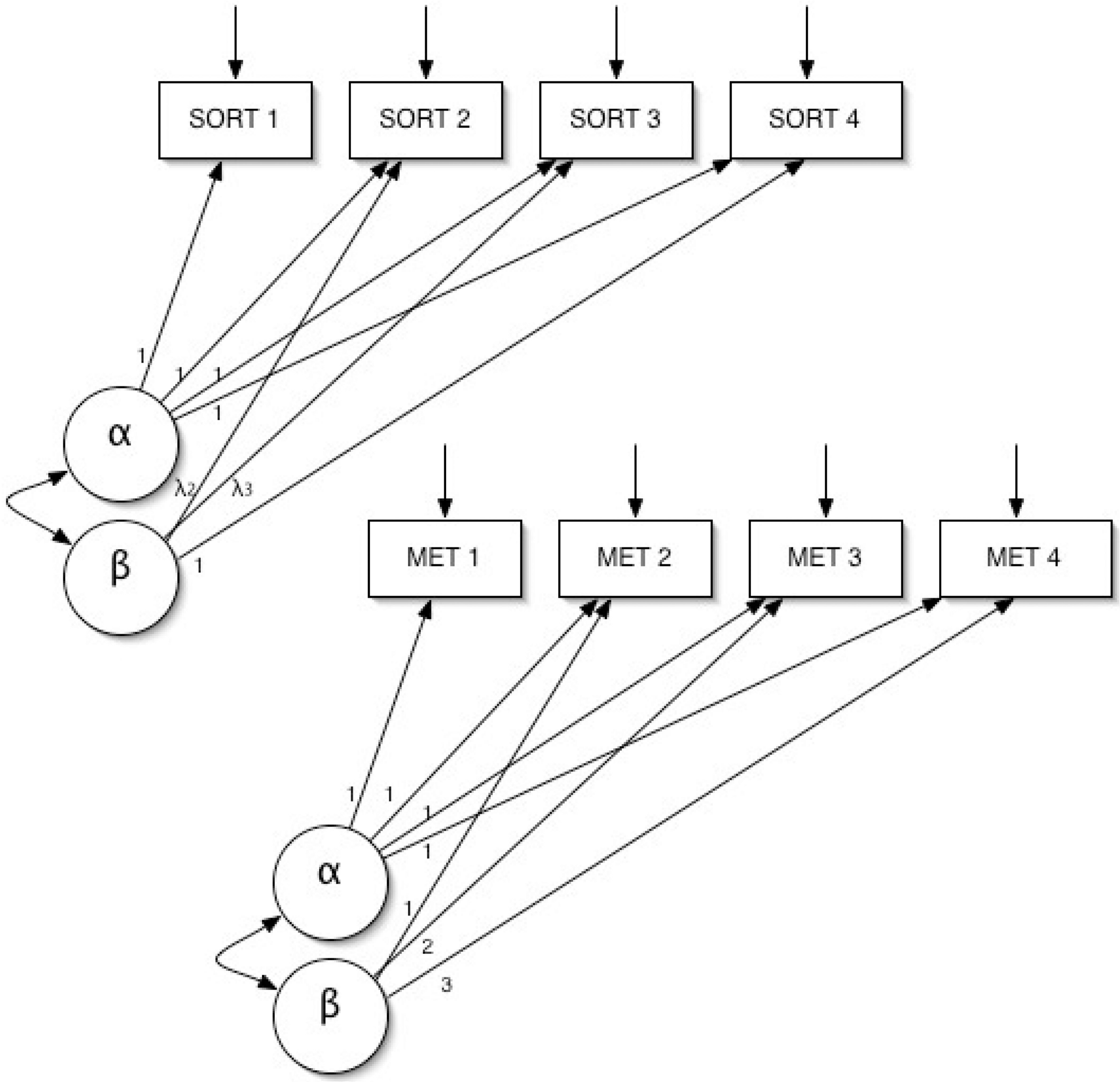

Figure 1.
Unconditional models of children’s strategic sorting and metamemory

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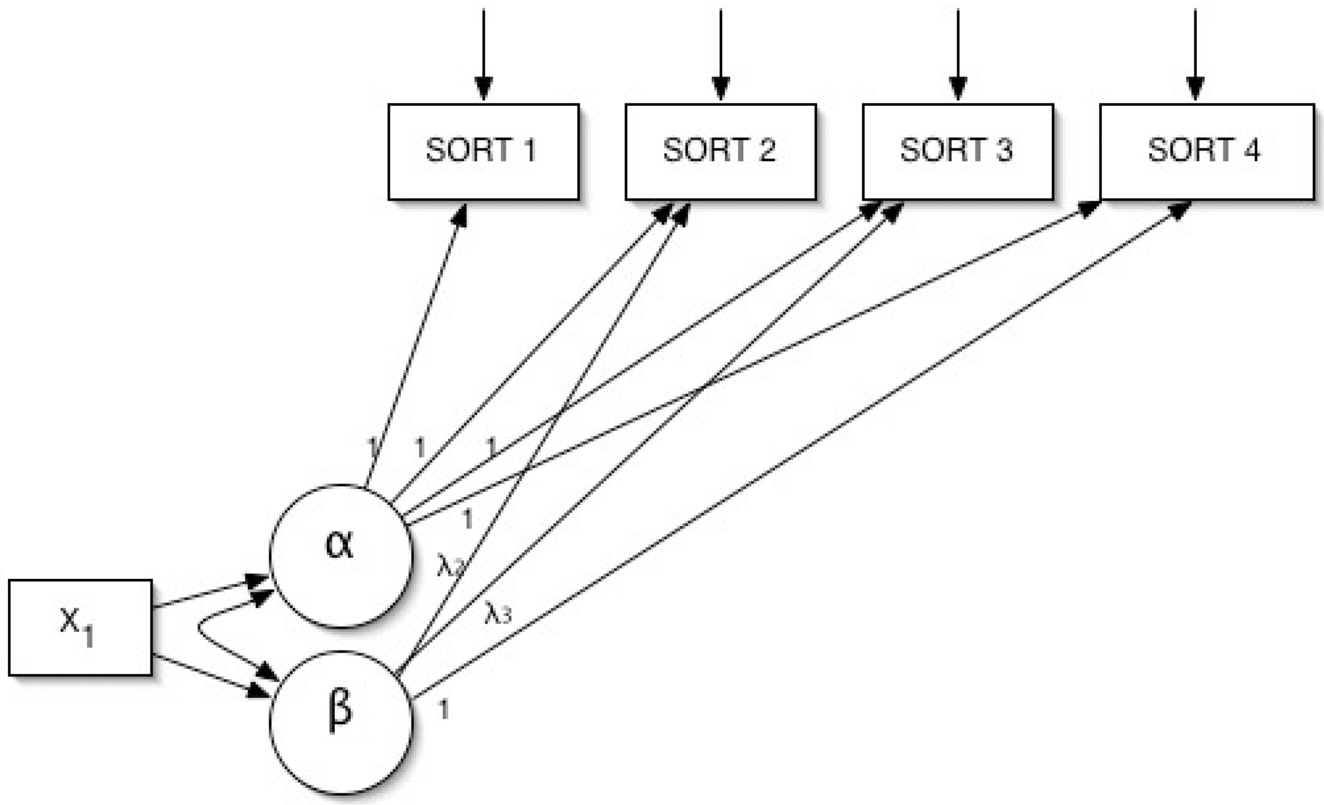

Figure 2.
Conditional free-form model of strategic sorting

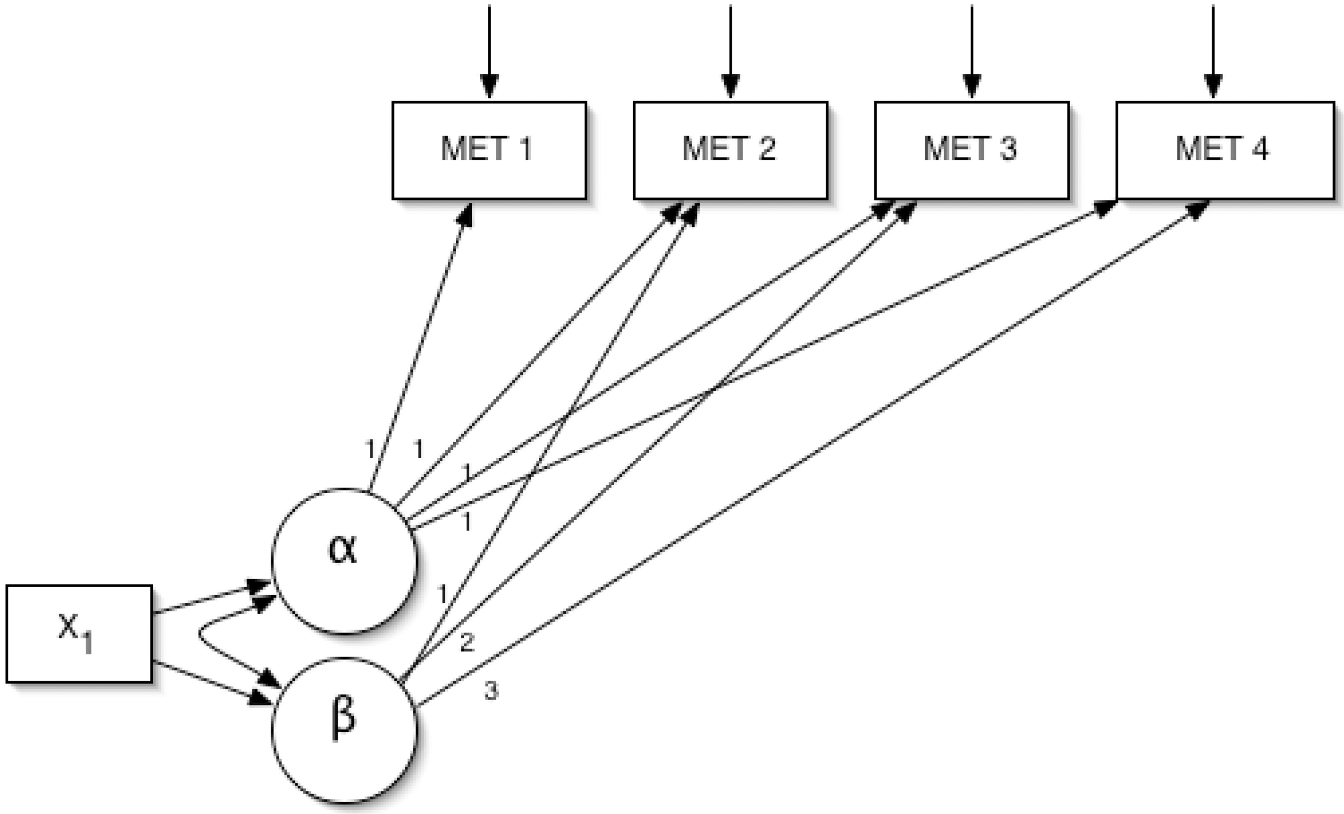

Figure 3.
Conditional linear model of declarative metamemory

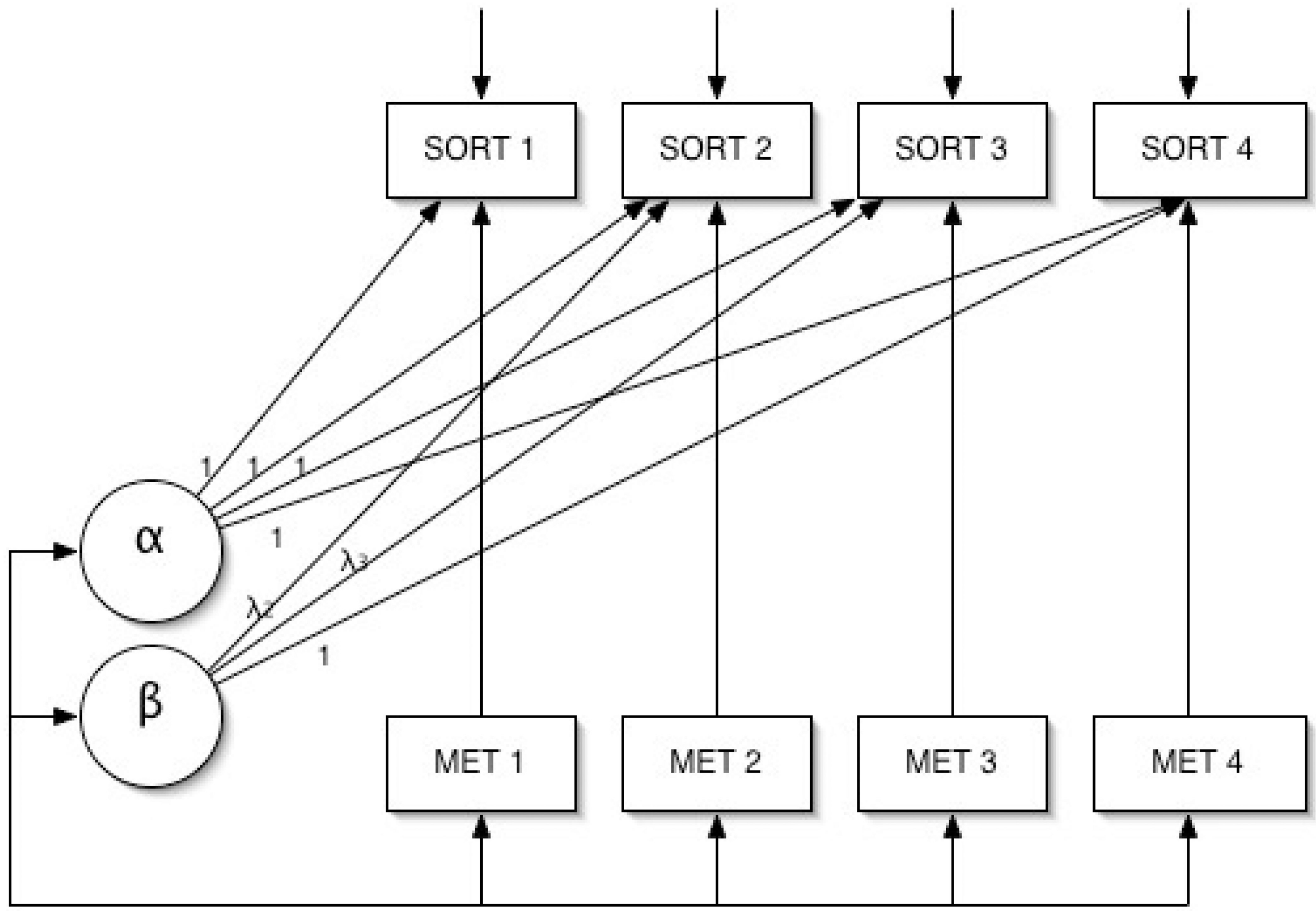

Figure 4.
Unconditional time-varying covariate model with contemporaneous regression of sort-recall performance on metamemory

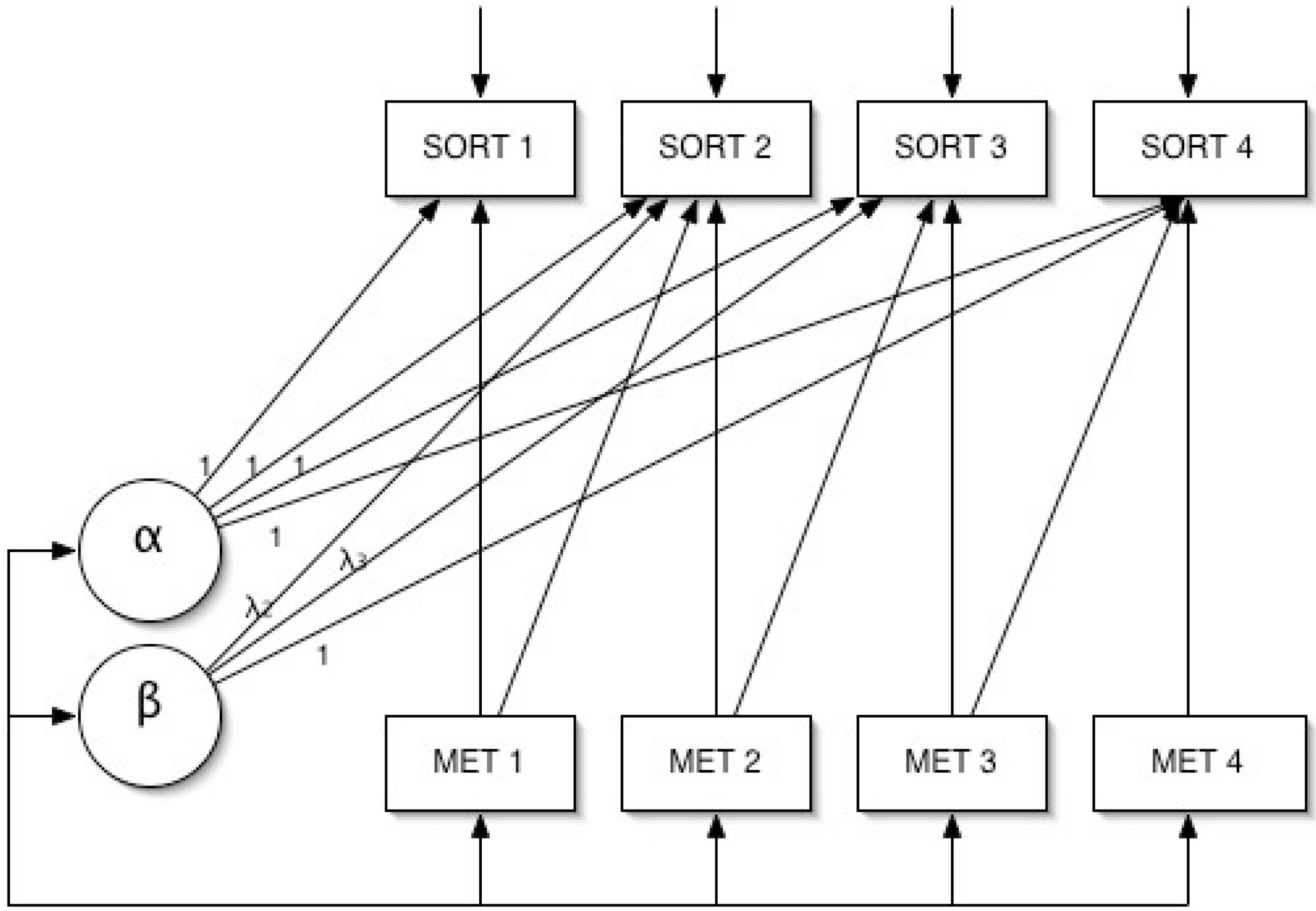

Figure 5.
Unconditional time-varying covariate model with lagged regression of sort-recall performance on metamemory

Table 1

Children's Memory Skills: Descriptive Statistics Across Grades 1 and 2

	Grade 1			Grade 2
	Time Point 1	**Time Point 2**	**Time Point 3**	**Time Point 4**
Tasks	**M *(SD)***	**M *(SD)***	**M *(SD)***	**M *(SD)***
Sort-Recall Sorting Scores	−.03 (0.42)	.50 (0.57)	.64 (.53)	.62 (.52)
Metamemory	17.2 (4.50)	17.7 (4.69)	18.7 (4.60)	19.6 (4.46)

Table 2

Results from Unconditional Models of Children's Sort-Recall Sorting Scores and Metamemory

	Estimates	S.E.	Est./S.E.	P-Value
Sort-Recall Sorting Scores				
Means				
Intercept	−.03	.04	−.76	.45
Slope	.62	.07	8.88	.00
Variances and Covariances				
Intercept	.09	.11	.79	.43
Slope	.21	.12	1.73	.08
Intercept with Slope	−.06	.11	−.55	.59
Metamemory				
Means				
Intercept	17.06	.41	42.06	.00
Slope	.82	.16	5.16	.01
Variances and Covariances				
Intercept	9.01	2.63	3.42	.00
Slope	.81	.50	1.63	.10
Intercept with Slope	−.01	.91	−.01	.99