Journal of Experimental Child Psychology 136 (2015) 17–29

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

That's a good one! Belief in efficacy of mnemonic strategies contributes to age-related increase in associative memory

Ana M. Daugherty [a,b], Noa Ofen [a,c,*]

[a] Institute of Gerontology, Wayne State University, Detroit, MI 48202, USA
[b] Department of Psychology, Wayne State University, Detroit, MI 48202, USA
[c] Department of Pediatrics, Wayne State University, Detroit, MI 48202, USA

ARTICLE INFO

Article history:
Received 1 June 2014
Revised 22 October 2014

Keywords:
Cognitive development
Associative memory
Metamemory
Episodic memory
Strategy efficacy
Strategy preference

ABSTRACT

The development of associative memory during childhood may be influenced by metacognitive factors. Here, one aspect of metamemory function––belief in strategy efficacy—was tested for a role in the effective use of encoding strategies. A sample of 61 children and adults (8–25 years of age) completed an associative recognition memory test and were assessed on belief in the efficacy of encoding strategies. Independent of age, belief ratings identified two factors: "deep" and "shallow" encoding strategies. Although the strategy factor structure was stable across age, adolescents and adults were more likely to prefer using a deep encoding strategy, whereas children were equally likely to prefer a shallow strategy. Belief ratings of deep encoding strategies increased with age and, critically, accounted for better associative recognition.

Introduction

Episodic memory refers to the awareness of earlier events that occurred in a certain place at a certain time and is crucial for everyday life. Episodic memory requires processes that allow the binding, or association, of disparate pieces of information over time and space (Tulving, 1972). This

* Corresponding author at: Institute of Gerontology, Wayne State University, 87 E. Ferry St., 226 Knapp Bldg., Detroit, MI 48202, USA.

E-mail address: noa.ofen@wayne.edu (N. Ofen).

http://dx.doi.org/10.1016/j.jecp.2015.02.008
0022-0965/

fundamental associative component of episodic memory is typically conceptualized as the linking of two pieces of information, content and contextual information, together into a memory representation (Shing, Werkle-Bergner, Li, & Lindenberger, 2008; Tulving, 1972). The current understanding of episodic memory function is largely predicated on the study of adults, whereas less is known about episodic memory during childhood and adolescence (Ofen, 2012). It is accepted that episodic memory develops throughout infancy and childhood (Bauer, 2005; Nelson, 1993; Perner & Ruffman, 1995; Tulving, 1983; Wheeler, Stuss, & Tulving, 1997). It is not clear, however, at what age children acquire a mature, functioning episodic memory system, and it appears that the episodic memory system continues to develop through middle childhood and adolescence (Brown, 1975; Ofen, 2012). Indeed, associative memory in children is more prone to false recognition errors than memory for single items (Shing, Werkle-Bergner, Li, & Lindenberger, 2009; Shing et al., 2008), suggesting prolonged maturation of associative memory recognition.

Metamemory—the knowledge about memory (Schneider, 1999; Schneider & Pressley, 1997)—is known to influence the encoding, maintenance, and retrieval of memories (Hertzog & Dunlosky, 2004; Schneider, 1999; Schneider & Pressley, 1997). Belief in memory efficacy (Bandura, 1997), together with the use of encoding or retrieval strategies (Bjorklund & Douglas, 1997; Hertzog & Dunlosky, 2004), metacognitive monitoring (Dunlosky & Connor, 1997; Hertzog, Kidder, Powell-Moman, & Dunlosky, 2002), and belief in control of memory outcomes (Lachman & Andreoletti, 2006), has been shown to influence memory outcomes individually or through a synergistic effect (Hertzog & Dunlosky, 2004).

The extent to which protracted development of episodic, or associative, memory between middle childhood and adulthood is supported by development of metamemory is not well understood. Some have speculated that development of metamemory functions partially explains the early development of memory systems (Bjorklund & Douglas, 1997; DeMarie-Dreblow & Miller, 1988; Flavell, 1970). Little is known, however, about the interactions of metamemory and episodic memory during middle childhood and adulthood. Because associative memory functions follow a protracted trajectory of development that extends through adolescence, there is substantial interest in capturing the factors that modify memory functioning during this period of development (Ofen, 2012). This study was designed to examine possible interactions between the development of metamemory and the development of associative memory during this developmental period.

In this study, we targeted two aspects of metamemory: belief in the efficacy of mnemonic strategies and use of mnemonic strategies. Our goal was to characterize developmental effects in those aspects of metamemory and assess their influence of memory functioning. Belief in efficacy of mnemonic strategies is known to modify recognition memory in older adults (Bender & Raz, 2012); however, the influence of age-related differences in the belief in the efficacy of mnemonic strategy in child development has never been tested before. Moreover, age-related differences in the belief in the efficacy of mnemonic strategies may be linked to strategy use across development and, thus, may add to the established findings that demonstrate beneficial effects of mnemonic strategy use during childhood (Bjorklund & Douglas, 1997).

Children rapidly grow in their ability to use mnemonic strategies during the elementary school years (Best, Miller, & Jones, 2009; Shing & Lindenberger, 2011; Schneider & Pressley, 1997). Prior to elementary school, children commonly do not display simple organizational and rehearsal strategies that are known to be effective (Reese, 1962). Furthermore, a young child might not benefit from explicit strategy instruction (Flavell, 1970), although there may be memory gain seen in a classroom setting (Grammer, Coffman, & Ornstein, 2013) or under specific training conditions (Bjorklund, Miller, Coyle, & Slawinski, 1997). Only by middle to late childhood do children begin to spontaneously demonstrate elaborative mnemonic strategies, but they might not necessarily benefit from the strategy as adolescents or young adults would (Bjorklund et al., 1997; DeMarie-Dreblow & Miller, 1988; Sander, Werkle-Bergner, Gerjets, Shing, & Lindenberger, 2012).

Children might not benefit from strategies because of a lack of spontaneous strategy use (i.e., production deficiency; Flavell, 1970) or due to an inability to benefit from a strategy regardless of explicit instruction (i.e., utilization deficiency; DeMarie-Dreblow & Miller, 1988). Utilization deficiency is more prevalent in younger children than in older children (Bjorklund et al., 1997) and is often contrasted against memory deficits in older adults. Unique to later-life decline, older adults are thought to produce fewer strategies spontaneously and to use these strategies less efficiently than young adults despite previous experience and knowledge of effective strategies (Kausler, 1994; Verhaeghen & Marcoen, 1994). Furthermore, older adults benefit from explicit strategy instruction and adaptive training but still demonstrate associative memory deficits (Kliegl, Smith, & Baltes, 1989, 1990; Singer, Lindenberger, & Baltes, 2003), whereas explicit strategy instruction and adaptive training have a greater effect at improving performance in children (Brehmer, Li, Muller, von Oertzen, & Lindenberger, 2007; Morrison & Chein, 2011).

Belief in the efficacy of mnemonic strategies has been found to modify memory outcomes in older adults. Older adults, compared with younger adults, are less likely to believe that intentional strategy use will benefit memory outcomes (Hertzog, McGuire, Horhota, & Joop, 2010). Critically, older adults with lesser belief in the efficacy of strategies will have worse memory recognition than their counterparts with greater belief (Bender & Raz, 2012). It is plausible that, like adults, stronger belief in the efficacy of mnemonic strategy across child development modifies successful strategy use for memory gains. Moreover, belief in strategy efficacy likely develops during childhood, much like the documented developmental effects in strategy use.

Use of a mnemonic strategy during encoding has been shown to facilitate memory; however, some strategies are more effective for accurate memory than others (Morrison & Chein, 2011; Sander et al., 2012). The development of strategy use during childhood and adolescence follows a gradient that can be grossly characterized as "shallow" to "deep" encoding (Bjorklund & Douglas, 1997; Craik & Lockhart, 1972; Craik & Tulving, 1975). Shallow encoding strategies such as simple repetition may aid familiarity-based recognition but cause errors during recollection (Craik & Lockhart, 1972; Craik & Tulving, 1975). Other strategies that are elaborative and include manipulation of studied information are commonly referred to as deep encoding strategies and lead to improved memory (Craik & Lockhart, 1972; Craik & Tulving, 1975). Thus, using deep encoding strategies rather than shallow ones results in a richer and more accurate memory representation (Craik & Lockhart, 1972; Craik & Tulving, 1975). It is possible that the parallel development in the belief in strategy efficacy that is hypothesized here modifies the selection of strategies and the gains from strategies during childhood.

Here, we combined the characterization of belief in efficacy of various mnemonic strategies with the characterization of the use of mnemonic strategies as reported by participants ranging in age from middle childhood to young adulthood (8–25 years). All study participants completed a recognition memory test that included item and associative memory components, which allowed examination of developmental differences in metamemory functions and their relation to age-related improvement in associative memory. We hypothesized that across age, ratings of belief in the efficacy of deep encoding strategies would cluster together separately from ratings of belief in the efficacy of shallow encoding strategies. Moreover, we hypothesized that younger age would be associated with poorer associative recognition memory. Finally, we hypothesized that belief in the efficacy of deep encoding strategies would increase with age and contribute to age-related improvement in associative memory.

Method

Participants

In total, 61 healthy participants (29 female and 32 male), aged 8 to 25 years (19 children, mean age = 10.45 years, *SD* = 1.45; 16 adolescents, mean age = 16.12 years, *SD* = 1.52; 26 adults, mean age = 21.50 years, *SD* = 2.06), were recruited. All participants spoke English as a native language and reported no neurological injury, psychiatric disorders, or learning disabilities. Standardized IQ scores (Kaufmann Brief Intelligence Test, KBIT-2) of the whole sample indicated average intelligence ($M = 109.05$, $SD = 12.34$) and did not differ by age, $F(1,58) = 0.13$, $p = .72$, or sex, $F(1,58) = 0.62$, $p = .44$. Participants completed all testing as part of a single 3-h session that included other standardized testing of cognitive processes and intelligence; the associative memory recognition task was administered at the beginning of the session.

Recognition memory paradigm

Participants completed a computerized recognition memory paradigm (adapted from Bender, Naveh-Benjamin, & Raz, 2010; Naveh-Benjamin, 2000). Participants studied 26 word pairs (each displayed for 5 s with a 1-s intertrial interval), followed immediately by a 1-min distraction task (counting backward from a randomly generated three-digit number) and recognition tests of item and associative memory. Words were presented in white on a black background at a font size of 52 on a 13-inch screen with a resolution of 1280 × 800 and a refresh rate of 60 Hz. The item recognition test consisted of 16 individual words; half were from the study list, and half were unseen foil words. The associative recognition test consisted entirely of words from the study list; here, 8 pairs were shown unchanged from study and 8 pairs were recombined pairs of words from study. Words displayed in the first and last pairs of the 26 studied pairs were not used in any of the following testing in order to minimize effects associated with differential memory for initial and final presentations. Participants completed two cycles of study and tests. The order of the study lists and the order of the item and word pair recognition tests were counterbalanced across participants. Performance measures of correct recognition (hits) and false recognition errors (false alarms) were calculated for item and associative tests and averaged across the two testing cycles. Item hit rate was calculated as the number of studied words correctly recognized as old, and item false alarm rate was calculated as the number of foil words erroneously recognized as old. Associative hit rate was calculated as the number of intact studied pairs correctly recognized as intact, and associative false alarm rate was calculated as the number of recombined pairs erroneously recognized as intact. Prior to the formal testing, participants completed a practice phase in which they had a presentation of six word pairs, a distraction task, and the two recognition tasks in the same order as in the formal testing. Participants were not informed about possible encoding strategies.

Recognition memory paradigm stimuli

Each study list contained 26 word pairs that were composed of words chosen from the Medical Research Council psycholinguistic database (Wilson, 1988). Words were selected to be concrete nouns (concreteness ⩾ 451, scaled 100–700) that are composed of 3 to 10 letters, moderately prevalent in written language (Kucera–Francis written frequency 2–763), and commonly acquired by an early age (acquisition age score ⩽ 551, scaled 100–700). From these criteria, 312 words were chosen at random to form 6 lists of 26 word pairs. Word pairs were created to minimize semantic relatedness (relatedness = −0.1 to 0.15, scaled −1.0 to 1.0; Latent Semantic Analysis database, University of Colorado, Boulder, http://lsa.colorado.edu; Landauer, Foltz, & Laham, 1998).

Belief in strategy efficacy: Personal Encoding Preferences questionnaire

Following the recognition test, participants were administered a modified version of the Personal Encoding Preferences (PEP) questionnaire (Bender & Raz, 2012; Hertzog & Dunlosky, 2004) assessing their beliefs in the efficacy of mnemonic strategy use. Participants rated seven encoding strategies on effectiveness for later remembering the word pairs during testing: "saying the word pair once," "repetition," "focusing on the word pair in one's mind," "creating a sentence," "imaging a scene," "assigning personal significance," and "rhyming." Each strategy was rated on a Likert item scale from 1 (*least effective*) to 10 (*most effective*). Participants had the opportunity to write in and rate additional strategies that were used but not specified on the form. Finally, participants reported which strategies they had used during the task and which one strategy they considered to be "best."

Data conditioning and statistical analyses

Recognition memory discriminability and hypothesis testing

Recognition memory performance was characterized by an index of discriminability (d'), a signal detection index based on the proportion of correct recognition of targets and incorrect recognition of foils (false alarms; Pollack & Norman, 1964). This index is well-suited for a two forced-choice recognition paradigm (Stanislaw & Todorov, 1999). Separate indexes were calculated for item recognition (d' item) and associative recognition (d' associative). Differences in recognition memory (d' item and d' associative) were analyzed in a mixed general linear model, treating item and associative recognition as a two-level repeated measure and including age (centered at the sample mean) and average factor belief ratings as continuous covariates and sex as a categorical covariate. This approach offers statistical control of covariates while avoiding the bias of stepwise regression (Antonakis & Dietz, 2011). Post hoc univariate regression and correlations were used to explore simple effects.

Belief in strategy efficacy factor reduction and reliability

The belief ratings of the seven suggested strategies were entered into a principal components analysis (varimax rotation). To assess whether the factor structure was invariant by age, we confirmed the factor structure separately in child, adolescent, and adult age groups following procedures in Jolliffe (2005). In all other analyses, age was treated as a continuous variable. Possible age-related differences in factor scores were tested in a general linear model, treating strategy factor as a two-level repeated measure and including age (mean-centered) and sex as predictors. Scores of belief in strategy efficacy for Factor 1 ("deep") and Factor 2 ("shallow") were calculated as the average ratings of the efficacy of strategies with respect to each factor.

Preferred strategy use

According to the factor solution, we classified participants' reports of the preferred strategy that would be "best" to later remember the word pairs. When a participant chose a strategy that was not included in the factor analysis, the strategy was classified according to the theoretical view within the literature. Outside of the specified strategies, 4 children chose a repetition strategy and 1 adult named a unique strategy ("counting the number of letters in each word") that we considered as shallow strategies (Craik & Lockhart, 1972; Craik & Tulving, 1975).

Results

Age differences in recognition memory

Differences in recognition memory (d' item and d' associative) were modeled with respect to age while controlling for sex. Recognition memory improved with age for both associative recognition (d' associative: $F(1,58) = 33.93$, $p < .001$, $\eta^2_p = .37$) and item recognition (d' item: $F(1,58) = 16.59$, $p < .001$, $\eta^2_p = .22$) (Fig. 1). The age-related improvement in associative recognition was greater than

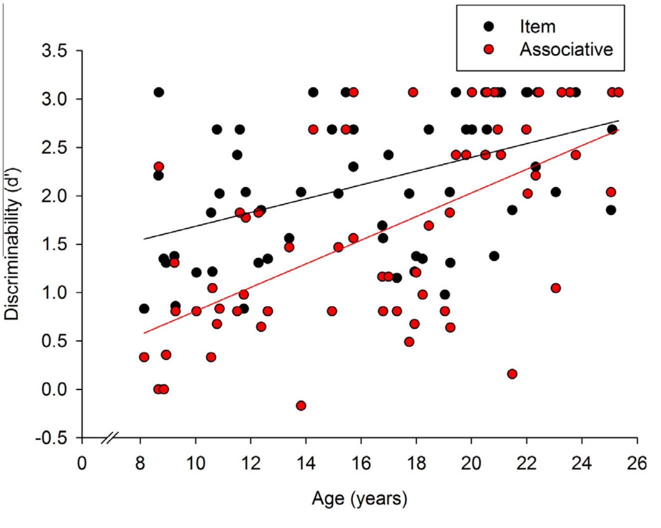

Fig. 1. Age-related differences in item and associative recognition. Both item and associative recognition (mean d') improved with age ($ps < .001$), and the age-related improvement in associative recognition was greater than that in item recognition ($p = .01$).

that in item recognition (Age × Test: $F(1,58) = 8.79$, $p < .01$, $\eta_p^2 = .13$). There were no sex differences in recognition of either items, $F(1,58) = 3.16$, $p = .08$, $\eta_p^2 = .05$, or associative pairs, $F(1,58) = 0.99$, $p = .32$, $\eta_p^2 = .02$.

Metamemory questionnaire: Factor reduction and reliability

Factor analyses were conducted across age groups in order to determine strategy factors that were invariant with age. Within child, adolescent, and adult age groups, the factor analysis identified two orthogonal factors (explaining at least 70% of age group variance). Belief in strategy efficacy loaded onto the factors similarly across age groups (see Table 1 for rotated factor loadings). Factor 1 was commonly identified by "creating a sentence" and "imaging a scene," whereas Factor 2 was commonly identified by "saying the word pair once" and "focusing on the word pair in one's mind." Consistent with prior literature, we considered Factor 1 to represent belief in the efficacy of deep encoding strategies and Factor 2 to represent belief in the efficacy of shallow strategies (Craik & Lockhart, 1972; Craik & Tulving, 1975). Two strategies (repetition and rhyming) were removed from the principal components analysis due to misidentification of the factors and negative covariance.

Interestingly, children rated "saying the word pair once" more similarly to the Factor 1 deep strategies (loading = .73) than the Factor 2 shallow strategies (loading = .32). In addition, children and adolescents rated "assigning personal significance" more similarly to the Factor 1 deep strategies, whereas in adults the belief in efficacy of this strategy was high but did not load strongly on Factor 1 (see Table 1). However, inspection of the whole sample scale reliability reinforced the identification of "saying the word pair once" with the Factor 2 component and "assigning personal significance" with Factor 1 across age groups. Thus, in the whole sample Factor 1 was composed of the three deep strategies (Cronbach's $\alpha = .70$) and Factor 2 was identified by the two shallow strategies (Cronbach's $\alpha = .55$). The lower reliability of the Factor 2 shallow strategies was largely driven by children identifying the "saying the word pair once" strategy on the deep factor. Reliability of Factor 2 (shallow) was higher in adolescent (Cronbach's $\alpha = .72$) and adult (Cronbach's $\alpha = .63$) groups as compared with the whole sample. These Cronbach's α values meet conventional standards of acceptable internal consistency (see Lance, Butts, & Michels, 2006, for a discussion).

Age differences in metamemory

Age differences in belief in strategy efficacy

Although the same factors were identified across age (above), we found age-related differences in ratings of belief in strategy efficacy that varied between factors (Age × Factor: $F(1,58) = 9.82$, $p < .01$, $\eta_p^2 = .15$). Belief in the efficacy of Factor 1 (deep) strategies increased with age, $F(1,58) = 5.44$, $p = .02$, $\eta_p^2 = .09$, whereas ratings of Factor 2 (shallow) strategies did not differ by age, $F(1,58) = 2.79$, $p = .10$, $\eta_p^2 = .05$.

Table 1
Ratings of belief in strategy efficacy: age group means and principal components analysis factor loadings.

	Mean rating (*SD*)			Factor loading		
	Children	Adolescents	Adults	Children	Adolescents	Adults
Factor 1 ("deep")						
Associate with a personal experience	5.84 (2.54)	7.81 (2.88)	8.23 (1.86)	.90	.79	.28
Create a sentence	6.16 (2.77)	5.94 (2.65)	6.58 (2.93)	.82	.60	.89
Imagine a scene	6.16 (2.67)	7.50 (2.78)	7.62 (2.48)	.75	.90	.83
Factor 2 ("shallow")						
Say the word pair once	7.21 (2.53)	7.50 (2.28)	6.54 (2.76)	.32	.86	.77
Focus on the word pair in mind	5.16 (2.67)	5.50 (3.31)	5.19 (2.50)	.95	.88	.82

Note. Rating the belief in strategy efficacy was made on a 10-point scale (1 = *least effective*, 10 = *most effective*). Group averages and standard deviations of belief in strategy efficacy ratings are provided for children (8–12 years, $n = 19$), adolescents (13–17 years, $n = 16$), and adults (18–25 years, $n = 26$).

Age differences in preferred strategy use

In addition to differences in belief in strategy efficacy, the reported preference for using either deep or shallow strategies differed by age (logistic $\beta = 0.19$, Wald $\chi^2 = 8.64$, $p = .003$). For every year older, a participant was 1.21 times more likely to report preferring a deep encoding strategy. To better understand this effect, we examined the frequency of reported strategy preference by age group (see Fig. 2). Whereas children had no definitive preference for deep strategies over shallow strategies ($\chi^2 = 2.58$, $p = .11$), by adolescence there was a preference for using a deep encoding strategy to aid later recognition (χ^2s = 6.25 and 9.85 for adolescents and adults, respectively, $p \leqslant .01$).

Memory recognition predicted by metamemory

Memory recognition predicted by belief in strategy efficacy

The relation between belief in strategy efficacy for either deep or shallow strategies and both item and associative recognition memory performance was modeled in a two-level (item vs. associative) repeated measures general linear model while controlling for age and sex. Stronger belief in the efficacy of Factor 1 (deep) strategies accounted for better item recognition, $F(1,56) = 4.83$, $p = .03$, $\eta_p^2 = .09$ (Fig. 3A), and for better associative recognition, $F(1,56) = 5.57$, $p = .02$, $\eta_p^2 = .08$ (Fig. 3B). The magnitudes of these two effects were similar, $F(1,56) = 0.34$, $p = .56$, $\eta_p^2 = .01$. The interaction term Age × Factor 1 was not significant in predicting differences in item recognition, $F(1,54) = 0.01$, $p = .91$, $\eta_p^2 < .001$, or associative recognition, $F(1,54) = 0.18$, $p = .67$, $\eta_p^2 = .003$; therefore, the effect of greater belief in the efficacy of deep strategies on better recognition memory was independent of age. Belief in the efficacy of Factor 2 (shallow) strategies was unrelated to recognition, $F(1,56) = 3.57$, $p = .06$, $\eta_p^2 = .06$, for either items or pairs (Factor 2 × Test: $F(1,56) = 2.92$, $p = .09$, $\eta_p^2 = .05$).

We tested for the possibility of additional covariates to memory recognition and belief in strategy efficacy. Sex was not related to differences in strategy use, belief in strategy efficacy, or recognition memory performance (Fs $\leqslant 2.90$, ps $\geqslant .09$). IQ was also unrelated to these measures of interest (Fs $\leqslant 2.44$, ps $\geqslant .13$). To confirm that the analysis of childhood development was not biased by inclusion of adults, the models were estimated again with only children and adolescents included ($N = 35$). The effects of greater belief in deep strategy efficacy on item recognition, $F(1,30) = 3.49$, $p = .07$, $\eta_p^2 = .10$, and associative recognition, $F(1,30) = 2.53$, $p = .12$, $\eta_p^2 = .08$, were of similar magnitudes to the original analysis but failed to reach significance due to the lack of power.

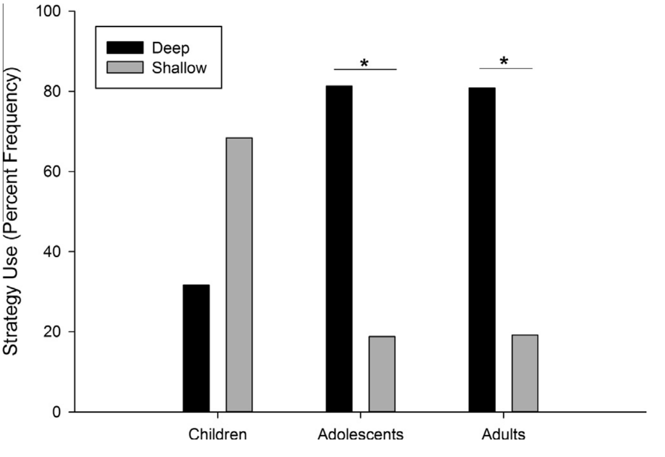

Fig. 2. Preferred use of deep and shallow strategies is shown by age group. Reported preferred use of Factor 1 ("deep") and Factor 2 ("shallow") strategies in children (8–12 years, $n = 19$), adolescents (13–17 years, $n = 16$), and adults (18–25 years, $n = 26$) are shown. Significant differences ($p < .05$) are indicated by an asterisk (*), estimated with Pearson chi-square tests for within-group comparisons. Older age was associated with greater preference to use a deep encoding strategy ($\beta = 0.19$, $p = .003$).

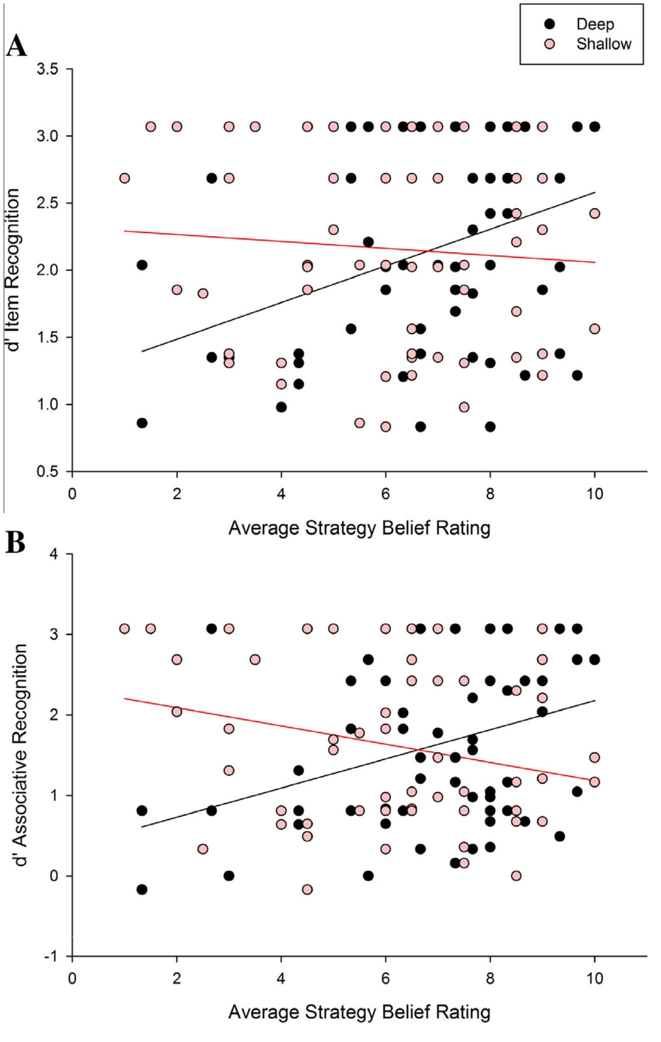

Fig. 3. Higher belief in efficacy of deep encoding strategies correlated with better recognition. Improvement in item recognition (A) and associative recognition (B) were related to higher belief in the efficacy of Factor 1 ("deep") strategies (*ps* $\leqslant$ .03) but not to belief in the efficacy of Factor 2 ("shallow") strategies.

Memory recognition predicted by use of shallow strategies

Without explicit instruction, participants spontaneously generated strategies to use during the task and reported these during the PEP questionnaire. Age was positively correlated with the number of deep strategies used ($r = .31$, $p = .02$) but not with the number of shallow strategies ($r = -.20$, $p = .13$) or with the total number of strategies used ($r = .13$, $p = .32$). However, the number of deep strategies used was unrelated to item recognition, $F(1,56) = 0.19$, $p = .66$, $\eta_p^2 = .003$, and associative recognition, $F(1,56) = 1.29$, $p = .26$, $\eta_p^2 = .02$. Interestingly, independent of age, participants who used more shallow strategies performed worse on both recognition tasks (item: $F(1,56) = 9.27$, $p = .004$, $\eta_p^2 = .14$; associative: $F(1,56) = 6.94$, $p = .01$, $\eta_p^2 = .11$). This may partially follow from greater belief in shallow strategies, which was associated with greater frequency of using shallow strategies (.23, Wald $\chi^2 = 4.26$, $p = .04$). When controlling for the number of shallow strategies used, greater belief in the efficacy of deep encoding strategies remained a significant predictor of memory recognition (both item and associative, $Fs(1,55) \geqslant 6.50$, $ps \leqslant .01$).

Memory recognition not predicted by strategy preference

In addition to testing the effect of the number of deep and shallow strategies used, we also assessed the possible role of preferring a deep or shallow strategy. The effect of preferred strategy use was modeled in a separate general linear model while controlling for age and sex. Preferred strategy use did not account for differences in recognition performance, $Fs(1,57) < 1.76$, $ps > .19$, possibly reflecting the fact that the majority of participants reported preferring a deep strategy.

Discussion

Memory function, particularly the ability to create and retrieve richly detailed episodic representations, improves during development (Billingsley, Smith, & McAndrews, 2002; Brainerd, Holliday, & Reyna, 2004; Ghetti & Angelini, 2008; Ofen, 2012; Ofen et al., 2007). Here, we explored the influence of belief in and use of mnemonic strategies on episodic associative memory in children, adolescents, and adults. As is commonly reported (Ghetti & Angelini, 2008; Ofen, 2012; Ofen et al., 2007), we found developmental effects in recognition memory. Age-related improvements were found in both item (single words) and associative (correct pairing of words) recognition memory; however, as expected, there was greater age-related improvement in the recognition of correct pairing of words compared with the recognition of single words. Metamemory also differed by age. Although all participants, independent of age, distinguished deep encoding strategies from shallow ones, older age was associated with greater belief in the efficacy of deep encoding strategies. Moreover, greater belief in the efficacy of deep encoding strategies partially accounted for better recognition memory. Together, these findings suggest that belief in efficacy of memory strategies may partially explain individual differences in the development of recognition memory.

Children's belief in the efficacy of strategies converged on two factors that were similar to those in adolescents and adults—what we identified as "deep" and "shallow" encoding strategies (Craik & Lockhart, 1972; Craik & Tulving, 1975). The Factor 1 (deep) encoding strategy component was identified by "creating a sentence," "imaging a scene," and "associating with a personal experience," whereas Factor 2 (shallow) was commonly identified by "saying the word pair once" and "focusing on the word pair in one's mind." Therefore, we show that, in children 8 years and older, there is a metacognitive awareness about deep encoding strategies that is distinguishable from that of shallow strategies. Moreover, that pattern was similar to what was observed in adolescents and adults, suggesting that the children tested in this study demonstrated an awareness of the efficacy of mnemonic strategies similar to that of adults.

Although the same deep and shallow factors were identified in all age groups, there were developmental differences in the strength of belief in strategy efficacy. Belief in the efficacy of deep encoding strategies increased with age, whereas belief in the efficacy of shallow strategies did not. Similarly, the number of deep encoding strategies used increased with age. Thus, children demonstrated metacognitive awareness of deep encoding strategies similar to that of adults, but children believed these strategies to be less effective than adults and were less likely to use such a strategy.

This intriguing phenomenon may be in part explained by age differences in the perception of a strategy, and children may over-estimate the effectiveness of a shallow encoding strategy. In the reported factor analysis, there were differences between the age groups in the loadings of certain strategies. The factor analysis of belief in strategy efficacy indicated that children identified the "say the word pair once" strategy similar to deep encoding strategies, whereas by adolescence this strategy was definitively clustered with other shallow strategies. Because children under-rated the efficacy of deep strategies, it is plausible that children were over-confident in specifically this simple repetition strategy. Furthermore, children may have preferred a simple repetition strategy over a deep encoding strategy because the former may demand fewer cognitive resources (Best et al., 2009; Craik & Lockhart, 1972; Craik & Tulving, 1975). Simple repetition can aid certain aspects of recognition memory such as item familiarity, but it may also lead to greater inaccuracy in associative recognition memory. Even in young children, intentional and consistent use of a shallow naming strategy during encoding can aid later recall (Henry & Norman, 1996). In this study, persons with greater belief in the efficacy of shallow strategies were more likely to use shallow strategies, which in turn accounted for poorer recognition memory. Thus, children's failure to identify repetition as a less effective shallow encoding strategy may partially account for poorer associative memory during childhood. Moreover, children's over-reliance on simple repetition may partially explain individual differences in familiarity ratings across ages that have been reported before (Ghetti & Angelini, 2008). However, we demonstrate that, independent of the negative effects of shallow strategy use, better recognition memory was associated with age and greater belief in the efficacy of deep encoding strategies.

A central question in the study of memory development is regarding the contribution of developmental changes in metamemory to memory functioning (Bjorklund & Douglas, 1997; Flavell, 1970, 1971; Schneider, 1999; Schneider & Pressley, 1997). In this study, we demonstrate that from middle childhood to early adulthood, greater belief in the efficacy of deep encoding strategies aided better recognition memory. The effect of belief in strategy efficacy on recognition memory was not unique to any age. Yet, children's belief in the efficacy of deep strategies was lower as compared with that of adults, and thereby the beneficial effects of greater belief in deep strategy may be diminished in children. Consistent with extant reports (e.g., Bjorklund & Douglas, 1997; McGilly & Siegler, 1989), children were also less likely to prefer using such strategies. Unlike belief in the efficacy of deep strategies, the preferred use of a deep strategy or the use of several deep strategies was not associated with better memory, highlighting the relevance of other metamemory functions in the improvement of memory functioning. Belief in the efficacy of memory strategies is one metamemory function that appears to be a relevant factor in recognition memory functioning across the lifespan, including during old age (Bender & Raz, 2012).

Metamemory modulates many aspects of memory functioning (Hertzog & Dunlosky, 2004; Nyberg et al., 2003). Here, we tested developmental effects in recognition memory with respect to one aspect of metamemory—belief in the efficacy of encoding strategies. Other aspects of metamemory include evaluating task difficulty, awareness of strategies, and strategy use (Kuhn, 2000). These various components of metamemory may follow different developmental trajectories (e.g., Fritz, Howie, & Kleitman, 2010) and may partially account for the development of memory functions. Indeed, the presence of metamemory functions in children younger than 8 years is debatable (DeMarie & Ferron, 2003; but see also Ghetti, Mirandola, Angelini, Cornoldi, & Ciaramelli, 2011; Larkin, 2007; Pressley & Hilden, 2006). It is plausible that the protracted development of metamemory observed in this study may mirror the developmental trajectories of memory and its neural correlates (Ofen, 2012; Ofen et al., 2007).

Metacognitive functioning, such as the use of mnemonic strategies, has been related to activations in the prefrontal and cingulate cortices (Dehaene, Kerszberg, & Changeux, 1998; Fletcher & Henson, 2001; MacDonald, Cohen, Stenger, & Carter, 2000). Although we did not measure the neural correlates of belief in the efficacy of strategies in the current study, it is possible that immaturity of prefrontal cortex functioning contributes to age-related differences in the strength of belief in deep strategies and to the lesser preference to use such strategies. The development of effective strategy use in school-age children has also been related to the development of interactions between the prefrontal cortex and medial temporal lobe structures, including the hippocampus (Cho et al., 2012; Ofen, Chai, Schuil, Whitfield-Gabrieli, & Gabrieli, 2012). Medial temporal lobe activation during encoding may, however, be independent of the use of a specific mnemonic strategy, whereas recruitment of frontal and parietal cortices may be specific to the mnemonic strategy used (Bernstein, Beig, Siegenthaler, & Grady, 2002; Kirchhoff & Buckner, 2006; Leshikar, Duarte, & Hertzog, 2012; Park & Rugg, 2011). Further study is needed to determine the underlying neural basis by which belief in strategy efficacy may relate to improvements in memory functioning.

The inability of children to effectively use a mnemonic strategy for memory gains has been termed the *utilization deficiency* hypothesis (Bjorklund et al., 1997; DeMarie-Dreblow & Miller, 1988). In this study, children demonstrated a metacognitive awareness that distinguished deep and shallow encoding strategies similar to that seen in adolescents and adults. Yet, children did not prefer a deep encoding strategy or use as many deep encoding strategies as their older counterparts. Children's metacognitive awareness of deep encoding strategies, but lesser preference for such strategies, extends support for the utilization deficiency hypothesis. As we observed here, better recognition memory during childhood and adulthood was related to greater belief in the efficacy of deep strategies and less frequent use of shallow strategies. Therefore, the utilization deficiency in children may be in part due to the lack of belief in the efficacy of deep encoding strategies and, conversely, an over-reliance on shallow strategies that are ultimately less effective. Thus, interventions for learning and memory disorders may include training belief in the efficacy of deep encoding strategies in addition to informing children about strategies. Future studies may test the effectiveness of explicit training in the belief of strategy efficacy as well as monitor performance under explicit training conditions.

Direct testing of the utilization deficiency hypothesis requires instructing participants about strategies. Here, we did not instruct a specific strategy and measured strategy use only retrospectively. This allowed us to study endogenous belief in the efficacy and use of mnemonic strategy but did not allow us to verify the frequency with which participants used the preferred strategy during study. We did not find that preferred strategy use accounted for differences in recognition memory. It is possible that strategy use differentiates memory performance only when the mnemonic task is challenging (Sodian, Schneider, & Perlmutter, 1986). Thus, we might not find a benefit of preferring a deep encoding strategy because some aspects of the task were relatively easy. Indeed, we observed performance at ceiling in item recognition measures, particularly in adults. With a more challenging task and explicit strategy instruction, we may have observed that children were unable to use a deep encoding strategy for the same memory gains as adults. This is likely one of several factors that contribute to memory accuracy during child development.

Finally, a limitation of this study is that we did not directly measure individual differences in executive function and attentional control. Such processes show robust maturation during childhood, account for improvements in memory (Best et al., 2009; Cowan & Alloway, 2009) and may mediate efficacious strategy use (Roebers, Schmid, & Roderer, 2010).

Conclusions

In the current study, we replicated an age-related improvement in associative memory that has been observed before (Ofen, 2012; Ofen et al., 2007, 2012) and demonstrated the unique role of belief in the efficacy of mnemonic strategies in recognition memory. Children had a metacognitive awareness of deep versus shallow encoding strategies that was similar to that in adolescents and adults. However, children had lower belief in the efficacy of deep strategies and were less likely to prefer a deep strategy as compared with their older counterparts. Greater belief in the efficacy of deep encoding strategies, but not preferred strategy use, accounted for better recognition memory. Therefore, the utilization deficiency in children may be related to the metamemory belief in the efficacy of mnemonic strategies. We conclude that a greater belief in the efficacy of deep encoding strategies partially accounts for individual differences in associative recognition from middle childhood to adulthood.

References

Antonakis, J., & Dietz, J. (2011). Looking for validity or testing it? The perils of stepwise regression, extreme-scores analysis, heteroscedasticity, and measurement error. *Personality and Individual Differences, 50*, 409–415.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.

Bauer, P. J. (2005). Developments in declarative memory: Decreasing susceptibility to storage failure over the second year of life. *Psychological Science, 16*, 41–47.

Bender, A. R., Naveh-Benjamin, M., & Raz, N. (2010). Associative deficit in recognition memory in a lifespan sample of healthy adults. *Psychology and Aging, 25*, 940–948.

Bender, A. R., & Raz, N. (2012). Age-related differences in recognition memory for items and associations: Contribution of individual differences in working memory and metamemory. *Psychology and Aging, 27*, 691–700.

Bernstein, L. J., Beig, S., Siegenthaler, A. L., & Grady, C. L. (2002). The effect of encoding strategy on the neural correlates of memory for faces. *Neuropsychologia, 40*, 86–98.

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review, 29*, 180–200.

Billingsley, R. L., Smith, M. L., & McAndrews, M. P. (2002). Developmental patterns in priming and familiarity in explicit recollection. *Journal of Experimental Child Psychology, 82*, 251–277.

Bjorklund, D. F., & Douglas, R. N. (1997). The development of memory strategies. In N. Cowan (Ed.), *The development of memory in childhood: Studies in developmental psychology* (pp. 201–246). New York: Psychology Press.

Bjorklund, D. F., Miller, P. H., Coyle, T. R., & Slawinski, J. L. (1997). Instructing children to use memory strategies: Evidence of utilization deficiencies in memory training studies. *Developmental Review, 17*, 411–441.

Brainerd, C. J., Holliday, R. E., & Reyna, V. F. (2004). Behavioral measurement of remembering phenomenologies: So simple a child can do it. *Child Development, 75*, 505–522.
Brehmer, Y., Li, S.-C., Muller, V., von Oertzen, T., & Lindenberger, U. (2007). Memory plasticity across the life span: Uncovering children's latent potential. *Developmental Psychology, 43*, 465–478.
Brown, A. L. (1975). The development of memory: Knowing, knowing about knowing, and knowing how to know. *Advances in Child Development and Behavior, 10*, 695–699.
Cho, S., Metcalfe, A. W. S., Young, C. B., Ryali, S., Geary, D. C., & Menon, V. (2012). Hippocampal–prefrontal engagement and dynamic causal interactions in the maturation of children's fact retrieval. *Journal of Cognitive Neuroscience, 24*, 1849–1866.
Cowan, N., & Alloway, T. (2009). Development of working memory in childhood. In M. L. Courage & N. Cowan (Eds.), *The development of memory in infancy and childhood* (pp. 303–342). New York: Psychology Press.
Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*, 671–684.
Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General, 104*, 268–294.
Dehaene, S., Kerszberg, M., & Changeux, J. P. (1998). A neuronal model of a global workspace in effortful cognitive tasks. *Proceedings of the National Academy of Sciences of the United States of America, 24*, 14529–14534.
DeMarie, D., & Ferron, J. (2003). Capacity, strategies, and metamemory: Tests of a three-factor model of memory development. *Journal of Experimental Child Psychology, 84*, 167–193.
DeMarie-Dreblow, D., & Miller, P. H. (1988). The development of children's strategies for selective attention: Evidence for a transitional period. *Child Development, 59*, 1504–1513.
Dunlosky, J., & Connor, L. T. (1997). Age differences in the allocation of study time account for age differences in memory performance. *Memory & Cognition, 25*, 691–700.
Flavell, J. (1971). First discussant's comments: What is memory development the development of? *Human Development, 14*, 272–278.
Flavell, J. H. (1970). Developmental studies of mediated memory. In H. W. Reese & L. P. Lipsitt (Eds.), *Advances in child development and behavior* (pp. 181–211). New York: Academic Press.
Fletcher, P. C., & Henson, R. N. A. (2001). Frontal lobes and human memory: Insights from functional neuroimaging. *Brain, 124*, 849–881.
Fritz, K., Howie, P., & Kleitman, S. (2010). "How do I remember when I got my dog?" The structure and development of children's metamemory. *Metacognition Learning, 5*, 207–228.
Ghetti, S., & Angelini, L. (2008). The development of recollection and familiarity in childhood and adolescence: Evidence from the dual-process signal detection model. *Child Development, 79*, 339–358.
Ghetti, S., Mirandola, C., Angelini, L., Cornoldi, C., & Ciaramelli, E. (2011). Development of subjective recollection: Understanding of and introspection on memory states. *Child Development, 82*, 1954–1969.
Grammer, J., Coffman, J. L., & Ornstein, P. (2013). The effect of teachers' memory-relevant language on children's strategy use and knowledge. *Child Development, 84*, 1989–2002.
Henry, L. A., & Norman, R. (1996). The relationship between memory performance, use of simple memory strategies, and metamemory in young children. *International Journal of Behavioral Development, 19*, 177–199.
Hertzog, C., & Dunlosky, J. (2004). Aging, metacognition, and cognitive control. In B. H. Ross (Ed.), *Psychology of learning and motivation* (pp. 215–251). San Diego: Academic Press.
Hertzog, C., Kidder, D. P., Powell-Moman, A., & Dunlosky, J. (2002). Aging and monitoring associative learning: Is monitoring accuracy spared or impaired? *Psychology and Aging, 17*, 209–225.
Hertzog, C., McGuire, C. L., Horhota, M., & Joop, D. (2010). Age differences in lay theories about memory control: Older adults believe in "use it or lose it". *International Journal of Aging and Human Development, 70*, 61–87.
Jolliffe, I. (2005). *Principal component analysis*. Hoboken, NJ: John Wiley.
Kausler, D. H. (1994). *Learning and memory in normal aging*. New York: Academic Press.
Kirchhoff, B. A., & Buckner, R. L. (2006). Functional–anatomic correlates of individual differences in memory. *Neuron, 51*, 263–274.
Kliegl, R., Smith, J., & Baltes, P. B. (1989). Testing-the-limits and the study of adult age differences in cognitive plasticity of a mnemonic skill. *Developmental Psychology, 25*, 247–256.
Kliegl, R., Smith, J., & Baltes, P. B. (1990). On the locus and process of magnification of age differences during mnemonic training. *Developmental Psychology, 26*, 894–904.
Kuhn, D. (2000). Theory of mind, metacognition, and reasoning: A life-span perspective. In P. Mitchell & K. J. Riggs (Eds.), *Children's reasoning and the mind* (pp. 301–326). London: Psychology Press/Taylor & Francis.
Lachman, M. E., & Andreoletti, C. (2006). Strategy use mediates the relationship between control beliefs and memory performance for middle-aged and older adults. *Journals of Gerontology B: Psychological Sciences and Social Sciences, 61*, 88–94.
Lance, C. E., Butts, M. M., & Michels, L. C. (2006). The sources of four commonly reported cutoff criteria: What did they really say? *Organizational Research Methods, 9*, 202–220.
Landauer, T. K., Foltz, P. W., & Laham, D. (1998). Introduction to latent semantic analysis. *Discourse Processes, 25*, 259–284.
Larkin, S. (2007). A phenomenological analysis of the metamemory of five six-year-old children. *Qualitative Research in Psychology, 4*, 281–293.
Leshikar, E. D., Duarte, A., & Hertzog, C. (2012). Task-selective memory effects for successfully implemented encoding strategies. *PLoS One, 7*, e38160.
MacDonald, A. W., Cohen, J. D., Stenger, V. A., & Carter, C. S. (2000). Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science, 288*, 1835–1838.
McGilly, K., & Siegler, R. S. (1989). How children choose among serial recall strategies. *Child Development, 60*, 172–182.
Morrison, A. B., & Chein, J. M. (2011). Does working memory training work? The promise and challenges of enhancing cognition by training working memory. *Psychology Bulletin Review, 18*, 46–60.
Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*, 1170–1188.

Nelson, K. (1993). Event, narratives, memory: What develops? In C. Nelson (Ed.), *Memory and affect in development* (pp. 1–24). Hillsdale, NJ: Lawrence Erlbaum.
Nyberg, L., Marklund, P., Persson, J., Cabeza, R., Forstam, C., Petersson, K. M., et al (2003). Common prefrontal activations during working memory, episodic memory, and semantic memory. *Neuropsychologia, 41*, 371–377.
Ofen, N. (2012). The development of neural correlates for memory formation. *Neuroscience Behavioral Review, 36*, 1708–1717.
Ofen, N., Chai, X. J., Schuil, K. D., Whitfield-Gabrieli, S., & Gabrieli, J. D. (2012). The development of brain systems associated with successful memory retrieval of scenes. *Journal of Neuroscience, 32*, 10012–10020.
Ofen, N., Kao, Y. C., Sokol-Hessner, P., Kim, H., Whitfield-Gabrieli, S., & Gabrieli, J. D. (2007). Development of the declarative memory system in the human brain. *Nature Neuroscience, 10*, 1198–1205.
Park, H., & Rugg, M. D. (2011). Neural correlates of encoding within- and across-domain inter-item associations. *Journal of Cognitive Neuroscience, 23*, 2533–2543.
Perner, J., & Ruffman, T. (1995). Episodic memory and autonoetic consciousness: Developmental evidence and a theory of childhood amnesia. *Journal of Experimental Child Psychology, 59*, 516–548.
Pollack, I., & Norman, D. A. (1964). A non-parametric analysis of recognition experiments. *Psychonomic Science, 1*(5), 125–126.
Pressley, M., & Hilden, K. (2006). Cognitive strategies. In *Handbook of child psychology*. *Cognition, perception, and language* (6th ed.) (Vol. 2, pp. 512–556). Hoboken, NJ: John Wiley.
Reese, H. W. (1962). Verbal mediation as a function of age level. *Psychological Bulletin, 59*, 502–509.
Roebers, C. M., Schmid, C., & Roderer, T. (2010). Encoding strategies in primary school children: Insights from an eye-tracking approach and the role of individual differences in attentional control. *Journal of Genetic Psychology: Research and Theory on Human Development, 171*, 1–21.
Sander, M. C., Werkle-Bergner, M., Gerjets, P., Shing, Y. L., & Lindenberger, U. (2012). The two–component model of memory development and its potential implications for educational settings. *Developmental Cognitive Neuroscience, 25*, 567–577.
Schneider, W. (1999). The development of metamemory in children. In D. Gopher & A. Koriat (Eds.), *Attention and performance XVII: Cognitive regulation of performance—Interaction of theory and application* (pp. 487–514). Cambridge, MA: MIT Press.
Schneider, W., & Pressley, M. (1997). *Memory development between two and twenty* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum.
Shing, Y. L., & Lindenberger, U. (2011). The development of episodic memory: Lifespan lessons. *Child Development Perspectives, 5*, 148–155.
Shing, Y. L., Werkle-Bergner, M., Li, S. C., & Lindenberger, U. (2008). Associative and strategic components of episodic memory: A life-span dissociation. *Journal of Experimental Psychology: General, 137*, 495–513.
Shing, Y. L., Werkle-Bergner, M., Li, S. C., & Lindenberger, U. (2009). Committing memory errors with high confidence: Older adults do but children don't. *Memory, 17*, 169–179.
Singer, T., Lindenberger, U., & Baltes, P. B. (2003). Plasticity of memory for new learning in very old age: A story of major loss? *Psychology and Aging, 18*, 306–317.
Sodian, B., Schneider, W., & Perlmutter, M. (1986). Recall, clustering, and metamemory in young children. *Journal of Experimental Child Psychology, 41*, 395–410.
Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, & Computers, 31*, 137–149.
Tulving, E. (1983). *Elements of episodic memory*. London: Oxford University Press.
Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381–403). New York: Academic Press.
Verhaeghen, P., & Marcoen, A. (1994). Production deficiency hypothesis revisited: Adult age differences in strategy use as a function of processing resources. *Aging and Cognition, 1*, 323–338.
Wheeler, M. A., Stuss, D. T., & Tulving, E. (1997). Toward a theory of episodic memory: The frontal lobes and autonoetic consciousness. *Psychological Bulletin, 121*, 331–354.
Wilson, M. D. (1988). The MRC psycholinguistic database: Machine usable dictionary (version 2). *Behavior Research Methods, Instruments, & Computers, 20*, 6–11.