Verbal and Spatial Working Memory in School-Age Children: Developmental Differences in Susceptibility to Interference

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The development of verbal and spatial working memory was investigated with an interference paradigm. Memory spans were obtained from 3 groups (8-, 10-, and 19-year-olds) under 6 different conditions: Two primary memory tasks (1 verbal, 1 spatial) were administered in isolation and in conjunction with 2 versions of a secondary task. The primary tasks required recalling a series of visually presented digits and recalling the locations of Xs in a series of visually presented grids. The secondary tasks required reporting the color of the stimuli as they were presented using either a verbal or a spatial response. Analyses revealed that all age groups showed domain-specific interference (i.e., interference by a secondary task from the same domain as the primary task), but only the 8-year-olds also showed nonspecific interference (i.e., interference by a secondary task from a domain different than the primary memory task), suggesting that at least some executive functions do not reach adult levels of efficiency until approximately age 10.

Developmental increases in memory span have been observed in many studies (for reviews, see Dempster, 1981, 1985; Gathercole & Baddeley, 1993). However, most research has focused on memory for words or material that can be verbally encoded (e.g., digits and nameable objects). In general, studies of verbal spans (i.e., digit, word, and letter spans) have shown that developmental improvement follows a negatively accelerated trajectory (Dempster, 1981). Although there has been relatively little exploration of memory span for exclusively visuospatial information, it appears to undergo a similar developmental trend (Siemens, Guttentag, & McIntyre, 1989, Experiment 2; Wilson, Scott, & Power, 1987).

In the past decade, developmental changes in memory span have often been interpreted in terms of the model of working memory proposed by Baddeley and his colleagues (e.g., Baddeley, 1983). Specifically, Baddeley (1983) postulated two functionally independent subsystems, specialized for handling verbal and nonverbal information, that are termed the phonological loop and the visuospatial sketchpad. In addition, Baddeley postulated an attentional control system termed the central executive that, among its other functions, is involved in the coordination of cognitive operations. Developmental researchers working within this framework have attempted to learn whether all three components of working memory are present in young children and gradually improve in efficiency with age, or whether different components emerge at different ages. For the most part, this research has focused on the development of the phonological loop (for an extensive review, see Gathercole & Baddeley, 1993). However, research has shown that although this subsystem is intact as early as age 4, younger children (under the age of 8 or 9) rely more heavily on visual (i.e., pictorial) information when trying to remember items over a short period of time when compared with older children (over the age of 8 or 9).

For example, Hitch, Woodin, and Baker (1989) have shown that compared with a neutral condition, younger children perform more poorly when a list of to-be-remembered familiar objects are drawn so as to be visually similar (e.g., a key and a pen) even though the object names are phonologically distinct, but they are unaffected when familiar objects are drawn so as to be visually dissimilar but phonologically similar (e.g., a hat and a rat). Older children show the opposite pattern. If, however, the items are presented auditorily, then both younger and older children show a similar pattern: Performance is worse for acoustically similar items (Hulme, 1984). Younger children's reliance on visual stimulus characteristics under certain conditions (i.e., visual presentation) may reflect a lower level of maturation of the verbal subsystem or a developmental preference to use visual rather than verbal codes.

To our knowledge, however, no study has directly compared children's verbal span with their memory span for visuospatial information that may not be verbally encoded, nor has any study attempted to determine whether the phonological loop and visuospatial sketchpad show the same functional independence in children that they do in adults. The purpose of the current study was to examine the development of both the efficiency and independence of the verbal and visuospatial components of working memory using tasks that produce comparable levels of performance in adults (Hale, Myerson, Rhee, Weiss, & Abrams, 1996).

Hale et al. (1996) developed an interference paradigm that permits comparison of performance on a primary working mem-
ory task presented in isolation with performance on the primary task under two different types of interference conditions (one verbal, one spatial). Adults experienced domain-specific interference, that is, a verbal secondary task selectively interfered with verbal but not spatial memory, whereas a spatial secondary task selectively interfered with spatial but not verbal memory. Importantly, the secondary tasks were selected so that rather than potentially interfering with encoding, they actually encouraged automatic encoding of the primary task information, thus avoiding a major criticism of dual-task methodology (Hale et al., 1996). Fry and Hale (1996) have reported that performance on the primary tasks in this paradigm improves with age from 8 to 20 years and that, in both adults and children, performance is specifically interfered with by secondary tasks from the same domain (i.e., verbal or spatial). However, susceptibility to non-specific interference in children (i.e., interference by a secondary task from a domain different from that of the primary task) has not previously been assessed using this paradigm.

Recently, Dempster (1992) proposed that the ability to inhibit irrelevant information is an important fundamental mechanism that underlies many of the changes observed during cognitive development (and many of the cognitive changes associated with adult aging as well). Thus, according to Dempster's (1992) view, the current study should reveal a decrease in the susceptibility to interference with increases in age. That is, although Dempster's (1992) hypothesis does not lead to separate predictions regarding domain-specific and non-specific interference effects, he would clearly predict that 8-year-olds should be more susceptible to interference (from any source) than 10-year-olds and 10-year-olds should be more susceptible to interference than adults.

Dempster (1992) suggested that developmental decreases in susceptibility to interference reflect the ongoing maturation of the frontal lobes, and this view is similar to that expressed by Baddeley (1992; Baddeley & Hitch, 1994). In terms of Baddeley's (1983, 1992) model, however, domain-specific interference is a basic characteristic of the specialized verbal and visuospatial components of working memory, and the efficiency of the central executive is more directly reflected in non-specific interference (although central executive deficits may also result in generally poorer performance whenever there are concurrent tasks). Because executive functions are generally thought to be associated with frontal lobe structures (Goldman-Rakic, 1987), according to Baddeley's (1983, 1992) model, the best evidence for maturation of these structures would be decreases in non-specific interference. Thus, developmental differences in the amount of interference with working memory as well as differences in susceptibility to different types of potentially interfering events are both of considerable relevance to the theoretical frameworks proposed by Dempster (1992) and Baddeley (1983, 1992), among others, and the goal of this study was to provide information regarding such differences.

Method

Participants

Three different age groups participated in this study: 8 male and 11 female second graders (M = 7.6 years, SD = 0.4), 8 male and 12 female fourth graders (M = 9.7 years, SD = 0.3), and 7 male and 13 female college students (M = 19.2 years, SD = 0.6). The two groups of children were enrolled in a local elementary school, and the 19-year-olds were enrolled in their first or second year of college at Washington University in St. Louis, Missouri.

Apparatus

The tasks were presented on a Compaq 286 IBM compatible computer with a NEC multisynch 14-inch color monitor. Computer software was written by Sandra Hale using Borland's Turbo Pascal and display and timing routines from the PCX toolkit by Genus. The experimenter used a three-button panel to initiate presentation of each series of stimuli and to terminate each task.

Design

Each participant was exposed to six different conditions: (a) verbal primary task only, (b) verbal primary plus verbal secondary task, (c) verbal primary plus spatial secondary task, (d) spatial primary task only, (e) spatial primary plus spatial secondary task, and (f) spatial primary plus verbal secondary task. Thus, this mixed-factorial design included two within-subjects factors, primary task domain (verbal or spatial), and type of secondary task (none, same domain as primary task, or different domain from primary task), as well as one between-subjects factor (age).

Stimuli

Schematic representations of the stimuli for the different conditions are shown in Figure 1. For the verbal tasks, the stimuli were digits (1.5 cm x 1.0 cm) that appeared, one at a time, inside a black square (3.25 cm x 3.25 cm) centered in the left half of the video screen. The recall signal was a filled green square (3.25 cm x 3.25 cm) located in the same position as the square in which the digits had appeared. For the spatial tasks, the stimuli were Xs (1.25 cm x 1.0 cm) that appeared, one at a time, in individual cells of a 4 x 4 black grid (6.5 cm x 6.5 cm) centered in the left half of the video screen. The recall signal was an empty 4 x 4 white grid located in the same position as the grid in which the Xs had appeared.

In all conditions, all stimuli except the recall signals were simultaneously accompanied by a circular palette (diameter = 4.5 cm) with six small circles (diameter = 0.5 cm) arranged inside the palette near its perimeter, centered in the right half of the video screen. For the conditions with a spatial secondary task requirement, three of the small, inner circles in the palette were filled with three different colors (i.e., red, white, and blue) and three remained empty (i.e., filled with the background color of the screen). The placement of the colors in the six inner circles varied randomly between stimulus presentations. In all other conditions, all six of the inner circles remained empty. In the two conditions in which the primary tasks were administered without any secondary tasks, the stimuli were always red. Finally, for all conditions that included a secondary task requirement, the stimuli (digits or Xs) appeared in one of three colors (red, white, or blue). The color of the stimuli was varied randomly, with the constraints that no color occurred more than twice in a row and that each color appeared approximately equally often across each task.

Procedure

A fixation point, consisting of a small black square outlined in white, was presented immediately before each series to signal the experimenter and the participant that a series of items was ready for presentation. When the participant indicated that he or she was ready, the experimenter
Figure 1. Schematic representation of the two types of primary tasks paired with the three types of secondary task requirements. Time is indicated by an arrow, rectangles are used to represent each computer screen display, and the correct primary task responses are shown next to the final display (which presents the recall prompt in each series). Where applicable, secondary task responses are given to the right of each display in the series of to-be-remembered items. In all panels, white is used to represent the dark gray background, black is used to represent the colored digits and Xs, and striped patterns are used to represent the three different palette colors (horizontal, diagonal, and vertical for red, white, and blue, respectively). So, for example, in the verbal primary plus spatial secondary task shown in the lower left panel, the second item in the series (i.e., the digit 8) would appear in blue (not black), and the patterned circles in the palette would each be a different color: one red (not horizontal stripes), one white (not diagonal stripes), and one blue (not vertical stripes). See text for further details.
pressed a button on the response panel to initiate the series. In each series, each stimulus appeared on the screen for 2.25 s followed by a 0.75-s blank interval. When the series was completed, a recall signal appeared on the video monitor. For the three conditions in which the primary task was verbal (i.e., to remember the names of a series of digits), the recall signal served as a cue for the participant to say the digits in the order that they had been presented. For the three conditions in which the primary task was spatial (i.e., to remember a series of locations), the recall signal served as a cue for the participant to mark those locations in the blank grid using an erasable marker.

Following the procedure used previously by Fry and Hale (1996) to test individuals ranging in age from 7 to 19 years, the maximum amount of time allowed for recalling the items was 3.0 s for the two shortest series (i.e., one and two items) and increased as a function of the number of items in a series (0.5 s for each additional digit in the verbal span tasks and 1.0 s for each additional location in the spatial span tasks). A tone was sounded by the computer when the maximum recall time had elapsed.

Each condition began with a set of 4 practice series. During the testing phase, participants were exposed to a sequence of experimental trials, each consisting of two series of a given length, beginning with one item. After each trial, the experimenter could choose to continue or discontinue testing. If either of the series in a trial was recalled correctly, the experimenter continued testing. If both series were incorrect, the experimenter discontinued testing in that condition. In an attempt to preclude ceiling effects, 12 trials were available for testing (i.e., 24 series); however, the maximum number required by any participant in any condition of the current study was 11.

Prior to presentation of the conditions that included secondary tasks, participants were instructed either to say the color of each item as it was presented using the color names red, white, or blue (verbal secondary task requirement) or to point to the color of each item as it was presented using the color palette (spatial secondary task requirement). Participants were also told that when the recall signal appeared at the end of a series, only the items (either their names in the case of the digits or their locations in the case of the Xs) would need to be recalled, not the colors of the items.

Finally, the order of the conditions was counterbalanced to control for order effects. Four different orders were used, and one fourth of the participants in each group were randomly assigned to each of the different orders. The orders used were (a) verbal primary task alone, spatial primary task alone, verbal primary plus verbal secondary task, verbal primary plus spatial secondary task, spatial primary plus verbal secondary task, and spatial primary plus spatial secondary task; (b) spatial primary task alone, verbal primary task alone, spatial primary plus spatial secondary task, spatial primary plus verbal secondary task, and spatial primary plus spatial secondary task; (c) verbal primary plus verbal secondary task, verbal primary plus spatial secondary task, spatial primary plus verbal secondary task, spatial primary plus spatial secondary task, verbal primary task alone, and spatial primary task alone; or (d) spatial primary plus spatial secondary task, verbal primary plus verbal secondary task, verbal primary plus spatial secondary task, verbal primary plus verbal secondary task, spatial primary task alone, and verbal primary task alone.

This ordering scheme counterbalanced for task difficulty (primary task vs. primary plus secondary task) by having the two primary tasks presented before the four conditions requiring a secondary task in the first two orders but having the last two orders present the two primary tasks after the four conditions requiring a secondary task. In addition, for the four conditions with a secondary task requirement, type of secondary task (same domain vs. different domain) was counterbalanced by having the same-domain secondary task precede the different-domain secondary task and vice versa for both the verbal domain (first and third orders vs. second and fourth orders) and the spatial domain (second and fourth orders vs. first and third orders). Finally, primary task domain was simultaneously counterbalanced by presenting the verbal before the spatial tasks (for both primary and primary plus secondary) in the first and third orders, and vice versa for the second and fourth orders.

### Results

Following the method used by Fry and Hale (1996) and Hale et al. (1996), the dependent variable (i.e., span) was calculated for each participant in each condition in the following manner. If the final correct trial consisted of two correctly recalled series, the span was determined to be the number of items in these series. However, if the final correct trial included only one correctly recalled series, the span was determined to be the number of items in the series minus 0.5. It should be noted that this calculation was not affected by the time limit for recalling items, because participants' responding rarely continued past the time limit, and in those few cases where responding continued past the time limit, errors had already occurred. Importantly, almost every participant obtained spans greater than 0 in all six conditions. Specifically, spans of 0 occurred in only one condition (spatial primary task plus spatial secondary task) and for only 2 of the participants (both 8-year-olds) in this condition. The mean spans and standard deviations for each condition are given separately for each age group in Table 1.

An initial analysis of variance (ANOVA) was conducted that included two between-subjects variables (age group and condition order) in conjunction with the two within-subjects variables (primary task domain and type of secondary task). This analysis revealed no main effect for condition order, $F(3, 47) = 2.00$, $p > .10$, and no interaction between age group and condition order, $F(6, 47) < 1$. Moreover, none of the other interactions were significant. Consequently, the dependent variable (i.e., span) was calculated for each participant in each condition in the following manner.

<table>
<thead>
<tr>
<th>Domain and secondary task requirement</th>
<th>Age group (in years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>19</td>
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<tr>
<td><strong>Verbal domain</strong></td>
<td></td>
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<tr>
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<td></td>
</tr>
<tr>
<td>$M$</td>
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<td>$SD$</td>
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<tr>
<td><strong>Verbal</strong></td>
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<tr>
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<td>2.61</td>
</tr>
<tr>
<td>$SD$</td>
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<tr>
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<tr>
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<tr>
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<tr>
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<tr>
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<tr>
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<td></td>
</tr>
<tr>
<td>$M$</td>
<td>1.82</td>
</tr>
<tr>
<td>$SD$</td>
<td>1.15</td>
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</table>

Table 1

Means and Standard Deviations of the Spans From All Six Conditions for Each Age Group
with condition order were significant, leading us to collapse across this variable in the remaining analyses.

Two primary analyses were conducted on the span data, and therefore the alpha level was adjusted to .025 for each. In the first primary analysis, a 3 (age group) x 2 (primary task) x 3 (secondary task) ANOVA revealed a main effect of age group, \( F(2, 56) = 71.04, p < .0001 \), attributable to the fact that, overall, the 19-year-olds performed better than the 10-year-olds performed, who, in turn, performed better than the 8-year-olds (see Figure 2); the mean spans for 8-year-olds, 10-year-olds, and 19-year-olds were 3.25, 4.24, and 6.49, respectively. On average, information in the verbal domain was retained better than information in the spatial domain, \( F(1, 56) = 40.65, p < .0001 \) (mean span for digits = 5.06, mean span for locations = 4.31). However, there was a significant interaction between primary task domain and age group, \( F(2, 56) = 6.63, p < .01 \).

As can be seen in Figure 2, the interaction between primary task domain and age group appears to reflect the fact that children recalled digits better than locations, whereas 19-year-olds showed little or no difference in recall for the two types of information. To localize this unexpected interaction statistically, separate two-way repeated-measures ANOVAs (Primary Task Domain x Secondary Task) were conducted for each age group. These post hoc analyses revealed that the tendency to retain verbal information better than spatial information was true only for the two groups of children. That is, there was no main effect for primary task domain for the 19-year-olds, \( F(1, 19) < 1 \), but there was an effect of primary task domain for both the second graders, \( F(1, 18) = 31.95, p < .0001 \), and the fourth graders, \( F(1, 19) = 29.56, p < .0001 \), even after the alpha level was adjusted to .008 using the Bonferroni inequality.

Returning to the primary three-group ANOVA, a main effect of secondary task requirement, \( F(2, 112) = 129.41, p < .0001 \), indicated that performance varied across the three levels of this factor (mean spans = 5.44, 3.65, and 4.97, for no secondary task, same-domain secondary task, and different-domain secondary task, respectively). However, the differences among these three levels of secondary task must be viewed in the context of a significant interaction between age and secondary task, \( F(4, 112) = 3.29, p < .05 \). No other interactions were significant.

Two planned contrasts, one comparing the 8- and 10-year-olds and the other comparing the 10- and 19-year-olds, were conducted to examine the time course of developmental changes in interference with working memory. The planned contrast comparing the 8- and 10-year-olds revealed an interaction between age and secondary task, \( F(2, 74) = 4.77, p < .05 \). Inspection of Figure 2 suggests that the source of this interaction may be the fact that although both groups of children experienced domain-specific interference, only the 8-year-olds appear to have experienced nonspecific interference. The planned contrast comparing the 10- and 19-year-olds revealed no interaction between age and secondary task, indicating statistically equivalent interference effects in these two groups.

However, although there was no statistically significant difference between the 10- and 19-year-olds' interference effects in absolute terms, it is possible that they do differ in relative terms. That is, because the 10-year-olds had smaller spans than 19-year-olds when there was no secondary task, equivalent absolute decreases due to interference may represent significantly larger decreases for the 10-year-olds in percentage terms. To address this issue, the planned contrast comparing the 10- and 19-year-olds was rerun using the logarithm of the spans. In this case, there was a significant interaction between age and secondary task, indicating that 10-year-olds were relatively more affected by interference than 19-year-olds, \( F(2, 76) = 9.59, p < .001 \).

A similar strategy was used to address the question of whether 8-year-olds are relatively more affected by interference than 10-year-olds. However, because it appeared that only the 8-year-olds were affected by nonspecific interference (see Figure 2 and the second primary analysis, below), the spans from the conditions in which the secondary task was from a different domain were not included in the analysis. In addition, because two of the 8-year-olds’ spans were equal to 0 in one condition (as mentioned previously) and the logarithm of 0 cannot be calculated, these two (0) scores were replaced with scores of

![Figure 2](image-url)
and 19-year-olds both showed equivalent interference when the proportion or percentage decrease. In absolute terms, the 10-year-olds experienced more domain-specific interference than the 10-year-olds.

The second primary analysis (on the raw scores) consisted of separate ANOVAs conducted to test directly for domain-specific interference (i.e., no secondary task requirement vs. same domain secondary task requirement) and nonspecific interference (i.e., no secondary task vs. different domain secondary task) in each age group. Domain-specific interference was present in the 8-year-olds, $F(1, 18) = 162.52, p < .001$, the 10-year-olds, $F(1, 19) = 131.38, p < .001$, and the 19-year-olds, $F(1, 19) = 14.11, p < .001$. However, nonspecific interference was found in the 8-year-olds, $F(1, 18) = 33.95, p < .001$, but not the 10-year-olds, $F(1, 19) = 1.76$, or the 19-year-olds, $F(1, 19) < 1$.

Discussion

The present study compared the efficiency and independence of the verbal and spatial components of working memory in school-age children and young adults. With respect to the independence of the verbal and spatial components, all age groups experienced domain-specific interference (i.e., interference by a secondary task from the same domain as the primary memory task). However, 8-year-olds, but not 10- or 19-year-olds, also experienced a significant amount of nonspecific interference (i.e., interference by a secondary task from a different domain than the primary memory task). From the perspective of Baddeley's (1983, 1992) model of working memory, this latter finding suggests that the central executive component of working memory may reach maturity sometime between the ages of 8 and 10 years. To the extent that executive functions are localized in the frontal lobes, this finding is also consistent with recent suggestions by Dempster (1992) and others that the relatively late development of the frontal lobes is central to slow emergence of certain key cognitive abilities, such as resistance to interference.

A comparison of the working memory performance of 8- and 10-year-olds clearly supports Dempster's (1992) hypothesis regarding development of the ability to inhibit irrelevant information. Specifically, the mean spans of the 8-year-olds were smaller than those of the 10-year-olds in all conditions. Moreover, the 8-year-olds showed significant interference when the secondary task was from a different domain than the primary memory task, whereas the 10-year-olds did not. Thus, as the increase in the ability to retain information over a brief period of time improves, as indicated by improved performance in the absence of any secondary task, resistance to the detrimental effects of interference also improves.

However, a comparison of the performance of the 10-year-olds with that of the 19-year-olds is somewhat more ambiguous with respect to the inhibition hypothesis. This ambiguity arises because it is not clear whether interference should be measured in terms of the difference in absolute number of items between secondary task and no secondary task conditions or whether interference should be measured in terms of the relative (i.e., proportion or percentage) decrease. In absolute terms, the 10- and 19-year-olds both showed equivalent interference when the secondary task was from the same domain as the primary task and neither showed significant interference when the secondary task was not from the same domain. Thus, although the 19-year-olds showed overall improvement in their spans in all six conditions when compared with the 10-year-olds, this improvement was not associated with a substantial decrease in the susceptibility to interference as measured in absolute terms. These results suggest that the improvement in working memory between 10 years of age and adulthood may not be due to increased resistance to interference and raise the question of whether resistance to interference causes, or merely accompanies, improvements in working memory before age 10.

It is possible, of course, that interference effects should be measured in relative (e.g., percentage) terms rather than absolute terms. Analyses based on the logarithms of the spans revealed that there was a decrease in the relative size of the domain-specific interference effect from 8 to 10 years and again from 10 to 19 years. In contrast to the analyses based on untransformed spans, the results of these latter analyses are consistent with a framework that emphasizes the development of the ability to inhibit irrelevant information. What would be most desirable is a formal, mathematical model of the development of working memory function that would provide a theoretical basis for choosing between absolute and relative interference measures. To our knowledge, however, no model addressing this measurement issue has been proposed.

Regardless of whether interference is measured in relative or absolute terms, the present results highlight the importance of distinguishing between domain-specific and nonspecific interference in theoretical accounts of the development of working memory. That is, regardless of the measurement scale, it is clear that although memory span continues to improve between age 10 and adulthood, resistance to nonspecific interference is already mature in 10-year-olds, at least when relatively simple secondary tasks are used. Moreover, even in 8-year-olds, specific interference effects are approximately twice as large as nonspecific interference effects, a pattern that other researchers have taken as evidence of functional independence of verbal and spatial working memory components in adults (e.g., Logie, Zucco, & Baddeley, 1990). Thus, our findings provide strong support for the independence of verbal and spatial working memory in school-age children, although the nonspecific interference observed in 8-year-olds suggests differences in executive functions among children in the early school years.

In a recent series of studies, Brainard (e.g., Brainard, Olney, & Reyna, 1993; Brainard, Reyna, Howe, & Kevershan, 1990, 1991; Harnishfeger & Brainard, 1994) has shown that in free recall, responses may be organized so that items of weaker memory strength are reported first, then stronger items, and finally weaker items again. This phenomenon is termed cognitive triage, and Brainard et al. (1990) have suggested that it functions to protect weaker items from output interference during recall. The tendency to emit weaker items at the beginning of recall increases with age and is associated with better recall. The theoretical significance of this finding lies in the fact that it suggests a possible mechanism underlying resistance to one form of interference, a mechanism whose maturation may be partly responsible for developmental improvements in free recall.
In the present study, one of the primary tasks (spatial working memory) involved free recall, whereas the other primary task (verbal working memory) required participants to recall both the identity and the order of the memory items. Yet both tasks showed similar effects of interference, as evidenced by the absence of any interactions between primary and secondary tasks, suggesting that triage effects did not play a major role in the present results. One difference between the present procedure and the procedures in studies that have reported triage effects is that the latter have examined memory for supraspan lists. Thus, the present findings suggest that developmental improvements in memory span and in the resistance to interference with working memory may reflect the maturation of mechanisms other than those involved in cognitive triage, although triage may play an important role when recall involves larger amounts of material.

Overall, the current findings provide relatively strong support for the framework provided by Baddeley’s (1983; Baddeley & Hitch, 1994) model of working memory (i.e., the distinction between verbal, spatial, and executive aspects of working memory). The finding that, on spatial and verbal working memory tasks of equivalent difficulty for young adults, children’s spatial performance is inferior to their verbal performance is not inconsistent with Baddeley’s (1983, 1992) model, although such an outcome has not been suggested previously. Interestingly, this finding parallels the pattern of age-related cognitive changes observed in adults: Hale, Myerson, and Rhee (1994) found that older adults (like children) show greater impairment in the spatial as compared with the verbal domain when performing working memory tasks similar to those in the current study.

Independently and in collaboration, Kail and Salthouse (Kail, 1992; Kail & Park, 1994; Kail & Salthouse, 1994; Salthouse, 1991) have argued that, at both ends of the life span, age differences in processing speed lead to age differences in working memory. This would suggest that where the size of the age difference in processing speed depends on the domain, the size of the age difference in working memory will also depend on the domain. This implication of a causal relation between speed and working memory is supported by recent research in our laboratory indicating that older adults both process nonverbal information more slowly and remember it more poorly than verbal information (e.g., Hale et al., 1994; Lima, Hale, & Myerson, 1991).

The present findings regarding the size of age differences in verbal and spatial working memory suggest that there may be corresponding processing-speed differences between the two domains in children. As noted by several researchers (e.g., Hale, 1990; Kail & Salthouse, 1994), differences in processing speed may have different neurobiological underpinnings in children (e.g., synaptic pruning) and older adults (e.g., loss of neurons). Nevertheless, evidence suggests that even though they may have different causes, age-related differences in speed appear to have somewhat similar effects in both children and the older adults.

Recent studies (Fry & Hale, 1996; Salthouse, 1991) suggest that the age-related changes in processing speed are just the beginning of a cascade that has important consequences for higher cognitive abilities. In childhood, for example, increases in speed lead to improvements in working memory that, in turn, lead to greater fluid intelligence as reflected in better performance on a test of nonverbal reasoning (i.e., the Raven’s Progressive Matrices). However, the role of susceptibility to interference in this developmental cascade has not yet been examined. Age differences in working memory are of obvious interest in their own right, but it is the relation of working memory to other cognitive abilities that gives these differences special significance. Thus, the present findings regarding age differences in domain-specific and nonspecific interference as well as differences in the rate of development of verbal and spatial working memory may prove to have important implications for other aspects of cognitive development.

References


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