Working Memory and Reading: A Life-span Perspective

Linda S. Siegel

Ontario Institute for Studies in Education, Canada

The relationships among working memory, memory span, and reading skills were studied in 1266 individuals, aged 6–49. They were administered tests of word recognition, pseudoword decoding, reading comprehension, a working memory (listening span) task that required the simultaneous processing of syntax and the recall of linguistic information, and a short-term memory task that required the recall of rhyming or nonrhyming letters presented visually. The results indicated that there is a gradual growth in the development of working memory skills from ages 6 to 19 and a gradual decline after adolescence. The short-term memory task did not show a decline in performance among older individuals. On both of these memory tasks and at most of the age levels, individuals with a reading disability performed at significantly lower levels than individuals with normal reading skills. An important component of the development of reading skills appears to be memory for verbal information. Age-related declines in memory appear to be related to the processing demands of the task, which may affect the degree to which rehearsal strategies are possible within the task.

INTRODUCTION

The construct of working memory has been used to explain performance on a variety of cognitive tasks (e.g. Baddeley, 1983; Hitch, 1978). Working memory refers to a temporary storage of information while processing incoming data and retrieving information from long-term storage. Working

Requests for reprints should be sent to Linda S. Siegel, Department of Applied Psychology, Ontario Institute for Studies in Education, 252 Bloor Street West, Toronto, Ontario, Canada M5S 1V6.

This research was supported by a grant from the Natural Sciences and Engineering Research Council of Canada. The author wishes to thank Susan D'Souza, Jane Heintz-Grove, Maureen Heywood, Norman Himel, Sharon Smith, and George Toth for help with the data collection and analyses, the individuals who graciously participated in this study, and Letty Guimela for secretarial assistance. This article was written while the author held a Senior Research Fellowship from the Ontario Mental Health Foundation.

© 1994 The International Society for the Study of Behavioral Development
memory can be conceptualised as a cognitive process in which certain bits of information are held in a memory store characterised by rapid decay while other bits are retrieved from long-term storage.

Working memory is composed of a central co-ordinating executive system and one or more subsidiary systems (e.g. Baddeley, 1983). The central executive is assumed to exert control functions, and the subsidiary systems are assumed to store specific information about items being processed, although there is some debate about the exact nature of the subsidiary systems (Reisberg, Rappaport, & O'Shaughnessy, 1984). Thus, working memory requires both the simultaneous processing of incoming information and the retrieval of other information. An important feature of working memory is that it has a limited capacity, so that if more demands are being made on the executive, there will be less processing space and cognitive energy available for the subsidiary systems.

Working memory is assumed to play an important role in reading (e.g. Baddeley, 1983; Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Daneman & Carpenter, 1980). During reading, the executive may be conceptualised as retrieving information about syntax, word meanings, and/or grapheme-phoneme conversion rules, while the subsidiary system retains the words, phrases, or sentences while they are being processed and for brief periods in order that longer units of text can be comprehended.

A particularly important feature of reading comprehension and one in which the concept of working memory may be critical, appears to be recall of the sentences that have been read. Daneman and Carpenter (1980) designed tasks to examine the interaction between sentence-processing skills and recall of items read. In these tasks, the individual was required to read or listen to a sentence and make a judgement about the truth of the statement and recall the last word of the sentences. As the number of words that the individual was required to remember increased, the demands on working memory were assumed to increase. The size of this sentence-based working memory span has been found to relate to reading comprehension as well as more specific aspects of text integration in adult readers (Daneman, 1987; Daneman & Carpenter, 1980, 1983). Therefore, one of the contributing factors to reading difficulties may be relatively poor working memory.

The study of individuals with difficulties in reading provides an opportunity to observe the influence of deficits in working memory on reading performance. To examine this issue, Siegel and Ryan (1989a) studied working memory in normal and disabled readers, ages 7–13, using a task based on one developed by Daneman and Carpenter (1980). The disabled readers performed significantly more poorly than the normal readers on this task, indicating significant difficulties with working memory in the
disabled readers. Similar difficulties with working memory in poor readers have been noted in Chinese (So & Siegel, 1992), Hebrew (Geva & Siegel, 1991), and Portuguese (Da Fontoula & Siegel, in press).

In addition to difficulties with working memory, children with reading problems experience difficulty with the phonemic coding process in short-term memory (e.g. Byrne & Shea, 1979; Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977; Mann, Liberman, & Shankweiler, 1980; Mark, Shankweiler, Liberman, & Fowler, 1977; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979; Siegel & Linder, 1984). Short-term memory tasks, unlike working memory tasks, typically do not require simultaneous processing and transformation of incoming information. In tasks involving short-term memory, young poor readers have been found to be less sensitive to phonemic similarity than normal readers. For example, Shankweiler et al. (1979) found that young poor readers, unlike good readers of the same age, did not show any differences in the recall of rhyming (e.g. B, C, D) and nonrhyming (e.g. Q, R, S) letters. If this pattern of performance is indicative of failure to use a phonemic code, and if this failure is a pervasive characteristic of reading difficulties, then we would expect that older children with reading disabilities might display the same pattern. However, Johnston (1982) and Siegel and Linder (1984) found that 9- to 14-year-old children with reading disabilities showed a phonemic-confusability effect with an auditory presentation of stimuli, and Bisanz, Das, and Mancini (1984) have shown that Grade 4 and Grade 6 poor readers showed phonemic-confusability effects for letters under conditions of delayed recall. Olson, Davidson, Kliegl, and Davies (1984) found that older disabled readers, as opposed to younger disabled readers, showed susceptibility to phonemic-confusability in a recognition memory task involving rhyming and nonrhyming words. In addition, Hall, Ewing, Tinzmann, and Wilson (1981) have found that adult poor readers did show sensitivity to phonemic similarity and had less difficulty in recalling nonrhyming than rhyming letters when an oral, as opposed to a written, response was required. However, a problem in integrating this evidence is the variation in methods across studies. The present study was designed to examine the nature of the deficit in phonemic coding in short-term memory in reading disabled individuals through childhood, adolescence, and adulthood in a single investigation.

An additional aspect of the present study was to assess the relationship between working memory and reading during childhood, adolescence, and adulthood. A maturational increase during childhood in the size of working memory has been postulated (e.g. Case, Kurland, & Goldberg, 1982; Hitch & Halliday, 1983; Pascual-Leone, 1970). The present study was designed to study the development of working memory in relation to
verbal information across a 43 year age span. We are also interested in determining whether individuals with less accurate reading skills would show difficulties with working memory.

Declines with increasing age in working memory in adulthood have been noted in a number of studies such as Babcock and Salthouse (1990), Hartley (1989), Light and Anderson (1985), Salthouse, Mitchell, Skovronek, and Babcock (1989), and Stine and Wingfield (1987), and in memory for digits in a dichotic listening task in which information is delivered to two channels simultaneously (e.g. Clark & Knowles, 1973; Craik, 1965; Inglis & Caird, 1963; Mackay & Inglis, 1963; Schonfield, Trueman, & Kline, 1972). (See Salthouse, 1990, for a detailed review.) The declines in working memory are particularly pronounced for the elderly (e.g. Gick, Craik, & Morris, 1988; Light & Anderson, 1985; Morris, Gick, & Craik, 1988; Salthouse & Babcock, 1991; Stine, Wingfield, & Poon, 1986; Wingfield, Stine, Lahar, & Aberdeen, 1988; Wright, 1981). Less complex short-term memory tasks that merely involve a recall of digits and do simultaneous processing and transformation of information do not show marked decline with age (e.g. Caird, 1966; Craik, 1977).

Thus, an additional purpose of the present study was to examine the development of memory skills in children, adolescents, and adults in a complex working memory task and a simpler short-term memory-span task that involved immediate memory span without concurrent processing demands. It was expected that the working memory task would show greater declines in adulthood with increasing age than the short-term memory task, which had minimal concurrent demands and allowed the possibility of rehearsal. Although it was expected that there would be differences between normal readers and reading disabled individuals in childhood, little is known about the developmental course of these differences in adolescence and adulthood. Study of the course development of these memory processes is facilitated by the use of the same tasks through a 43 year age span from childhood to adulthood; apparently the present study is unique in this respect.

**METHOD**

**Subjects**

There were 1266 subjects in this sample, 843 individuals with normal reading skills and 423 individuals with a reading disability. Some of these individuals had participated in one of a series of published and unpublished studies (e.g. Shafrrir & Siegel, 1992; Siegel, 1988, 1992, Siegel & Ryan, 1988, 1989b). They came from schools, colleges, universities, community
agencies or were volunteers from the community. The sample was predominantly middle class, although there were some individuals from the lower socioeconomic class. All were educated in English, and had English as their major language. The subjects were defined as reading disabled if they had scores $\leq 25$ percentile on the Wide Range Achievement Test (J.R. Jastak & S.R. Jastak, 1978; Jastak & Wilkinson, 1984) and an IQ $\geq 80$ on an abbreviated version of the WISC-R (Sattler, 1982; Wechsler, 1974) or WAIS-R (Silverstein, 1982; Wechsler, 1981) that included the Vocabulary and Block Design subtests. A rationale for this definition is provided in Siegel (1989) and Siegel and Heaven (1986). Individuals with neurological problems, emotional difficulties, inadequate educational opportunities, English as a second language, severe behavioural deficits, and sensory deficits were excluded.

This sample was arbitrarily divided into 13 age groups. These age groups and the numbers of subjects in the reading disabled (first number) and normal reader (second number) groups are as follows: 6 years (20, 58), 7 years (37, 93), 8 years (53, 93), 9 years (35, 106), 10 years (38, 73), 11 years (16, 61), 12 years (25, 30), 13–14 years (31, 48), 15–16 years (14, 43), 17–19 years (18, 43), 20–29 years (81, 106), 30–39 years (43, 57), and 40–49 years (12, 32). A smaller sample ($N = 962$) was administered the letter span task, with proportionally smaller numbers in each age group.

Reading Tests


The Stanford Reading Comprehension Test (Gardner, Rudman, Karlsen, & Merwin, 1982) involves the silent reading of a series of graded paragraphs and answering multiple choice questions. For individuals 18 years and older, the Nelson–Denny Reading Comprehension Test (Brown, Bennett, & Hanna, 1981) was used. The format of the Nelson–Denny Test is similar to the Stanford Reading Test.

Tasks

Working Memory (Listening Span). The working memory task was modelled on the procedure developed by Daneman and Carpenter (1980). The subject sentences were presented aurally with the final word missing. The task was to supply the missing word and to repeat all the missing words from the set. There were three trials at each set size or level (2, 3, 4, and 5). Examples of sentences were: “In summer it is very ______”; “People go to see monkeys in a ______”; “With dinner we sometimes eat bread and
FIG. 1. Mean number correct on the working memory task for the reading disabled and normal readers.

"______". The child was then required to repeat the three words that he or she selected, in this case *hot, zoo, butter*, in the same order that the sentences had been presented. Task administration was stopped when the individual failed all the items at one level. To calculate the total score, one point was awarded for each set in which all the words were given in the correct order. To minimise word-finding problems, the sentences were chosen so that the word was virtually predetermined. None of the individuals experienced any difficulty in supplying the missing word.

*Short-term Memory.* The short-term memory task was similar to those used by Shankweiler et al. (1979) but with some minor procedural differences. For this task the individuals were shown cards with five letters on them. Half of the sets had rhyming letters, B, C, D, G, P, T, V (the Z had to be eliminated from the rhyming sets because it is pronounced "zed" in the Canadian dialect), and half of the sets were composed of nonrhyming
TABLE 1
Mean Number Correct (Maximum = 12) on the Working Memory Task

<table>
<thead>
<tr>
<th>Age</th>
<th>Reading Disabled</th>
<th>Normally Achieving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>s.d.</td>
</tr>
<tr>
<td>6</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>7</td>
<td>2.4</td>
<td>1.5</td>
</tr>
<tr>
<td>8</td>
<td>2.9</td>
<td>2.1</td>
</tr>
<tr>
<td>9</td>
<td>3.7</td>
<td>2.1</td>
</tr>
<tr>
<td>10</td>
<td>4.4</td>
<td>2.0</td>
</tr>
<tr>
<td>11</td>
<td>4.3</td>
<td>3.0</td>
</tr>
<tr>
<td>12</td>
<td>5.2</td>
<td>1.8</td>
</tr>
<tr>
<td>13–14</td>
<td>5.5</td>
<td>3.2</td>
</tr>
<tr>
<td>15–16</td>
<td>6.5</td>
<td>2.1</td>
</tr>
<tr>
<td>17–19</td>
<td>6.3</td>
<td>1.8</td>
</tr>
<tr>
<td>20–29</td>
<td>5.2</td>
<td>1.8</td>
</tr>
<tr>
<td>30–39</td>
<td>5.2</td>
<td>1.6</td>
</tr>
<tr>
<td>40–49</td>
<td>4.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>

letters, e.g. H, K, L, Q, R, S, W. (Y was included in the Shankweiler et al. (1979) study but eliminated from the nonrhyming sets in this study.) There were seven trials of each type of stimuli, and the order was intermixed and determined randomly. The stimuli were presented for 3 seconds, and then the cards were removed. The individual was required to write down the letters that had been on the card. The maximum scores were 35 for the rhyming and nonrhyming sets. Only letters recalled in the correct serial position of each trial were scored as correct.

Some subjects were given only one of the tasks; some were administered two tasks. Of the individuals who had both tasks, approximately half of each age group had the working memory task first, the other had the short-term memory task first. The subjects were administered the WRAT Reading subtest, parts of the WAIS or WISC-R, the working memory (or short-term memory) task, a number of reading and spelling tasks that lasted 30 minutes, and then the memory task that they had not been administered previously.

RESULTS

The mean scores on the working memory task for the normal readers and the reading disabled group at each age are shown in Fig. 1 and Table 1. An ANOVA on age level and group indicated significant effects of age $F(12,1240) = 88.68$, $P < 0.0001$, effects of group $F(1,1240) = 50.95$, $P < 0.0001$ and no significant interaction. As can be seen from the data
presented in Fig. 1, there was an increase in working memory capacity for the normal readers until age 20 at which point, scores on this task start to decline. A similar pattern is evident for the reading disabled group although the rate of decline appears to be steeper in this group. Individual comparisons (t-tests) indicated that the normal reader group had higher scores than the reading disabled group at each age except at 12, 15–16, and 17–19. At 10 years, the difference between the two groups did not reach conventional levels of statistical significance \((P < 0.06)\). In general, there were not significant differences between adjacent age groups but there were significant differences among groups separated by 2–5 age levels. For example, there were significant increases until age 20 and the 30–39 and 40–49 year old groups had significantly lower scores than the 17–19 year olds.

### TABLE 2
**Mean Number Correct (Maximum = 35) on the Short-Term Memory Task**

| Age | **Reading Disabled** | | | | **Normally Achieving** | | |
|-----|----------------------|----------------------|----------------------|----------------------|
| | **Rhyming** | **Nonrhyming** | | **Rhyming** | **Nonrhyming** | |
| 6 | 9.0 (4.7) | 11.2 (6.3) | 11.0 (4.4) | 14.4 (7.5) | |
| 7 | 10.34 (3.6) | 12.2 (5.3) | 15.8 (4.7) | 21.2 (6.7) | |
| 8 | 13.2 (5.0) | 17.0 (6.4) | 18.4 (6.6) | 24.2 (7.1) | |
| 9 | 15.6 (5.9) | 21.5 (7.0) | 22.1 (5.3) | 27.8 (5.9) | |
| 10 | 17.8 (5.6) | 21.4 (6.8) | 21.9 (5.5) | 27.2 (6.0) | |
| 11 | 17.6 (3.2) | 23.2 (5.3) | 26.0 (6.4) | 30.2 (4.7) | |
| 12 | 21.4 (3.5) | 26.5 (4.9) | 25.7 (4.7) | 29.7 (4.2) | |
| 13–14 | 23.2 (5.2) | 26.4 (5.6) | 27.5 (4.5) | 31.3 (3.3) | |
| 15–16 | 25.8 (5.8) | 30.1 (4.5) | 28.6 (4.5) | 32.0 (3.3) | |
| 17–19 | 26.6 (7.0) | 28.9 (6.5) | 29.0 (3.9) | 31.9 (3.2) | |
| 20–29 | 25.0 (5.3) | 28.4 (4.3) | 29.7 (4.2) | 32.6 (3.0) | |
| 30–39 | 24.6 (5.1) | 29.3 (5.7) | 28.7 (4.2) | 31.9 (4.3) | |
| 40–49 | 23.8 (6.4) | 25.7 (6.0) | 28.2 (4.7) | 32.2 (3.2) | |

*Standard deviations are in parentheses.*
FIG. 2. Mean number correct on the letter span task for the reading disabled and normal readers.

The results for the short-term memory (letter span) task are shown in Table 2 and Fig. 2. A three-way ANOVA was performed with two between-subjects variables of group (reading disabled vs. normal readers) and age (13 levels) and one within-subjects variable stimulus (rhyming vs. nonrhyming trials). There were significant effects of group, $F(1,936) = 207.24$, $P < 0.0001$, age, $F(12,936) = 105.51$, $P < 0.0001$, stimulus, $F(1,936) = 507.98$, $P < 0.0001$, a significant Group $\times$ Age interaction, $F(12,936) = 2.18$, $P < 0.02$, Age $\times$ Stimulus interaction, $F(12,936) = 2.61$, $P < 0.002$, and a significant Group $\times$ Age $\times$ Stimulus interaction, $F(12,936) = 1.96$, $P < 0.03$. As can be seen in Fig. 2, there were significant differences between the normal and disabled readers on both the rhyming and nonrhyming trials at every age except 6 years, which was probably due to a floor effect. Differences between the reading disabled and normal...
TABLE 3  
Correlations Among the Tasks$^{a,b}$

<table>
<thead>
<tr>
<th></th>
<th>Short-term Memory</th>
<th>WRAT Reading</th>
<th>Reading Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working Memory</td>
<td>0.44 (939)</td>
<td>0.23 (1266)</td>
<td>0.29 (535)</td>
</tr>
<tr>
<td>Short-term Memory</td>
<td></td>
<td>0.42 (962)</td>
<td>0.31 (533)</td>
</tr>
<tr>
<td>WRAT Reading</td>
<td></td>
<td></td>
<td>0.45 (535)</td>
</tr>
</tbody>
</table>

$^{a}$Ns are indicated in parentheses. $^{b}$All correlations were significant, $P < 0.0001$.

readers did not reach conventional levels of statistical significance ($0.10 > P > 0.05$) on the nonrhyming trials for the 15–16-year-olds and on the rhyming trials for the 17–19-year-old group. For each group at each age, except the 6-year-old reading disabled children (again, possibly a floor effect), the scores on the nonrhyming trials were significantly higher than the scores on the rhyming trials. In general, there were not significant differences between adjacent age levels but there were differences among groups separated by 1–4 age levels.

The correlations among the variables are shown in Table 3. As can be seen in Table 3, the scores on the working memory task and the short-term memory task were significantly but moderately correlated with the word recognition and reading comprehension and with each other.

DISCUSSION

There were differences between the reading disabled and the normal readers on the working memory task at most of the ages included in the study. Thus, the difficulties in working memory for individuals with reading problems extend beyond the period of childhood (as has been documented previously) to adolescence and adulthood. Although working memory is clearly not the only process that is important in reading (see Siegel, 1993a, 1993b, and Stanovich, 1988, for extended discussions of this issue), it is clearly one of the important ones. The correlations between the reading tasks and the memory tasks were statistically significant but moderate. For example, the present study found a correlation of 0.29 between reading comprehension and working memory. Daneman and Carpenter (1980) reported significant correlations ranging from 0.59 to 0.90 between a working memory test and various reading comprehension
tests; however, the working memory task differed from the one used in the present study in that the task involved reading sentences. The working memory task in the present study involved listening to, not reading sentences, so that the reading and memory tasks are not as directly related. However, in the Daneman and Carpenter (1983) study, these correlations were between two reading tasks. However, Daneman and Carpenter did find that a listening span task was highly correlated with reading comprehension ($r_s$ ranged from 0.53 to 0.72). Light and Anderson (1985) found a correlation between a listening span measure (similar to Daneman & Carpenter, 1983) and a paragraph memory test of 0.3. This correlation is similar in magnitude to the one found in the present study. Unlike Daneman and Carpenter who used a university-based sample, the present study and Light and Anderson used a community-based sample. In addition, the relationship may not be a linear one in that very poor readers and very good readers may show, respectively, deficits or strengths in working memory and in the middle range of reading skill (the level of most of the individuals in this study), the relationship may not be as strong. Dividing the sample into poor readers and normally achieving readers did result in significant differences at most ages, indicating a relationship between reading ability and working memory. In addition, it should be noted that Cohen and Heath (1990) and Henry (this issue) provide evidence that individual differences in working memory are not related to articulation speed and proficiency, therefore differences in articulation speed probably are not the cause of the differences between the disabled and normal readers.

There were also significant differences at almost every age level, except late adolescence, between the reading disabled and normal readers on the short-term memory task. As this task involved phonological encoding and as disabled readers have difficulties in phonological processing (e.g. Bruck, 1990; Stanovich, 1988), it is not surprising that they had lower scores; however, this is the initial demonstration of this phenomenon in adults with reading disabilities. The absence of a different between the normally achieving and reading disabled on the memory tasks in late adolescence probably indicates that both groups were performing in an optimal manner at this age level. In addition, the results did not suggest, as had some previous studies, that disabled readers fail to make use of phonological coding because the disabled readers did have lower scores on the rhyming trials, indicating a phonemic similarity effect. Failures to find this effect in previous studies may have been a result of lack of statistical power. In any case, the disabled readers did appear to use some phonological coding in short-term memory but their short-term memory skills are significantly less adequate than normally achieving readers.

Both tasks showed increases in performance with increasing age up to
age 15 and the working memory task showed a decline after age 20 whereas the short-term memory task did not. Some caution must be used in interpreting these differences as we do not know that the tasks measure the same components over the life span. The working memory task is a more complex one than the short-term memory because the working memory task requires the simultaneous processing and storage of information. Craik (1977, p. 391) has suggested: “There is much evidence that older subjects are especially penalised in situations where they must divide their attention: perhaps their capacity is largely taken up in ‘programming’ the division of attention leaving relatively little capacity to process the stimuli.” Although this statement was qualified in a later publication (Morris et al., p. 366) where it was noted that “it seems possible that divided attention is too broad a category to treat as a unitary factor”. Tasks that require greater processing demands show more decline with age (e.g. Gick et al., 1988; Morris et al., 1988; Salthouse, Rogan, & Prill, 1984; Spilich, 1983; Wright, 1981). The working memory task used in the present study requires a division of attention between the incoming stimulus and the previous trials; the short-term memory task does not, as only incoming information on a particular trial is relevant. These differences in task complexity may account for the differences between the tasks. In addition, the working memory task involved auditorily presented stimuli and the short-term memory task visually presented stimuli. These differences mean that caution must be used in interpreting the differences in the age trends in performance on the two tasks.

It is not possible to understand the mechanisms for the age-related decline in working memory on the basis of the data obtained in this study. However, Salthouse and Babcock (1991) have suggested that there may be declines with age at the rate at which information is activated (encoded) but not the rate at which it is lost. It may be that rehearsal helps the encoding process thus minimising age-related declines. In the working memory task, rehearsal of previous items may interfere with processing incoming information and therefore, there may be declines with age. However, the short-term memory task allows rehearsal so that there are no declines with age for normally achieving readers. The reading disabled individuals did show declines with age on the nonrhyming stimuli for which rehearsal is important so they may have a deficit in rehearsal.

Salthouse (1990) has proposed an hypothesis to account for task-related differences in the degree of memory decline with increasing age in adulthood. Specifically, he noted (1990, p. 109): “One hypothesis proposed to account for this pattern of results is that, because of smaller working-memory capacities, older adults are more likely than younger adults to lose the early information (from the initial frames) during the encoding and integration of later information (from subsequent frames).” Because of
this loss of information in the initial frames, rehearsal becomes more difficult. The results of Salthouse, Babcock, and Shaw (1991) suggest that age-related decrements may be related to stimulus encoding which suggests rehearsal deficits.

In summary, deficits in working memory and in serial order recall are characteristic of disabled readers in childhood, adolescence, and adulthood. Working memory and short-term memory skills develop through adolescence but working memory skills show declines in adulthood whereas short-term memory skills do not, at least until age 50. Where rehearsal processes are possible and do not interfere with stimulus encoding, then age-related declines in adulthood in memory processes are not apparent, at least until age 50.

REFERENCES


Working Memory and Reading


Stanovich, K.E. (1988). Explaining the differences between the dyslexic and garden variety


