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Processing speed, exposure to print, and naming speed

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ABSTRACT
The aim of the present research was to determine the role of reading-related experience and processing speed on the time it took for children to name familiar stimuli. A total of 168 children, aged 7 to 13, were administered measures of global processing speed, title and author recognition, naming time, and reading ability. Naming times were predicted by age-related change in processing time but not by reading experience (as assessed by author and title recognition). The results are discussed in terms of the factors responsible for the relation between naming speed and reading.

The speed with which children name familiar stimuli is a potent predictor of reading skill. That is, the speed with which children name digits, letters, or colors is related to many measures of reading skill, including accurate word decoding, skilled comprehension, and expressive oral reading (Spring & Davis, 1988; Young & Bowers, 1995). The relation between naming and reading skill has been obtained within samples of normal readers, within samples of dyslexic readers, and when normal readers were compared to dyslexic readers (Kail & Hall, 1994; Wimmer, 1993; Wolf & Obregon, 1992).

The meaning of the link between naming speed and reading skill remains unclear. Many investigators have proposed that naming tasks measure a child's ability to execute reading-specific skills automatically. Spring and Davis (1988), for example, argued that "naming speed is an index of the automaticity with which letter codes are accessed in memory, and that automatization of this process is a prerequisite for the accurate performance of certain other higher level reading processes" (p. 330). Along similar lines, Bowers and Wolf (1993; Bow-

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ers, 1995; Wolf, 1991) suggested that naming speed measures a child's mastery of orthographic codes and their associated phonological codes.

Thus, the argument is that successive exposure during reading to individual letters and words strengthens the associated orthographic and phonological representations in long-term memory. As these representations become stronger, they are retrieved more readily, thereby speeding the naming of familiar stimuli and improving reading by allowing mental resources to be devoted to other, higher level reading processes.

An alternative view is that the link between naming speed and reading skill reflects more general cognitive processes, not those specific to processes required for skilled reading. Kail and Hall (1994), for example, proposed that the naming–reading link reflects a global developmental change in processing speed. During childhood and adolescence, the speed of processing increases on a range of perceptual and cognitive tasks, a pattern which seems to indicate that a common, global mechanism is responsible for age-related change in processing speed (Kail, 1991). Access to name codes for digits, letters, and colors may become more rapid with age simply because age-related change in the global mechanism speeds retrieval, not because access to specific name codes is automatic. According to this view, the correlation between naming speed and reading reflects the fact that both are linked to age-related change in processing speed.

Kail and Hall (1994) argued that, if rapid naming reflects automatic access to characters, measures of global processing speed should not predict naming speed because automaticity is based on an individual's experience. Instead, age – as a proxy for the age-related accumulation of reading-relevant experience – should predict naming time. In contrast, if more rapid naming is simply another manifestation of age-related change in processing speed, then measures of processing speed should predict rapid naming. In fact, Kail and Hall (1994) found that naming times were predicted by processing speed but not age, a result consistent with the processing speed explanation of the naming–reading relation.

A drawback to the Kail and Hall (1994) study is that, although processing speed was assessed directly, reading-related experience was assessed indirectly, using age. To the extent that age inaccurately estimates reading-related experience, the Kail and Hall (1994) study was biased against the automaticity interpretation of the naming–reading link. The potential problem of the previous study was addressed in the present work by estimating reading experience more accurately – specifically, by testing children's recognition of titles of children's books and their recognition of the names of authors. Performance on title and author recognition tasks is related to other measures of children's reading experience, such as reading diaries (Allen, Cipielewski, & Stanovich, 1992), and it predicts both decoding and comprehension scores (McBride-Chang, Manis, Seidenberg, Custodio, & Doi, 1993). We also administered processing speed, decoding, and comprehension tasks. If naming speed reflects automaticity that is a product of reading experience, then title and author recognition should predict naming times. If, instead, naming speed reflects a global developmental change in the speed of processing, then the processing speed tasks should predict naming times.

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METHOD

Participants

We tested 168 individuals, 24 each of 7, 8, 9, 10, 11, 12, and 13 years of age. The sample included 86 females, and at each age approximately half of the participants were female. The mean ages of the children were 7;3, 8;2, 9;3, 10;3, 11;3, 12;2, and 13;3 years. All testing took place in one of three locations in the midwestern United States: a small city in Indiana, a small town in Wisconsin, and a larger city and an adjacent small town in Ohio. At the Indiana and Ohio sites, some children were recruited via advertisements in school newsletters or local newspapers and via letters to parents; they were paid between $4.00 and $4.50. Other children in Indiana were recruited through the schools; they were not paid. At the Wisconsin site, all of the children were recruited through the schools and were not paid.

Tasks

Processing speed was measured with two tasks used by Kail and Hall (1994): the Visual Matching and Cross-Out tasks, both from the Woodcock–Johnson Tests of Cognitive Ability. These tasks were chosen because previous work established them as effective measures of processing speed. The tasks were chosen for three reasons: (1) they were devised initially to assess the processing speed factor in the theory of fluid and crystallized intelligence (Horn, 1985); (2) in factor analyses, they load on a common processing speed factor (Kail, 1997); and (3) age-related change in performance on these tasks resembles age-related change in performance on the perceptual and cognitive tasks used to infer that a global mechanism is responsible for developmental change in processing speed (Kail & Salthouse, 1994).

In Visual Matching, each of the 60 rows includes six digits, two of which are identical (e.g., 8, 9, 5, 2, 9, 7); the subject is to circle the identical digits. The performance measure is the number of rows completed correctly in 3 minutes. In Cross-Out, each of the 30 rows consists of a geometric figure on the left and 19 similar figures to the right. In one row, for example, the figure on the left consists of a triangle enclosing a single dot, and the figures on the right are triangles with various objects in the interior (e.g., a single dot, three dots, a plus, a square). The child is to place a line through the 5 figures that are identical to the one on the left. The performance measure is the number of rows completed correctly in 3 minutes.

Naming time was assessed with two of the tasks used by Kail and Hall (1994): naming digits and naming letters. In each case, children first practiced naming 15 exemplars of the stimuli; then they were shown a page with 50 stimuli arranged in 10 rows of five stimuli each. The experimenter recorded the amount of time required for the child to name all 50 stimuli and noted any naming errors.

The title recognition task was based on materials used by previous investigators (Cunningham & Stanovich, 1991, 1993; McBride-Chang et al., 1993) and

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included 32 titles of books appropriate for 7- to 13-year-olds along with 12 foils. Children were told that they would read a list that included some titles of real books and some titles that were "made up"; they were to circle "yes" if the title referred to a real book or "no" if it did not. The titles were ordered randomly in the list.

The author recognition task was similar; it included the names of 16 well-known authors of children's books along with 6 foils. Most names and foils were taken from Allen et al. (1992); we added the names of four well-known authors who were not represented in the Allen et al. set. Children were asked to read a list that included names of people who wrote children's books as well as names of people who did not; they were to circle "yes" if the person wrote books for children or "no" if the person did not. The names appeared in a constant, random order.

The Reading Recognition and Reading Comprehension tasks of the Peabody Individual Achievement Test were administered, following standard procedures. In the former, the child reads individual words aloud; in the latter, the child reads a sentence silently and then points to one of four pictures that corresponds to the meaning of the sentence.

Procedure

In Indiana and Ohio, some children were tested in quiet rooms in the authors' laboratories at the university; others were tested in quiet rooms in their schools (in Indiana) or in public libraries (in Ohio). In Wisconsin, all children were tested in their schools. All tasks were presented in a single session that lasted about 45 minutes for the youngest children and about 35 minutes for the oldest. Tasks were presented in the following constant order: Visual Matching, naming digits, title recognition, Cross-Out, naming letters, author recognition, Reading Recognition, and Reading Comprehension. The order of tasks was not counterbalanced across children so that individual differences would not be confounded with differences in task order. As part of the testing, the children were also administered three memory tasks that are not relevant to the focus of this article.

RESULTS

Performance on the title and author recognition tasks was measured using procedures followed by Cunningham and Stanovich (1992, 1993). We determined the percentage of titles (or authors) that were identified correctly and subtracted from this value the percentage of foils that were incorrectly identified (i.e., the false alarms). Preliminary analyses indicated that both the gender of the participant and the testing site were rarely related to performance; consequently, these variables are not discussed further.

Shown in Table 1 are the correlations between the nine variables of interest. All variables were correlated with performance on the Reading Recognition and Reading Comprehension tasks, but the correlations were largest for age and Visual Matching. Also, measures assumed to assess the same construct were correlated, although these correlations were higher for the speeded and reading tasks than for the print exposure tasks. As expected, age was correlated with performance on all tasks. Figure 1 shows that performance improved between 7

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Table 1. *Correlations between measures*

Variable	1	2	3	4	5	6	7	8	9
1. Age	—								
2. Visual Matching	–.82	—							
3. Cross-Out	–.74	.83	—						
4. Naming digits	–.67	.77	.71	—					
5. Naming letters	–.56	.70	.63	.83	—				
6. Title recognition	.70	–.62	–.53	–.52	–.43	—			
7. Author recognition	.49	–.50	–.48	–.43	–.32	.52	—		
8. Reading Recognition	.77	–.76	–.66	–.71	–.67	.73	.53	—	
9. Reading Comprehension	.72	–.70	–.62	–.66	–.61	.68	.50	.92	
M	10.2	37.2	19.9	26.3	26.1	0.3	0.2	64.0	65.6
s	2.0	8.1	6.2	7.8	8.7	0.3	0.3	21.1	20.1

Note: $N = 168$. Age is expressed in years; Visual Matching, Cross-Out, Reading Recognition, and Reading Comprehension in number correct; naming digits and letters in seconds; title and author recognition as the proportion of titles (or authors) identified correctly minus the proportion of foils identified incorrectly. All *r*s are significant at $p < .01$. Signs for correlations involving Visual Matching and Cross-Out were reversed for consistency with the naming tasks.

and 13 years on the processing speed, naming, print exposure, and reading tasks, but that variability around the age-group means was stable over this range.

Relations between the variables can be seen more clearly in composite scores that were created for the speed, naming, and print exposure tasks. For each construct (e.g., processing speed), raw scores on the two constituent tasks (e.g., Visual Matching, Cross-Out) were converted to standard scores and summed. Correlations between variables, age, Reading Recognition, and Reading Comprehension are shown in Table 2.

If naming times reflect automatic access to characters and words, reading-relevant experience should predict naming time. If, instead, naming times reflects age-related change in processing speed, then measures of processing time should predict rapid naming. To evaluate these views, multiple regression analyses were conducted in which age, processing time composite scores, and print exposure composite scores were used to predict naming time. The first two rows of Table 3 depict the results of a forward stepwise multiple regression analysis in which print exposure was entered into the regression equation first, followed by processing time and age. Shown in the next two rows are the results of a second analysis in which processing time was entered into the equation first, followed by print exposure and age. The results provide clear support for the view that naming time reflects speed of processing. When print exposure was entered first, the addition of processing time accounted for a substantial increase in the explained variance in naming time. However, when processing time was entered first, print exposure did not increase the explained variance in naming time. This pattern was found for composite scores as well as for raw times on the digit- and letter-naming tasks.

To ensure that these results were not artifacts of using composite scores as

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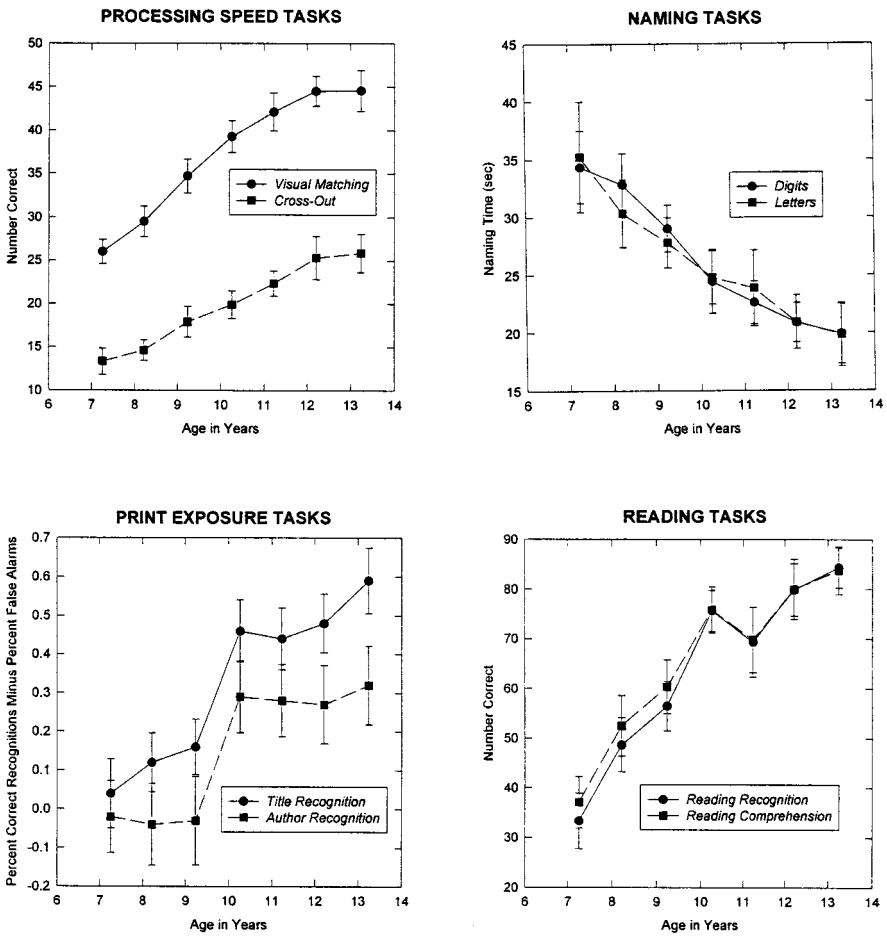


Figure 1. Performance on processing speed, naming time, print exposure, and reading tasks as a function of age. Error bars show 95% confidence intervals about the age-group mean.

predictors, we repeated these analyses using the original test scores. In one analysis, the scores on title and author recognition were entered as a block, followed by Visual Matching and Cross-Out. In a second analysis, the order of entry was reversed. The results, shown in the bottom half of Table 3, reveal the same patten seen in the top half of the table. Print exposure measures accounted for significant variance when entered before the processing time measures, but not when entered after them.

Additional analyses were conducted to evaluate the links between naming and reading. Previous investigators (Kail & Hall, 1994; Spring & Davis, 1988) found

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Table 2. *Correlations between age, speed composite, naming time composite, and reading scores*

Variable	1	2	3	4	5
1. Age	—				
2. Processing time composite	–.81				
3. Naming time composite	–.65	.77			
4. Print exposure composite	.68	–.64	–.51		
5. PIAT Reading Recognition	.77	–.74	–.72	.72	
6. PIAT Reading Comprehension	.72	–.69	–.66	.68	.92

Note: $N = 168$. All *r*s are significant at $p < .01$.

Table 3. *Results of stepwise regression analyses in which age, processing time, and print exposure were used to predict naming times*

	Dependent variable					
	Naming time composite		Naming digits		Naming letters	
Step/variable	R^2	ΔR^2	R^2	ΔR^2	R^2	ΔR^2
Composite scores as predictors						
1. Print exposure	.260	.260**	.299	.299**	.183	.183**
2. Processing time	.589	.329**	.600	.301**	.483	.300**
1. Processing time	.588	.588**	.595	.595**	.483	.483**
2. Print exposure	.589	.001	.600	.005	.483	.000
3. Age	.590	.001	.603	.003	.483	.000
Raw scores as predictors						
1. Title and author recognition			.306	.306**	.193	.193**
2. Visual Matching, Cross-Out			.608	.302**	.500	.307**
1. Visual Matching, Cross-Out			.605	.605**	.497	.497**
2. Title and author recognition			.608	.003	.500	.003
3. Age			.609	.001	.501	.001

Note: ΔR^2 denotes the increment in R^2 associated with the addition of the variable(s) to the regression equation.
**$p < .01$.

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Table 4. *Results of stepwise regression analyses in which age, processing time, print exposure, naming time, and Reading Recognition were used to predict Reading Comprehension*

Step	Variable	R^2	ΔR^2
1.	Reading Recognition	.855	.855**
2.	Age		
	Processing time		
	Print exposure		
	Naming time	.855	.000
1.	Age		
	Processing time		
	Print exposure		
	Naming time	.638	.638**
2.	Reading Recognition	.855	.217**

Note: ΔR^2 denotes the increment in R^2 associated with the addition of the variable to the regression equation.
**$p < .01$.

that naming times were correlated with both decoding and comprehension scores, but that the naming–comprehension correlation was no longer significant with decoding partialed out. To examine these relations, two multiple regression analyses were performed in which age, processing time composite scores, naming time composite scores, print exposure composite scores, and Reading Recognition scores were used to predict Reading Comprehension scores. In the first analysis, Reading Recognition scores were entered into the regression equation first, and then the remaining variables were entered as a block. In the second analysis, age, processing time composite scores, naming time composite scores, and print exposure scores were entered into the regression equation first, followed by Reading Recognition scores. Table 4 depicts the results, which are consistent with the view that the naming–comprehension correlation is no longer significant with decoding partialed out. When Reading Recognition was entered first, the other variables (including naming time) did not explain any additional variance in Reading Comprehension. However, when the other variables were entered first, Reading Recognition time still accounted for substantial increase in the explained variance in Reading Comprehension.

A final analysis was performed to determine how effectively age, naming time, processing time, and print exposure would predict Reading Recognition. Because we had no specific hypotheses about the relations between these variables, they were all entered into the regression equation simultaneously. The results, shown in Table 5, indicate that age, naming time, and print exposure were related to Reading Recognition, but processing time was not.

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Table 5. *Summary of multiple regression analysis on Reading Recognition scores*

Dependent variable	R^2	Independent variables	β
Reading Recognition	.74**	Age	.32**
		Processing time	–.01
		Naming time	–.34**
		Print exposure	.33**

**$p < .01$.

DISCUSSION

The present research was designed to determine why naming predicts reading skill. According to the view that the correlation between decoding skill and the rapid naming of digits, letters, and colors reflects automaticity, naming times should have been predicted by print exposure because automaticity is a function of reading experience. However, naming times were not predicted by print exposure but by processing time composite scores. This outcome is consistent with the view that the time to name familiar stimuli reflects a global developmental change in the speed with which many cognitive processes are executed.

A possible argument against this conclusion is that the print exposure tasks that we used did not, in fact, measure the accumulated reading experience that is the basis for automatic processing. We counter this argument in two ways. First, as noted earlier, Stanovich and others (Allen et al., 1992; West, Stanovich, & Mitchell, 1993) consistently showed that title and author recognition tasks are reliable and sensitive measures of the time spent reading. Second, we found that performance on the print exposure tasks was related to decoding skill, a result reported by several other investigators (e.g., Cunningham & Stanovich, 1991; McBride-Chang et al., 1993). Thus, our version of the print exposure tasks apparently measured the reading experience that leads to effective word decoding. Apparently, these same experiences are not responsible for older children's more rapid naming of familiar stimuli such as digits and letters.

Another possible argument against our conclusions about the contribution of processing speed to naming concerns the sample used in our research. In contrast to much of the research on the link between naming speed and reading, in which the samples have been relatively homogeneous in age, our sample included a wide range of ages. Perhaps our evidence implicating processing time can be attributed, at least in part, to a sample that varied widely in age, reading skill, and processing time. To address this issue, we divided the sample into quartiles based on age and calculated correlations between naming time, processing time, print exposure, and Reading Recognition. The results, shown in Table 6, are quite consistent. In each case, naming time is correlated more strongly with processing time than with print exposure. Yet Reading Recogni-

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Table 6. *Correlations between naming time, Reading Recognition, processing time, and print exposure*

Age (years)	*N*	NT–PT	NT–PE	RR–PT	RR–PE
7–8	43	.58**	.07	–.50**	.30*
8–10	44	.54**	–.36*	–.30*	.66**
10–12	37	.60**	–.08	–.32*	.47**
12–13	44	.63**	–.30*	–.42**	.51**

Note: NT denotes naming time; RR, Reading Recognition; PT, processing time; PE, print exposure.
*$p < .05$; **$p < .01$.

tion is correlated more strongly with print exposure than with processing time in three of the four samples. The results suggest that, although the print exposure tasks did measure reading-related experiences at each age, these experiences do not lead to more rapid naming. Thus, our conclusion that processing time determines naming time is not an artifact of a sample that varies widely in age.

Our interpretation of these results, then, is that naming and reading are linked because skilled performance in both naming and reading depends, in part, on the rapid execution of the underlying processes. As children develop during the elementary school years, they process information more rapidly (Kail, 1991), which means that they name digits, letters, and colors faster; it also means that they read better.

Another possible explanation of these findings warrants comment. The size of the correlation between naming speed and reading is influenced by the manner in which naming speed is measured. The correlation is often smaller when children name individual letters, digits, or colors as they are presented on distinct trials and larger when stimuli are presented in sequence and named continuously (Bowers, 1995; Stanovich, 1981). By this account, the naming–reading correlation reflects the fact that the continuous naming procedure and reading both involve the rapid sequential processing of individual symbols. That is, efficient serial processing is thought to be involved in both rapid naming and skilled reading. This explanation is consistent with the present results because both of the processing speed tasks used here involved rapid serial processing: both required scanning a series of stimuli to find those that matched. Thus, these results might simply mean that rapid sequential processing is common to the processing speed and naming tasks and to reading.

Finally, the present results have implications concerning the use of naming tasks for assessment. Low scores on naming tasks clearly forecast reading difficulties. Based on the automaticity view, the interpretation is often that inadequate orthographic and phonological representations give rise to slow naming, which leads to the prescription of additional reading instruction designed to strengthen these representations. The present results show that the naming–read-

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ing link may not reflect reading-specific skills and, hence, may not have direct implications for reading remediation. That is, the naming–reading link may stem from common roots in global processing speed or sequential processing. In either case, slow naming apparently reflects a more systemic problem and not localized in ineffective reading skills, which may be less susceptible to remediation through reading-specific instruction.

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