The Influence of Item Composition on RAN Letter Performance in First-Grade Children

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This study investigated whether changing the letter composition of the Denckla and Rudel (1976) RAN task influenced task performance (speed and accuracy) and the RAN-word identification skill relationship in first-grade children. To accomplish this, 383 first-grade children were administered four different RAN tasks in October, and performance on these measures was used to predict word identification skill in April. The various RAN tasks consisted of the Denckla and Rudel RAN letter-naming task and three alternative RAN tasks constructed by making a letter substitution that replaced the letter *o* within the Denckla and Rudel letter matrix (*a, d, o, p, s*) with another letter. The three alternative RAN tasks were designed to increase visual confusion (*q* for *o*), phonological confusion (*v* for *o*), or the combination of visual and phonological confusion (*b* for *o*). The results suggest that (a) substituting a letter that was visually similar to other letters within the Denckla and Rudel letter matrix had the greatest influence on RAN speed and accuracy performance, (b) substitutions that increased the phonological similarity of letters in the matrix predicted more unique variance in future word identification skill, (c) RAN accuracy performance as a predictor of future word identification skill provided little unique variance beyond that associated with RAN speed performance, and (d) RAN predicted significant variance in future word identification skill beyond that associated with the autoregressor in children who were at the earliest stages of reading development.

As early as first grade, individual differences in children's word identification skills act as a significant predictor of future reading performance (Foorman, Francis, Shaywitz, Shaywitz, & Fletcher, 1997; Juel, 1988; Stanovich, 1986; Wagner et al., 1997). Considering the substantial influence that early word identification skill has on future reading achievement, it is not surprising that a great deal of attention has been directed toward identifying factors that lead to individual differences in this skill during first grade (e.g., Adams, 1990; Snow, Burns, & Griffin, 1998). Overwhelming evidence now indicates that phonological processing abilities play a critical role in supporting the acquisition of early word reading skills (e.g., Adams, 1990; Brady & Shankweiler, 1991). It is equally well established that severe disruptions in phonological processes are a primary cause of early reading failure (Bradley & Bryant, 1983; Felton & Brown, 1990; Olson, Wise, Conners, Rack, & Fulker, 1989; Shankweiler & Liberman, 1989; Share, 1995; Siegel & Ryan, 1988; Stanovich, 1988, 1992; Torgesen, Wagner, & Rashotte, 1994; Vellutino & Scanlon, 1987; Wagner & Torgesen, 1987).

In addition to phonological processing abilities, rapid automatized naming (RAN) performance has been identified as an independent source of variance in predicting concurrent and future reading achievement in developing readers and children who are poor readers (Ackerman & Dykman, 1993; Blachman, 1984; Bowers, 1995; Compton, 2000; Felton & Brown, 1990; Manis, Seidenberg, & Doi, 1999; McBride-Chang & Manis, 1996; Meyer, Wood, Hart, & Felton, 1998a, 1998b; Scarborough, 1998; Vellutino et al., 1996; Wagner, Torgesen, & Rashotte, 1994; Wolf, 1986, 1991; Wolf, Bally, & Morris, 1986; Wolff, Michel, & Ovrut, 1990). For instance, RAN performance assessed in the beginning of first grade has been reported to be a unique predictor of later reading skill in samples of typically developing readers (e.g., Compton, 2000; Manis et al., 1999; Schatschneider, Francis, Fletcher, & Foorman, 2002). Similarly, RAN performance has been reported to be a unique predictor of word identification development in both children who are at risk of developing reading disabilities and children with diagnosed reading disabilities (e.g., Ackerman & Dykman, 1993; Badian, 1994, 1995; Berninger, Abbott, Thomson, & Raskind, 2001; Compton, Davis, DeFries, Gayan, & Olson, 2001; Compton, DeFries, & Olson, 2001; Compton, Olson, DeFries, & Pennington, 2002; Davis, Knopik, Olson, Wadsworth, & DeFries, 2001; McBride-Chang & Manis, 1996; Meyer et al., 1998b).

The RAN task involves the rapid naming of a visual array of 50 items, consisting of five symbols within a given category (e.g., the letters *a, d, o, p, s*) that are presented 10 times each in random order over five rows (Denckla & Rudel, 1976). Performance is represented as a latency score corresponding to the total time necessary to name all 50 items, without regard for error rate. The relation between RAN and word-level

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reading skill seems to vary on at least two dimensions. The first is the particular word-level reading skill being assessed. For instance, RAN has consistently been shown to be a more potent predictor (both concurrent and prospectively) of word identification skill compared to nonword reading skill in both typically developing children and children who are poor readers (for a review, see Manis et al., 1999). The second dimension is the category of symbols used to construct the RAN task (i.e., letter, numbers, colors, objects). Studies investigating the relationship between reading skill and various symbol categories (e.g., Meyer et al., 1998a; Wolf et al., 1986) have reported that serial naming of alphanumeric symbols (i.e., letters and numbers) is more closely associated with reading development than is serial naming of nonalphanumeric symbols (i.e., colors and objects). The alphanumeric advantage develops and differentiates as a predictor of reading skill only after children begin to demonstrate automatic processing of letters and numbers (Meyer et al., 1998a). For instance, Wolf et al. reported that naming speeds for all stimulus categories in kindergarten were significantly related to future reading performance in second grade; however, only rapid naming of alphanumeric symbols concurrently predicted reading skill in second grade. Furthermore, differences between good and poor readers tend to be stronger for alphanumeric stimuli than for nonalphanumeric stimuli (Bowers, Steffy, & Tate, 1988; Felton & Brown, 1990; Murphy, Pollatsek, & Well, 1988; Wolf, 1999; Wolf et al., 1986). These results imply the existence of a unique association between serial naming speed of alphanumeric symbols (in particular letters) and word identification skill development.

Although differences in the RAN–word identification relationship have been examined across various alphanumeric and nonalphanumeric symbol sets, little is currently known about what effect variations in item composition within a given symbol category set might have on naming speed performance and the RAN–word identification relationship. For example, it is unknown whether the RAN measure developed by Denckla and Rudel (1976) that uses the letters *a, d, o, p,* and *s* and the Rapid Naming subtest of the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999) that uses the letters *a, t, s, k, c,* and *n* are equivalent in predicting future reading skill in developing readers. Compton et al. (2002) found that two versions of alphanumeric naming speed differed significantly as predictors of performance on word-level reading skills. Differences in item composition, item layout, and administrative procedures across the two tasks made it impossible for Compton et al. to isolate the reason for differences in the RAN–word-level reading relationship across the rapid naming tasks. Unfortunately, in addition to differences in item composition, the RAN task and the Rapid Naming subtest differ in physical layout of the items, making direct comparisons across the two tasks difficult. What is needed is a study that systematically varies item composition on the RAN task, while keeping all else constant, to investigate the effect on naming speed and the RAN-reading relationship.

This study investigated whether systematic substitutions of letters into the Denckla and Rudel (1976) RAN task would affect naming speed and the relationship with future reading skill in first-grade children. Four basic questions about the influence of letter composition on RAN task performance were addressed.

Question 1 was simply whether making a letter substitution within the RAN letter array would alter naming speed and accuracy on the RAN task. To accomplish this, I modified the Denckla and Rudel RAN letter naming task (consisting of the letters *a, d, o, p,* and *s*) by using a single substitution procedure that replaced the letter *o* within the array with another letter. This substitution procedure was used to construct three alternative RAN tasks designed to do the following:

1. increase visual confusion within the letter array (i.e., substituting *q* for *o,* because *q* is visually similar to *d* and *p*),
2. increase phonological confusion by adding a letter that rhymed with other letters in the array (substituting *v* for *o,* because the letter name *v* rhymes with *d* and *p*), or
3. increase both by substituting a letter that was both visually and phonological confusing (substituting *b* for *o,* because *b* is visually similar to and rhymes with *d* and *p*).

Studies using a priming paradigm to examine letter naming processes (e.g., Arguin & Bub, 1995) have reported slower naming times when target letters are primed with letters that are visually similar and no effect when target letters are primed with a phonetically similar letter (i.e., a letter name that rhymes with the target letter name). These priming results suggest that visually confusing substitutions should negatively affect RAN performance more than phonological substitutions. It is unclear, however, whether these substitution patterns relate in any way to reading development.

Question 2 was whether differences in naming speed across the four RAN tasks (i.e., the original and three altered forms) assessed at the beginning of first grade would differentially predict unique variance in word identification at the end of first grade. To accomplish this, I used an extension of multiple regression analysis known as dominance analysis to make pairwise comparisons among all of the RAN tasks as they relate to future word identification skill (Budescu, 1993; Schatschneider et al., 2002). These pairwise comparisons were not a test of the amount of unique variance each predictor contributes but instead were a direct comparison of the differing amounts of unique variance attributed to the two predictors as they relate to a criterion. In this study, dominance analysis was used to test whether any of the four RAN tasks differentially predicted more unique variance in future word identification skill compared to the other three RAN measures.

Question 3 was whether including error rates on the RAN task would increase the power of RAN to predict future reading performance beyond that accounted for by the latency measure. Although the RAN task has been conceptualized as a measure tapping an individual's ability to access the phonological representations of overlearned stimuli from long-term memory—therefore, errors on the task should be infrequent—first-grade children frequently make errors on the RAN letter naming task. These errors occur even if children are 100% accurate at identifying the letters contained in the matrix. For instance, Vellutino et al. (1996) reported an error rate of approximately 2% on the RAN letters task in children assessed in the fall of first grade. The error rate was above 4% for the first-grade children with the poorest reading skills. Likewise, in Stanovich's (1981) study of first-grade children, Stanovich reported error rates of approximately 4% on a confrontational naming task of letters, with the majority of the errors being made by the less-skilled readers. The question then is whether errors slow down performance on RAN and therefore are represented in the overall latency score, or whether error rates on RAN are somehow disassociated from the latency measure and perhaps tap a different aspect of phonological representational quality associated with reading. This latter explanation might allow accuracy rates to correlate with future reading skill somewhat independently of naming speed. Multiple regression analysis was used to test this relationship by examining the amount of variance in future word identification skill explained by RAN accuracy after accounting for the influence of RAN speed. Separate analyses were conducted for each RAN task using the entire sample of children and the subsample of children considered at-risk for developing reading problems.

Finally, previous studies have reported higher concurrent correlations between RAN and word-reading skills in children with poor reading skills compared to age-matched (e.g., McBride-Chang & Manis, 1996) and reading-age–matched typically achieving peers (e.g., Compton, Davis, et al., 2001; Davis et al., 2001; Meyer et al., 1998a). RAN performance has also been shown to be a significant predictor of future reading skills, above and beyond the effects of intelligence and phonological processing skill, in children with poor reading skills (e.g., Badian, 1993; Cornwall, 1992; Felton & Brown, 1990; Manis et al., 1999; Meyer et al., 1998a; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997). However, it is well known that reading ability itself is the best predictor of future reading skill (see Scarborough, 1998), and only a portion of these prospective studies controlled for reading skill at the initial assessment wave (known as the *autoregressor*). Thus, Question 4 addressed the extent to which performance on the four RAN tasks accounted for variance in end-of-the-year word identification skill after controlling for beginning-of-the-year word identification skill. Separate analyses were again conducted using the entire sample of children and the subsample of children considered at-risk for developing reading problems.

Method

Participants

First-grade children from 33 different classrooms located in eight schools in the Nashville metropolitan area were recruited. Parental consent letters were distributed to all children in the 33 classrooms, and children who returned signed forms (n = 528) were screened to identify 16 students per classroom as study participants. First, scores were inspected for the entire classroom on a screening measure of rapid letter naming administered in October. The rapid letter naming task asked children to name as many letters from an array of 52 letters as possible in 1 minute. The array consisted of each letter of the alphabet listed twice, once in lower case and once in upper case, displayed in random order on a sheet of paper. Performance was rated by the number of letters named correctly in 1 minute (prorated if the child finished before the minute ended). In each classroom, the children's performance on the rapid letter naming task was rank ordered. Using this ranking as a proxy of early reading skill, 8 low-reading, 4 average-reading, and 4 high-reading children were designated in each of the 33 classrooms. This sampling procedure was designed to oversample children at-risk for developing reading problems while also selecting a representative sample of typically achieving children. For corroboration purposes, project staff then showed teachers the list of children in their classroom classified as low, average, and high achieving in reading. Generally, the classification of children into the three groups corresponded with the teachers' estimates. If a teacher disagreed with a designation, the child was eliminated as a target and replaced by the child with the next closest rapid letter naming score. The children in the low target group were designated as children at risk for developing reading problems. The children in the average and high groups were designated as typically achieving. Of the 528 children initially assessed in October, 497 were still available for testing in April.

To assess a participant's familiarity with the letter names that made up the four RAN tasks, each child was asked to provide the name of each of the eight letters used to construct the RAN tasks (i.e., *a, d, b, p, s, q, o, v*). Children who were not able to accurately name the eight letters were removed from the data analysis. Following this, the children were presented with a card containing a matrix of 20 letters in two rows that contained a random assortment of the eight letters, constructed in the same way as the RAN tasks. They were instructed to name each item from left to right as quickly as possible. Children who made more than 25% errors on this practice task were also removed from the data analysis. This procedure was used to remove children from the analyses who did not know their letter names well enough to ensure that the task was really a rapid naming task of overlearned knowledge.

Of the original 497 children who were tested at both pretest and posttest, data from four classrooms (56 children) were removed from analysis because the children in these classrooms were only administered one RAN measure. An additional 58 children were removed from the data analysis because they (a) were unable to accurately name the eight letters that were used to construct the four different RAN tasks or (b) missed more than 25% of the items on the 20-item practice test. This left 383 children as study participants. The mean age among these children was 5.8 years (*SD* = .43); 53.5% were boys; and 30% were African American, 48% were Caucasian, and the remaining 22% were primarily Asian or Hispanic. A total of 166 of these 383 children were rated as being at risk for reading difficulties.

Procedure

Each child was individually administered a battery of tests in October and April of first grade. Results reported in this study represent a small portion of the data collected on these children during the course of the yearlong study.

Measures

Rapid Automatized Naming. The children were administered four versions of the RAN letter task. Each RAN measure involved the rapid naming of a visual array of 50 items, consisting of five letters presented 10 times in random order in rows of 10 items each. The RAN task that formed the basis of the three alternative versions of RAN was designed by Denckla and Rudel (1976) and used the letters *a, d, o, p,* and *s* (RANDR). The three alternative RAN tasks were constructed using a single substitution procedure that replaced the letter *o* within the RAN array with another letter. This substitution procedure was used to construct tasks that were intended to (a) increase visual confusion (RANV) by adding a letter that looked similar to other letters in the array (i.e., substituting *q* for *o,* because it is visually similar to *d* and *p*), (b) increase phonological confusion by adding a letter that rhymed (RANR) with other letters in the array (substituting *v* for *o,* because it rhymes with *d* and *p*), or increase both (RANVR) by substituting a letter that was both visually and phonological confusing (substituting *b* for *o,* because it is visually similar to and rhymes with *d* and *p*) within the letter array (see the appendix for each RAN task stimulus). Letter order within each line was retained throughout all four RAN tasks; however, line order was changed by rotating lines down one position, with the last row being brought to the top in each successive RAN task. This was done to avoid practice effects for the initial items over the course of administering the four RAN tasks. The letter matrix for each of the RAN tasks was presented to the children on a separate piece of 8½" × 11" white paper (the 11" side of the paper representing the horizontal edge), with letters printed in 28-point Century Gothic font. Century Gothic was chosen because the letter a in this font is most consistent with the letter formation taught in the first-grade classrooms (i.e., a). Individual letters were separated from adjacent letters on all four sides by a space of 2 mm.

The four RAN tasks were then administered in random order to each child. The child's errors were noted on the scoring sheet, with self-corrections scored as correct responses. Error rates were converted into accuracy rates (number named correctly). The latency score was the total time necessary to name all items. To reduce the skew in the data, latency performance was converted into a speed score (items named per second). The test–retest reliability of the Denckla and Rudel RAN measure has been estimated at .88 in first-grade children (Blachman, 1984).

Word Recognition. The children's ability to recognize words in isolation was assessed using the *Woodcock Reading Mastery Test–Revised Form G* (WRMT–R, Woodcock, 1987). The WRMT-R is a nationally normed, individually administered test that contains six measures of reading skill. The Word Identification subtest consists of 106 words arranged in order of increasing difficulty. Each child was instructed to read each word orally until he or she made six consecutive errors or attempted all words, whichever came first. Split-half reliability in first-grade children has been reported as .98.

Results and Discussion

Distributions for each of the variables are displayed in Figure 1. For the RAN speed measures, higher scores represent faster item naming speed. The distribution of RAN speed scores was fairly normal. As expected, naming accuracy scores were negatively skewed, with the majority of the children accurately naming 48 or more letters correctly. Slight floor effects were present on the pretest measure of word identification skill. The distribution of posttest word identification scores was normally distributed.

Intercorrelations, means, and standard deviations for the variables are presented in Table 1. All correlations were significant ($p < .001$). The correlation between naming speed on the four RAN tasks ranged from .75 to .87 and between .64 and .77 for naming accuracy. The correlations between RAN speed and accuracy were modest, ranging from .27 to .38. The correlations between the four RAN speed measures and word identification skill each exceeded .50 for both pre- and posttest measures of word identification. The correlations between RAN accuracy and word identification skill were more modest, none of which exceeded .40. Finally, the overall stability of word identification skill from pretest to posttest was high at .80. Transforming the RAN accuracy scores (i.e., reflect and logarithm transformations) and the pretest word identification scores (i.e., logarithm transformation) to reduce the skew in the distributions (Tabachnick & Fidell, 1989) had negligible effects on the correlations between variables; therefore, raw scores were used.

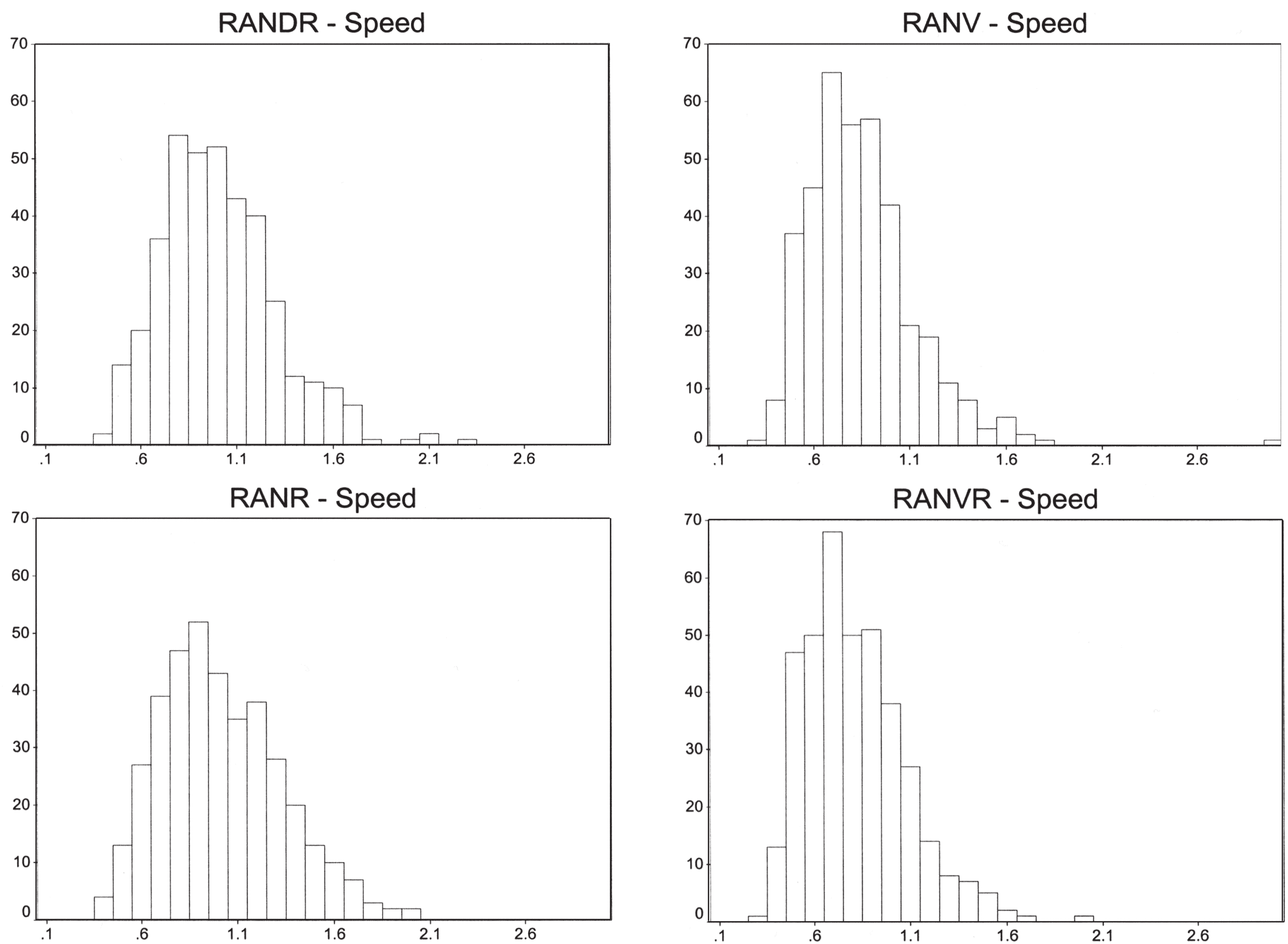

FIGURE 1. Distribution of scores for the experimental measures. RANDR = original Denckla & Rudel (1976) RAN task; RANV = visually confusable substitution; RANR = rhyming substitution; RANVR = visually confusable and rhyming substitution.

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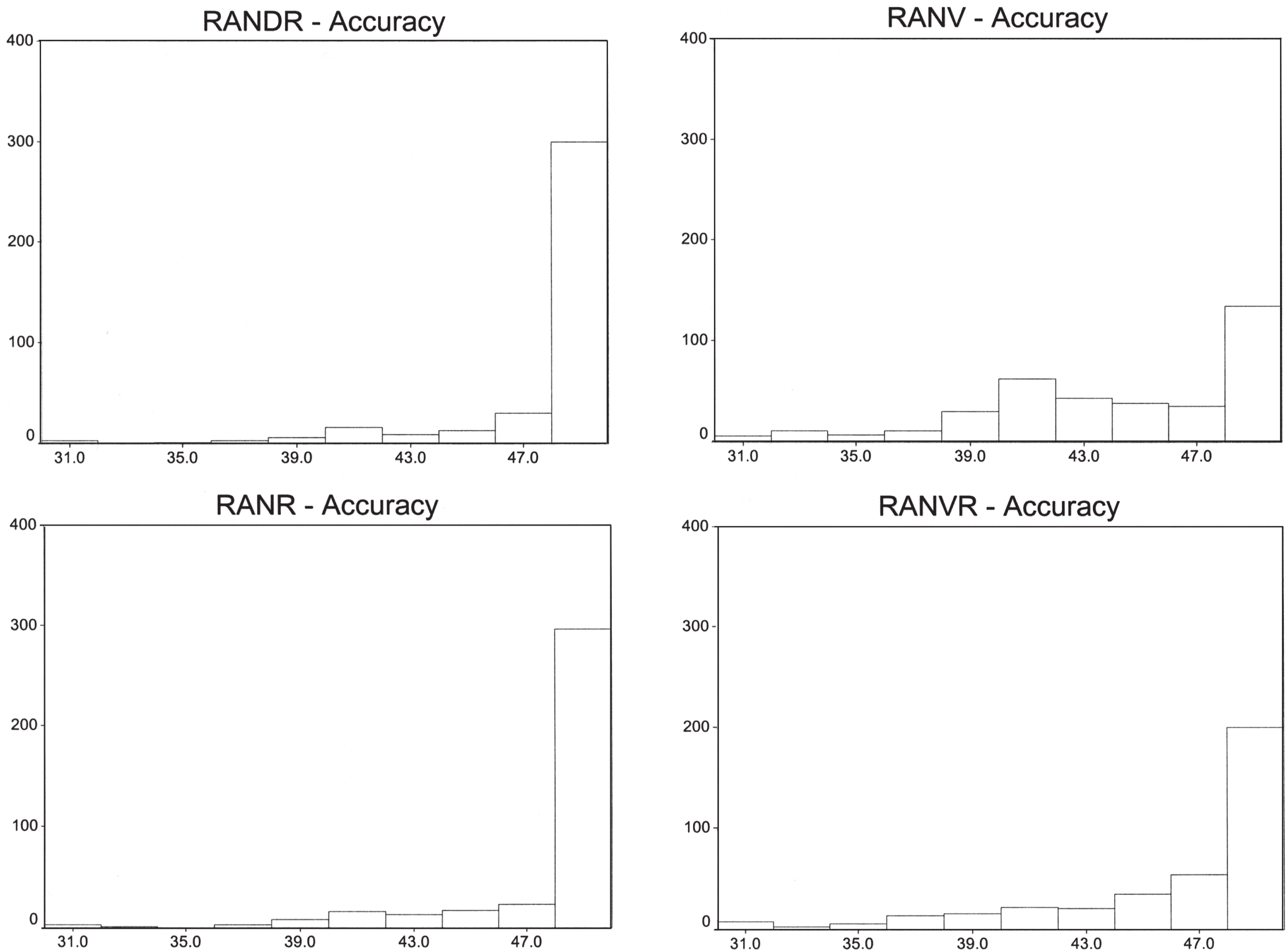

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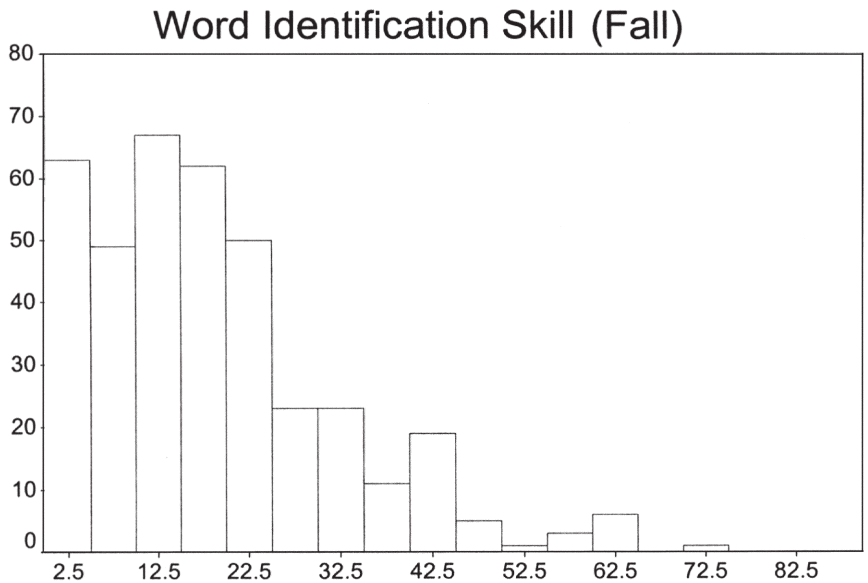

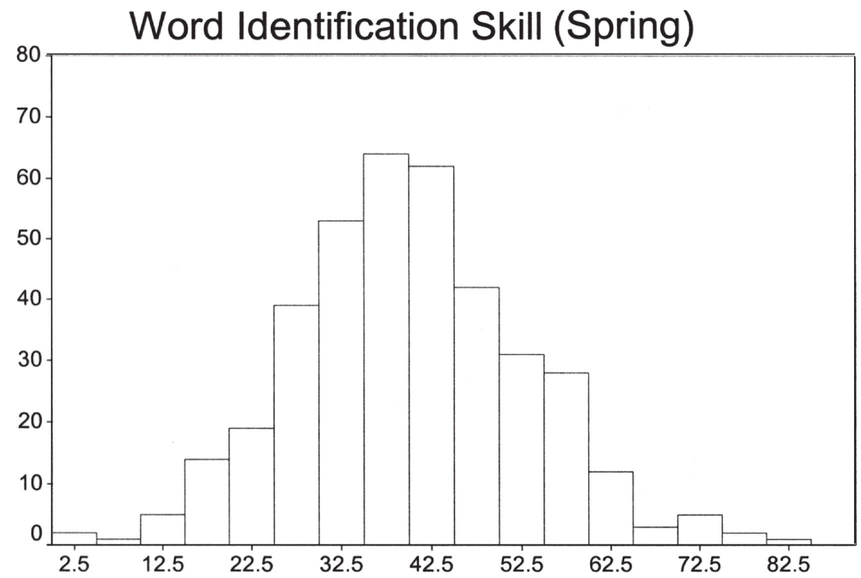

TABLE 1. Intercorrelations, Means, and Standard Deviations for the Experimental Measures

Measure	1	2	3	4	5	6	7	8	9	10
1. RANDR–Speed	—									
2. RANV–Speed	.77	—								
3. RANR–Speed	.87	.75	—							
4. RANVR–Speed	.85	.78	.84	—						
5. RANDR–Accuracy	.37	.29	.34	.27	—					
6. RANV–Accuracy	.36	.32	.38	.34	.74	—				
7. RANR–Accuracy	.35	.27	.36	.28	.77	.64	—			
8. RANVR–Accuracy	.36	.30	.34	.30	.64	.64	.73	—		
9. Fall Word ID	.64	.59	.64	.66	.29	.39	.30	.32	—	
10. Spring Word ID	.61	.54	.62	.62	.25	.35	.28	.31	.80	—
M	.96	.80	.96	.76	47.99	43.64	47.73	45.64	17.99	39.66
SD	.30	.28	.32	.26	4.06	5.98	4.43	5.48	13.71	12.82

Note. RANDR = original Denckla & Rudel (1976) RAN task; RANV = visually confusable substitution; RANR = rhyming substitution; RANVR = visually confusable and rhyming substitution. All correlations were significant at the $p < .001$ level.

Mean comparisons between the typically achieving children and the children at risk for developing reading problems revealed significant differences ($p < .001$) on all of the experimental measures (t values ranged from 4.49 to 13.12, $df = 381$). Compared to typically developing readers, the children at risk for developing reading problems were slower to name letters on the rapid letter naming task; slower and less accurate at naming letters on each of the RAN tasks; and less accurate at identifying words in isolation.

The Influence of Letter Composition on RAN Performance

A one-way ANOVA with repeated measures was used to examine the within-subjects effect of varying letter composition on RAN performance. The within-subjects factor had four levels representing the four RAN tasks. Separate analyses were conducted for the speed and accuracy scores. The effect of letter composition was significant for speed, $F(3, 1140) = 250.19$, $p < .001$, and accuracy, $F(3, 1140) = 185.81$, $p < .001$. Figure 2 displays naming speed performance (upper portion) and naming speed accuracy (lower portion) for each RAN task (with 95% confidence intervals). The plots indicate that speed and accuracy performance on the RANR task was quite similar to performance on the RANDR task. This result suggests that increasing phonological confusion on the RAN task by introducing a letter that rhymes with the letters *d* and *p* in the letter matrix has little effect on naming performance.

By contrast, the plots indicate that adding a letter that was visually confusable (i.e., substituting *q* for *o*) with the *d* and *p* in the letter matrix slowed naming speed and decreased naming accuracy on the RAN task. Adding a letter that both rhymed with *d* and *p* and was visually confusing (i.e., substituting *b* for *o*) improved letter naming accuracy slightly compared to simply adding a visually similar letter. Finally, adding a rhyming and visually confusing letter did not affect naming speed performance any more than simply adding a visually confusing letter. Overall, results indicate that RAN naming speed and accuracy can be significantly affected by simple letter substitutions. Furthermore, these results suggest that changes in naming speed and accuracy across the three alternative RAN tasks were functions of visual similarity of the letter substituted compared to the other letters in the matrix, with no appreciable influence of phonological similarity. These results are congruous with priming studies that have reported (a) increased naming times when target letters were primed with visually similar letters and (b) no effect when the target letter was primed with a phonetically similar letter (e.g., Arguin & Bub, 1995).

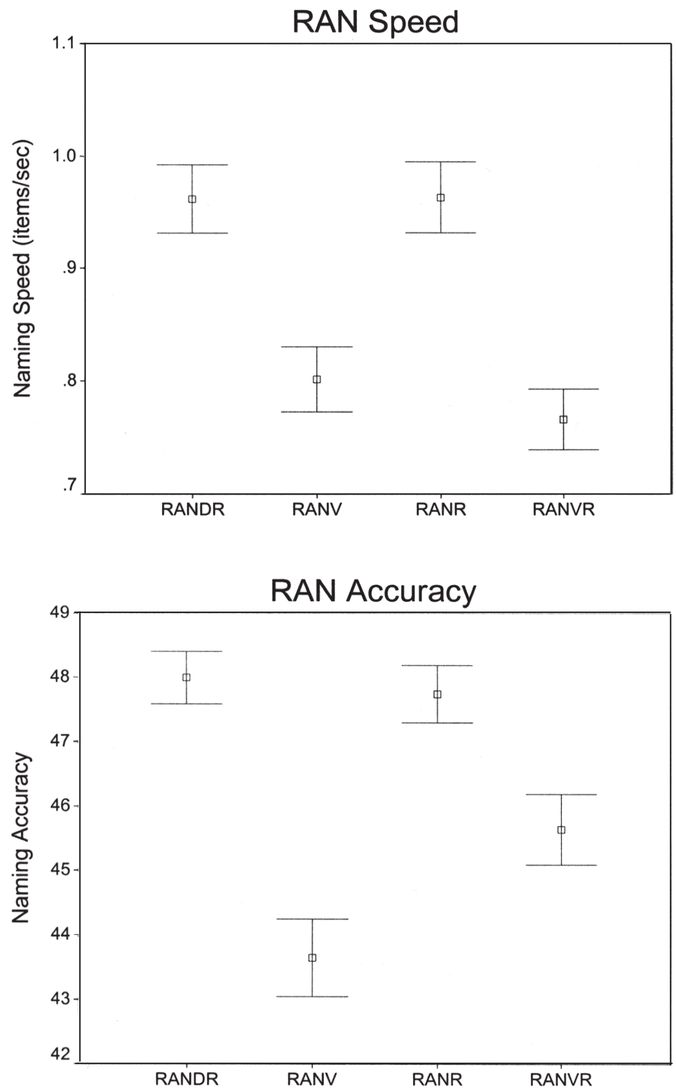

FIGURE 2. Mean speed and accuracy performance on the four RAN tasks (error bars represent 95% confidence intervals). RANDR = original Denckla & Rudel (1976) RAN task; RANV = visually confusable substitution; RANR = rhyming substitution; RANVR = visually confusable and rhyming substitution.

RAN–Word Identification Relationships

Having established that RAN letter naming can be influenced by letter substitutions, the next step was to determine if differences in naming speed across the four RAN tasks assessed at the beginning of first grade would differentially predict variance in word identification at the end of first grade. Dominance analysis was performed on the measure of word identification to statistically compare the unique effects of the four RAN tasks as predictors of end-of-the-year word-level reading skill. Dominance analysis is an extension of multiple regression that involves the pairwise comparison of all predictors as they relate to a criterion (Budescu, 1993). A variable is considered dominant over another if the predictive ability of that variable exceeds the other, both alone, and in the presence of all other predictors in the model. Dominance analysis uses asymptotic confidence limits to test differences in the unique effects among pairwise comparisons. These pairwise comparisons are not a test of the amount of unique variance each predictor contributes but instead are direct comparisons of the differing amounts of unique variance attributed to the two predictors as they relate to a criterion. In this study, dominance analysis was used to test whether any one of the four RAN tasks differentially predicted more unique variance in future word identification skill compared to the other three RAN measures. Results of these analyses are presented separately for naming speed and accuracy in Tables 2 through 5.

Tables 2 and 4 present the results of all possible subsets of the regression model using the four different predictor variables. The first column identifies the variables in each submodel, and the second column describes the fit of that model. The next four columns (one for each predictor) describe the increase in the model's fit (expressed as ΔR^2) as a result of the addition of that particular variable. For example in Table 2, the first row describes the increase in goodness of fit of the null model associated with addition of each variable, and the second row describes the degree to which a model consisting of RANDR is improved by adding to it one of the additional RAN measures. In the speed models, adding RANV to a model consisting of RANDR accounted for an additional 1% variance, RANR an additional 3% variance, and RANVR an additional 4% variance.

Tables 3 and 5 summarize the calculation of asymptotic confidence intervals for all six pairs of predictors. The first column lists the names of the variables being compared. The second column presents the difference between the relevant squared multiple correlations, the third column presents the standard errors of the differences, and the last two columns show the lower and upper bounds of the 95% asymptotic confidence intervals (using the approach outlined by Budescu, 1993, and Hedges & Olkin, 1981). Any confidence interval that does not include zero implies that the difference in unique variances was significant at an alpha level of .05 (Budescu). For example, in Table 3, the first row compares the unique variance that RANDR accounted for above and beyond RANV (9%) to the unique variance that RANV accounted for independently of RANDR (1%). The difference in unique variance between these two variables was 8%. The confidence interval does not cross zero (.017 to .139), indicating that RANDR accounted for significantly more unique variance in future word identification skill compared to RANV.

Results of RAN speed measures indicate that the four measures of RAN collectively accounted for 43% of the variance in word identification skill, with each RAN task independently accounting for between 30% and 39% of the variance. The results reveal that RANR and RANVR each contributed

TABLE 2. Dominance Analysis Predicting First-Grade Word Identification Skill in Spring Using Different RAN Measures (Speed) Assessed in the Fall

Predictor	R^2	Unique contribution			
		RANDR	RANV	RANR	RANVR
		.38	.30	.39	.39
RANDR	.38	—	.01**	.03**	.04**
RANV	.30	.09**	—	.10**	.10**
RANR	.39	.02**	.01**	—	.03*
RANVR	.39	.03**	.01**	.04**	—
RANDR, RANV	.39	—	—	.03**	.03**
RANDR, RANR	.41	—	.01**	—	.02**
RANDR, RANVR	.41	—	.00	.01**	—
RANV, RANR	.40	.01**	—	—	.02**
RANV, RANVR	.40	.02**	—	.03**	—
RANR, RANVR	.42	.01**	.00	—	—
RANDR, RANV, RANR	.42	—	—	—	.01**
RANDR, RANV, RANVR	.42	—	—	.01**	—
RANDR, RANR, RANVR	.43	—	.00	—	—
RANV, RANR, RANVR	.42	.00	—	—	—
ALL	.43	.11	.08	.12	.12

Note. RANDR = original Denckla & Rudel (1976) RAN task; RANV = visually confusable substitution; RANR = rhyming substitution; RANVR = visually confusable and rhyming substitution.
$^{**}p < .01$.

TABLE 3. Asymptotic 95% Confidence Interval for Pairwise Differences for Speed

Variables compared	R^2 Diff	Asymptotic *SE*	95% Confidence interval	
			Lower	Upper
RANDR–RANV	.08	.031	.017	.139
RANDR–RANR	–.01	.025	–.061	.036
RANDR–RANVR	–.01	.017	–.044	.024
RANV–RANR	–.09	.033	–.155	–.025
RANV–RANVR	–.09	.031	–.149	–.027
RANR–RANVR	.00	.028	–.052	.057

Note. RANDR = original Denckla & Rudel (1976) RAN task; RANV = visually confusable substitution; RANR = rhyming substitution; RANVR = visually confusable and rhyming substitution.

TABLE 4. Dominance Analysis Predicting First-Grade Word Identification Skill in Spring Using Different RAN Measures (Accuracy) Assessed in the Fall

Predictor	R^2	Unique contribution			
		RANDR	RANV	RANR	RANVR
		.06	.12	.08	.09
RANDR	.06	—	.06*	.02*	.03*
RANV	.12	.00	—	.01*	.01*
RANR	.08	.00	.05*	—	.02*
RANVR	.09	.01*	.04*	.01*	—
RANDR, RANV	.12	—	—	.01*	.01*
RANDR, RANR	.08	—	.05*	—	.02*
RANDR, RANVR	.09	—	.04*	.00	—
RANV, RANR	.14	.00	—	—	.00
RANV, RANVR	.13	.00	—	.00	—
RANR, RANVR	.10	.00	.04*	—	—
RANDR, RANV, RANR	.14	—	—	—	.00
RANDR, RANV, RANVR	.14	—	—	.00	—
RANDR, RANR, RANVR	.10	—	.04*	—	—
RANV, RANR, RANVR	.14	.00	—	—	—
ALL	.14	.02	.07	.03	.03

Note. RANDR = original Denckla & Rudel (1976) RAN task; RANV = visually confusable substitution; RANR = rhyming substitution; RANVR = visually confusable and rhyming substitution.
$^*p < .05$.

significant unique variance to word recognition skill, regardless of the combination of other RAN tasks in the model. The asymptotic confidence intervals indicate that RANDR, RANR, and RANVR each predicted significantly more unique variance in word identification skill compared to RANV. Interestingly, substituting a visually confusing letter into the matrix had the greatest effect the on speed of item naming, but this variation in speed was not uniquely associated with individual differences in word reading skill development. In contrast, differences in naming speed associated with rhyming letter substitutions (i.e., RANR and RANVR) were uniquely associated with word identification skill variance beyond that associated with RANV. The predictive advantage of RANVR over RANV suggests that this variation in the predictive power between the two RAN tasks is probably phonological rather than visual.

TABLE 5. Asymptotic 95% Confidence Interval for Pairwise Differences for Accuracy

			95% confidence interval	
Variables compared	R^2 Diff	Asymptotic *SE*	Lower	Upper
RANDR–RANV	–.06	.022	–.105	–.020
RANDR–RANR	–.02	.018	–.055	.016
RANDR–RANVR	–.03	.024	–.073	.020
RANV–RANR	.04	.026	–.008	.094
RANV–RANVR	.04	.026	–.016	.088
RANR–RANVR	–.01	.021	–.048	.034

Note. RANDR = original Denckla & Rudel (1976) RAN task; RANV = visually confusable substitution; RANR = rhyming substitution; RANVR = visually confusable and rhyming substitution.

Tables 4 and 5 present results of using the four RAN accuracy measures as predictors of word identification skill. The measures of RAN accuracy independently accounted for between 6% and 12% of the variance in end-of-the-year word identification skill, and the four measures collectively explained 14% of the variance. In contrast to the results of the speed measures, RANV contributed a significant unique variance to word recognition skill, regardless of the combination of the other RAN tasks in the model. The asymptotic confidence intervals indicated that RANV predicted significantly more unique variance in word identification skill compared to RANDR. This result is in the opposite direction of the RAN speed measures and does not support a purely phonologically based explanation of the differential relationships between the four RAN measures and word identification skill. However, given that RAN speed measures predicted between two and four times more word identification variance than did the RAN accuracy measures, conclusions regarding the effect of substitutions on the RAN–word reading relationship will focus primarily on RAN speed measures.

The results of the dominance analysis indicated that letter substitutions do affect the predictive relationship between RAN and future word identification skill in first-grade children. Substitution patterns that increased the phonological similarity between letters in the matrix were associated with greater unique variance accounted for between RAN speed and word identification skill. These results seem to suggest that simply slowing the RAN task performance by increasing the visual similarity of items is not related to reading performance. Instead, it appears that individual differences in naming speed on the RAN task containing a higher proportion of rhyming letters were associated more strongly with individual differences in future word reading performance. These results suggest at least a partial disassociation between the effects of visual and phonological related factors on the speed of naming and the RAN–word reading relationship. Furthermore, results seem to suggest that manipulating phonological factors related to the RAN task will have a greater effect on the RAN–reading relationship compared to manipulating visual factors related to RAN.

RAN Accuracy as a Predictor of Word Identification

The distinction between the predictive properties of letter substitutions across speed and accuracy measures is noteworthy only if RAN accuracy predicts variance in future word identification skill beyond that associated with RAN speed and the autoregessor. Multiple regression analysis was used to assess this—specifically, the amount of variance. Separate analyses were conducted for each RAN task using the entire sample of children and the subsample of children considered at risk for developing reading problems. Presented in Table 6 are results of regression models for the different RAN tasks. The first two rows of each model evaluate the unique variance in word identification skill associated with RAN accuracy skill after removing the effect of RAN speed. In each of these regression models, RAN speed was entered first, followed by RAN accuracy, with the increase in the model's fit expressed as ΔR^2. The next three rows in each of the regression models represent the same analyses with the autoregessor entered before either the RAN speed or accuracy measures. This last set of analyses was intended to assess the extent to which performance on the four RAN tasks accounted for variance in end-of-the-year word identification skill after controlling for beginning-of-the-year word identification skill.

The results revealed three important trends. The first is the general tendency of RAN to predict more variance in word identification skill in the entire sample compared to the subsample of children at risk for developing reading problems. This decrease in the predictive power of RAN in the smaller sample was likely due to a restriction of range in the word identification skill within this group of children at the end of first grade. The second trend is that RAN accuracy added very little unique variance beyond that accounted for by RAN speed in the children at risk for developing reading problems.

TABLE 6. Variance in Word Identification Skill in Spring as Predicted by RAN Speed and Accuracy Assessed in the Fall

	Total sample				At-risk sample			
Predictor	*B*	*SE B*	ß	ΔR^2	*B*	*SE B*	ß	ΔR^2
Model 1–RANDR								
1. RANDR Speed	25.61	1.84	.61	.38*	20.40	3.55	.44	.18*
2. RANDR Accuracy	.09	.14	.03	.00	–.09	.15	–.05	.00
1. Autoregressor	.65	.04	.70	.64*	.61	.10	.44	.28*
2. RANDR Speed	7.22	1.72	.17	.02*	11.78	3.50	.26	.04*
3. RANDR Accuracy	–.05	.10	–.01	.00	–.18	.14	–.09	.01
Model 2–RANV								
1. RANV Speed	21.90	1.99	.49	.30*	12.80	2.95	.32	.11*
2. RANV Accuracy	.42	.10	.19	.04*	.15	.11	.10	.01
1. Autoregressor	.68	.04	.73	.64*	.65	.10	.47	.28*
2. RANV Speed	4.76	1.72	.11	.01*	6.88	2.77	.17	.03*
3. RANV Accuracy	.08	.07	.04	.00	.02	.10	.01	.00
Model 3–RANR								
1. RANR Speed	24.53	1.75	.60	.39*	23.21	3.37	.50	.25*
2. RANR Accuracy	.19	.13	.06	.00	.03	.13	.01	.00
1. Autoregressor	.64	.04	.68	.64*	.53	.10	.38	.28*
2. RANR Speed	7.61	1.63	.19	.02*	15.28	3.46	.33	.08*
3. RANR Accuracy	.03	.09	.01	.00	–.07	.12	–.04	.00
Model 4–RANVR								
1. RANVR Speed	28.42	2.01	.59	.39*	21.11	3.91	.39	.17*
2. RANVR Accuracy	.29	.10	.12	.02*	.18	.12	.11	.01
1. Autoregressor	.64	.04	.69	.64*	.60	.10	.43	.28*
2. RANVR Speed	7.49	1.97	.16	.02*	12.09	3.86	.22	.04*
3. RANVR Accuracy	.08	.08	.03	.00	.07	.11	.04	.00

Note. RANDR = RANDR = original Denckla & Rudel (1976) RAN task; RANV = visually confusable substitution; RANR = rhyming substitution; RANVR = visually confusable and rhyming substitution. Total $N = 383$; at-risk $n = 166$.
*$p < .05$.

By contrast, in the total sample, accuracy on the three alternative RAN forms did contribute between 2% and 4% of the unique variance in word identification skill beyond that accounted for by RAN speed. This variance associated with RAN accuracy was no longer unique, however, once the autoregressor was added as a predictor to the regression models. This seems to support a model in which accuracy and speed do not disassociate as predictors of future word identification skill, and it thus suggests that once children have been prescreened for letter knowledge, there is little need to collect accuracy rates. Finally, the amount of unique variance accounted for by RAN speed beyond the effects of the autoregressor was relatively larger in the sample of children at risk for developing reading problems. This increase in the role of RAN in predicting future reading skill in this subsample probably was due to these children's limited range of word identification skills at the start of the year. This result suggests that RAN may be a better predictor of future word identification skill prior to the onset of reading development in children, after which time the variance in future word identification skill associated with RAN is a common variance shared with the autoregressor.

Conclusions

This study examined four questions regarding the influence of letter composition on RAN task performance and the RAN–word identification skill relationship in first-grade children. The following results were found. First, substituting a letter that was visually similar to the other letters within the Denckla and Rudel (1976) letter matrix had the greatest influence on RAN speed and accuracy performance. Second, the change in RAN performance associated with a visually similar substitution was not uniquely associated with future word identification skill. Instead, letter substitutions that increased the phonological similarities among letters in the matrix predicted unique variance in future word identification skill. Third, adding RAN accuracy scores provided little added predictive power for future word identification skill beyond that associated with RAN speed. Finally, RAN predicted significant variance in future word identification skill beyond that associated with the autoregressor in children who were at the earliest stages of reading development. This was particularly true of the RANR measure. In general, these results confirm the importance of RAN as an early predictor of word identification development and suggest that letter composition represents a third dimension that should be considered when examining RAN–reading relationships.

AUTHOR'S NOTES

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Appendix: Four Versions of the RAN Letter Task

Denckla & Rudel (1976) RAN task

o	a	s	d	p	a	o	s	p	d
s	d	a	p	d	o	a	p	s	o
a	o	s	p	s	d	p	o	d	a
d	a	p	o	d	s	a	s	o	p
s	o	d	p	a	p	o	a	d	s

Visually Confusing

a	q	s	p	s	d	p	q	d	a
d	a	p	q	d	s	a	s	q	p
s	q	d	p	a	p	q	a	d	s
q	a	s	d	p	a	q	s	p	d
s	d	a	p	d	q	a	p	s	q

Phonologically Confusing

d	a	p	v	d	s	a	s	v	p
s	v	d	p	a	p	v	a	d	s
v	a	s	d	p	a	v	s	p	d
s	d	a	p	d	v	a	p	s	v
a	v	s	p	s	d	p	v	d	a

Visually and Phonologically Confusing

s	b	d	p	a	p	b	a	d	s
b	a	s	d	p	a	b	s	p	d
s	d	a	p	d	b	a	p	s	b
a	b	s	p	s	d	p	b	d	a
d	a	p	b	d	s	a	s	b	p