Longitudinal Studies of Phonological Processing and Reading

Joseph K. Torgesen, Richard K. Wagner, and Carol A. Rashotte

One of the most exciting developments in research on reading over the last two decades is the emerging consensus about the importance of phonological processing abilities in the acquisition of early reading skills (Shankweiler & Liberman, 1989; Stanovich, 1988; Wagner & Torgesen, 1987). As the term is used by those who study early reading development, *phonological processing* refers to an individual's mental operations that make use of the phonological or sound structure of oral language when he or she is learning how to decode written language. The last 20 years of research have produced a broad variety of converging evidence that at least three kinds of phonological processing skills are positively related to individual differences in the rate at which beginning reading skills are acquired (see Adams, 1990; Brady & Shankweiler, 1991; Crowder & Wagner, 1991; and Torgesen, 1993, for recent reviews of this work). The kinds of phonological processing skills and knowledge that have been most frequently studied include phonological awareness, phonological memory, and rate of access for phonological information.

Types of Reading-Related Phonological Skill

Phonological awareness is generally defined as one's sensitivity to, or explicit awareness of, the phonological structure of the words in one's language. It is measured by tasks that require children to identify, isolate, or blend the individual phonemes in words. At a beginning level, phonological awareness is frequently assessed by tasks that require sensitivity to rhyme or alliteration. A typical task at this level might involve identifying which of three words begins (or ends) with the same sound as a target word. More difficult measures of phonological awareness require explicit manipulation or separation of the sounds in words. For example, children might be asked to pronounce the first sound of a word in isolation, or they might be asked to indicate the word that is produced if the /l/ sound is deleted from the word *slit*. Usually, children do not attain full development of explicit phonological awareness until reading instruction begins, in first grade, although they can frequently perform quite well on simpler measures of phonological sensitivity in kindergarten.

Children who are relatively strong in phonological awareness in kindergarten, before reading instruction begins, typically learn to read more easily than those with relatively delayed development in this area (Bradley & Bryant, 1985; Byrne, Freebody, & Gates, 1992; Felton & Wood, 1989; Stanovich, Cunningham, & Cramer, 1984). Correlations between performance on phonological awareness tasks in kindergarten and word-reading skills at the end of first grade usually fall within the range of .4 to .6. These empirical relationships are consistent with the idea that some degree of awareness of the phonological structure of words helps to make learning to read words a more understandable task for young children (Liberman, Shankweiler, & Liberman, 1989). Without awareness of the phonological segments in words, our alphabetic system of writing is not very comprehensible. Delayed development of phonological awareness is commonly found in children with developmental reading disabilities (Alexander, Anderson, Heilman, Voeller, &

JOURNAL OF LEARNING DISABILITIES
VOLUME 27, NUMBER 5, MAY 1994
PAGES 276-286

Torgesen, 1991; Bradley & Bryant, 1978; Gough & Tunmer, 1986).

Phonological memory is typically assessed by tasks that require the brief, verbatim retention of nonmeaningful sequences of verbal items. The most commonly accepted explanation for performance difficulties on this type of task (frequently referred to as *memory span* tasks) involves problems in mentally representing the phonological features of language (Baddeley, 1986; Dempster, 1985; Hansen, 1989; Torgesen, Kistner, & Morgan, 1987). A variety of converging evidence suggests that the representations, or codes, used to store verbal material (such as digits, letters, words, or pronounceable nonwords) on memory span tasks requiring immediate, verbatim, and ordered recall are composed primarily of the phonological features of the stimuli. Difficulty with this type of task is one of the most frequently reported cognitive characteristics of children with severe reading disabilities (Baddeley, 1986; Hulme, 1988; Jorm, 1983; Torgesen, 1985), and performance on span tasks in kindergarten is also predictive of individual differences in word reading skill at the end of first grade (Jorm, Share, Maclean, & Matthews, 1986; Mann & Liberman, 1984). Difficulties with the mental representation of phonological information should make it more difficult to engage in any task that requires the simultaneous storage and processing of individual sounds in words (as when blending sounds together to form a word, or when comparing the sounds in different words with one another).

Children's ability to easily and rapidly access phonological information that is stored in long-term memory has typically been assessed in the reading literature by rapid automatic naming tasks. Martha Denckla and her colleagues (Denckla & Rudel, 1976) first introduced this type of task as a way of predicting and understanding individual differences in reading ability; typically, it requires the child to name, as rapidly as possible, a series of 30 to 50 items (digits, colors, letters, or objects) printed on a page. Individual differences in the speed with which children can name these types of items in kindergarten is strongly predictive of later differences in the rate at which they acquire word-reading skills in first grade and beyond (Bowers, Steffy, & Tate, 1988; Felton & Wood, 1989; Wolf, 1991). Presumably, the efficiency with which children can access phonological codes associated with letters, word segments, and whole words influences the extent to which phonological information is useful in decoding.

State of Knowledge When We Began This Project

When we began our research in 1988, we already had a substantial amount of knowledge about the development of these three types of phonological skills and their relationships to individual differences in reading development. For example, we knew that individual differences in each type of skill were positively correlated with differences in the rate at which children acquired beginning reading skills. Not only were there strong concurrent relationships between phonological processing skills and reading achievement, but also early assessment of these skills (before reading instruction began) was reliably predictive of subsequent achievement in reading. Relationships between phonological measures and subsequent reading achievement were impressive not only for their consistency and strength, but also because these tasks did not involve letters. In general, the relationships between phonological skills and early reading development remained strong even when the effects of overall intelligence and socioeconomic status were controlled (Blachman & James, 1985; Felton & Wood, 1989). These relationships were taken as evidence that a family of phonological skills developing from the child's prereading language experiences, and existing independently of reading and general intelligence, may be uniquely important in helping children acquire early reading skills that involve translating between oral and written language.

At the time we began our research, there was also some beginning evidence that one of these phonological skills—phonological awareness—could be trained in young children, and this training had a positive impact on the rate at which reading skills were acquired. However, the effects of training in phonological awareness, by itself, were relatively weak (Lundberg, Frost, & Peterson, 1988). The interventions that produced the most powerful effects on subsequent growth in reading skills were those that combined training in phonological awareness with explicit training in application of these skills to reading, which always involved some instruction in grapheme–phoneme correspondences (Ball & Blachman, 1991; Bradley & Bryant, 1985).

Research comparing the phonological skills of older good and poor readers also showed that children with specific reading disabilities who were delayed in the development of phonological awareness showed performance deficits on verbal short-term memory tasks and were slower at accessing the names of highly familiar verbal material. Thus, deficits in reading-related phonological processes had come to be viewed as a very common characteristic of children who experienced extreme difficulty acquiring word-reading skills, even through late elementary school and into adolescence (Stanovich, 1988).

Finally, at the time we began our study, there had been a small amount of research investigating the relationships among the different kinds of reading-related phonological skills. Most of the research examining the relationship between these skills and reading had studied only one type of phonological skill at a time. Thus, it was appropriate to ask whether these three constructs represented essentially different abilities, or whether

they were simply different names for the same underlying construct. In 1988, there were some indications that different kinds of phonological skills were correlated with one another in development, but this evidence was spotty and inconsistent (Wagner & Torgesen, 1987).

To summarize, previous research had established that (a) individual differences in phonological processes were predictive of later differences in development of reading skills; (b) training in phonological awareness, coupled with instruction in specific letter-sound relationships, significantly enhanced growth in early word-reading skills; (c) older good and poor readers consistently differed in phonological processing skills; and, (d) phonological skills were related to one another in development.

Project Goals and Rationale

Although substantial information was available about relationships between phonological skills and reading, there were still some critical gaps in our knowledge, and our research was designed to help fill those gaps. In our view, what was required was a longitudinal study that employed measures of reading and phonological skills at several points in time across the period of early reading development. Also required was a more sophisticated measurement technology than had been available prior to our project, coupled with assessment of all three major areas of phonological skill.

Prior to our project, both longitudinal-correlational and training studies had attempted to address the question of causality between individual differences in phonological skills and differences in the rate at which word-level reading skills were acquired. Although there was a relatively strong consensus that phonological skills were causally related to reading growth, weaknesses in the design of most experiments that addressed this question threatened the validity of this consensus. Because most of the evidence came from longitudinal-correlational studies, our research was specifically designed to overcome many of the limitations of this body of research.

Longitudinal-correlational studies can be used to test alternative causal models, but *misspecified models* can lead to erroneous estimates of both the direction and the magnitude of causal relations. *Model specification* refers to the assumptions that are associated with any given model. A problem with most of the longitudinal investigations of the relations between phonological skills and reading is that they all contained one or more problems related to model specification. Thus, actual causal relations among these variables had not been solidly identified.

Three types of model misspecification were found in most studies. The first problem involved omitting other known plausible causes of individual differences in reading growth from the model. Of course, it is impossible to know all the possible causes for a behavior as complex as reading skill acquisition, but we should not omit the most obvious plausible causes from our models. If, for example, we test a model of causal relations between phonological skill and reading and do not include a measure of general verbal ability as an additional plausible cause of individual differences in reading growth, we may easily overestimate causal relations between phonological skill and reading.

Most previous longitudinal-correlational studies followed a common pattern, in which the effects of a phonological processing variable measured at an earlier point in development (T_1) were examined in relation to a reading outcome measured at a later point in development (T_2). However, two obvious variables that might exert causal influences on reading at T_2 are reading skills measured at T_1 and general verbal ability at T_1. If these variables are not included, the model will be seriously misspecified and will likely lead to a misinterpretation of the strength of the causal relationship between phonological processes and reading development.

Another problem with many of the earlier models is the failure to allow for bidirectional causality between phonological processing skills and reading development. Theoretically, we might expect that reading instruction, particularly if it contains instruction in "phonics," would at least have an impact on the growth of phonological awareness skills in young children. In fact, several early studies produced relatively clear evidence of just such a connection: Learning to read does appear to have a measurable impact on growth in phonological awareness (Morais, Alegria, & Content, 1987; Perfetti, Beck, Bell, & Hughes, 1987). The impact of reading growth on the other two areas of phonological skill had not been studied systematically at the time we began our project.

Because of the potential for reciprocal causality between phonological processes and reading growth, a complete examination of causal relations between these two variables should allow examination of the relative strengths of each causal direction. Thus, both reading and phonological skills should be measured at all assessment points in the longitudinal study. This would allow an examination of the effects of reading at T_1 on phonological processes at T_2, as well as an assessment of the reverse pattern of causal relations.

A final problem with the longitudinal studies undertaken prior to our project is that they examined relationships among variables that had been measured with imperfect reliability. That is, these variables contained both true score and error variance. Causal analyses assume that the variables in the model are measured without error, and this assumption is usually violated in practice. If variables in causal models have different measurement reliabilities, or include varying amounts of other measurement error, this can lead to unpredictable biases in the causal estimates that are produced by the analyses. To avoid this problem in our own work, we used latent variables to stand for the phonological and reading constructs under consideration. Latent

variables consist of the common variance in a set of tasks designed to measure the same construct. They are somewhat like factor scores and do not include task-specific variance (including various sources of unreliability), so they allow analyses of variables that are measured without error (provided that the tasks that make up the latent variables vary in content and occasion of administration).

We designed our research to overcome the two other problems with model misspecification outlined above by including measures of both reading and phonological processes at all assessment points in the project, and by including a measure of general verbal ability as well. We also included measures of all three types of phonological skills. By measuring word-level reading skills and three types of phonological processing skills in a large number of randomly selected children at three points in development (beginning kindergarten, first grade, and second grade), we hoped to be able to accomplish three goals. First, we wanted to examine the structure of phonological processing skills both before and after reading instruction began. Important questions here focused on whether phonological skill is best conceptualized as one or several distinct abilities, and whether the structure of these abilities changes with age and reading instruction. Second, we wanted to examine similarities and differences in the growth rate of each of these abilities in the period between kindergarten and second grade. This analysis was planned to complement our examination of the structure of these abilities at different ages. Third, our final and most important goal was to examine the causal relationships between phonological skills and reading using a methodology that overcame many of the limitations of previous research.

Step 1: Testing the Measurement Model

Before actually beginning our longitudinal project, we felt it was necessary to conduct a preliminary study of our measures of phonological processing. This preliminary study was important for two reasons: We needed to be sure that our measures were reliable and sensitive to individual differences across the age range that would be included in the longitudinal investigation, and we needed to determine whether we had enough valid measures of each construct to identify latent variables in each area. To identify a latent variable for the kind of analyses we were proposing to accomplish, we needed at least two (but preferably three) valid measures of each construct. Thus, an important goal of our first study was to determine whether our tests for the different phonological skills were related to one another strongly enough to consider them measures of the same constructs.

In our first study (Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993), we administered a broad range of phonological tasks to approximately 100 kindergarten children with an average age of 5 years 11 months and to 100 second-grade children with an average age of 8 years 1 month. Our tasks included seven measures of phonological awareness, four measures of ability to represent phonological information in working memory, and four measures of rate of access to phonological information in long-term memory. We also administered five measures of nonphonological intellectual abilities and one measure of reading.

An initial inspection of the data indicated that all of the tasks were sufficiently reliable, and, with the possible exception of two phonological awareness tasks, all were sensitive to individual differences across the age range tested. We next used a series of confirmatory factor analyses to determine which measures should be included within our measurement model for each phonological construct. Our first analysis indicated that our phonological awareness measures did not all assess the same construct, but, rather, assessed two distinct but correlated constructs. One of these constructs, *phonological analysis*, was composed of tasks that required children to identify the sounds within words that were presented as wholes, whereas the other construct, *phonological synthesis*, represented children's ability to blend separately presented phonological segments into whole words. Apparently, either the type of phonological knowledge or the specific processing skills required by analytic versus synthetic tasks are sufficiently distinct to warrant their identification as separate domains of phonological skill.

A test of the model fit for all tasks used to assess phonological coding in working memory yielded satisfactory fits for both the kindergarten and the second-grade samples, which indicated that all four of our tasks were adequate measures of this construct. However, the model tests for the rate-of-access factor yielded unsatisfactory results at both ages we tested. The four tasks we had used to assess rate of access for phonological information in long-term memory were (a) Naming Digits: Isolated, which involved naming digits as rapidly as possible that were presented, one at a time, on a computer screen; (b) Naming Digits: Serially, which required children to name, as rapidly as possible, a series of digits presented on a card; (c) Naming Letters: Isolated, which was the same as the Naming Digits: Isolated task, except that high-frequency letters were used instead of digits; and (d) Naming Letters: Serially, which was the same as the Naming Digits: Serially task, except that letters were used instead of digits.

Because there are two obvious ways in which these tasks differ from one another (digits vs. letters, or serial vs. isolated presentation), we tested two different measurement models that reflected these differences. A model that proposed separate but correlated factors for naming digits versus naming letters fit as poorly as the overall model; however, fits were excellent at both ages for a model that proposed separate but correlated factors for isolated trial naming versus serial naming. This analysis indicated that tasks

that assess ability to rapidly access phonological information when items are presented as a series printed together on a card actually measure a substantially different set of skills than tasks in which the items to be rapidly named are presented one at a time in discrete trials on a computer screen. Accordingly, in all of our subsequent analyses, we have included two different kinds of rapid naming tasks.

Because our preliminary confirmatory factor analysis indicated that we had satisfactory measurement models for five latent phonological variables (analytic awareness, synthetic awareness, phonological memory, serial naming, and isolated naming), we could next ask about the relationships of these latent variables to one another at kindergarten and second grade. This larger modeling analysis showed that measures of analytic phonological awareness and phonological coding in working memory assessed the same construct in kindergarten. However, these abilities apparently underwent differentiation with development, so that by second grade they were best represented as two separate abilities. All the other phonological abilities were clearly differentiated from one another at both ages.

The finding that analytic awareness and phonological memory tasks measure essentially the same construct in kindergarten children is consistent with an earlier study of preschool children reported by Wagner et al. (1987). However, that study did not make a distinction between analytic and synthetic awareness tasks, so the results from our sample of kindergarten children help to clarify the earlier results. The early union of analytic awareness and phonological memory into a single construct might stem from their mutual dependence on the quality of the child's phonological representations for words. We know that impoverished or degraded phonological representations impair performance on memory span tasks, and these same impoverished representations may also limit the child's ability to acquire the kind of linguistic knowledge about spoken words that is measured by analysis tasks at an early age. This argument implies that the type of phonological awareness assessed by analysis tasks is more complex, or subtle, than that measured by synthesis tasks, which is consistent with the fact that synthetic skills emerge earlier in development (Torgesen & Morgan, 1990) and are easier to train in young children (Torgesen, Morgan, & Davis, 1992).

Another interesting finding from this first study was that phonological abilities, when measured as latent variables, are more closely related to general intellectual ability than previous studies had indicated. Our battery of nonphonological tasks included measures of both verbal and nonverbal abilities, and when these five tasks were combined into a single cognitive/control factor, correlations between this factor and the five phonological factors ranged between .52 and .83 for the kindergarten children and between .32 and .70 for the second-grade children.

In sum, the most important results from this preliminary study included (a) the verification that we had adequate measurement models for five separate phonological variables; (b) the finding that the analysis and memory tasks measured essentially the same ability in kindergarten children, but that these abilities became more differentiated with age; (c) the finding of substantial stability in the structure of phonological skills across a period in which children were rapidly acquiring reading skills; and (d) the indication that phonological skills may be more closely related to general intellectual ability than previously thought.

We consider the correlations we obtained in this study between phonological abilities and general cognitive development to be the best existing estimates of the true degree of relation between these variables. The justification for our belief is that our correlations are between latent, rather than observable, measures. As mentioned earlier, relationships among latent factors provide estimates of the correlations that are obtained when variables are measured without error. Although these findings call into question the strict "modularity" of phonological processing, they do not seriously undermine the idea that phonological abilities can exercise an important causal influence on early reading acquisition that is independent of general cognitive ability. In fact, our longitudinal study, to which we now turn, provides strong evidence for just such a conclusion.

The Longitudinal Study

In the first year of our study, we began with a sample of 288 children selected randomly from kindergarten classrooms in six elementary schools. During October, November, and December, these children were given a battery of 22 tasks that assessed the five phonological abilities described previously, reading and prereading skills, and general verbal ability. The tasks we used in this study were similar to those used in our preliminary cross-sectional research, with minor refinements to improve their psychometric characteristics. We also added one synthetic awareness task, one isolated naming task, and one serial naming task, so that these constructs would be represented by three tasks in the battery.

All tasks were readministered to the same children at the beginning of first and second grades. At the time of the second-grade testing, 244 children were left in the sample; all of the analyses reported here are based on data from these children. The sample was 53% female and 75% white, with almost all of the other children being African American. When first tested in kindergarten, the children's average age was 5 years 8 months, and English was the primary language spoken in all of their homes. Children were not accepted into the sample who did not pass a screening measure (Bryant &

Bryant, 1983) designed to detect gross articulation difficulties.

All the schools from which our sample of children was selected had adopted the whole language approach to reading instruction several years prior to the beginning of the study. However, there was substantial variability in implementation of this method across schools. At several of the schools, very little instruction in phonics was provided, whereas at others, the choice was left to each teacher, with some teachers electing to provide relatively explicit instruction in alphabetic decoding skills. However, at the time the children were tested in the first semester of kindergarten, none of them had received any formal reading instruction. Some kindergarten teachers began instruction in letter names and simple writing activities in the second semester of kindergarten, but these activities did not start until after our initial testing was completed.

Because these data are formally reported elsewhere (Wagner, Torgesen, & Rashotte, in press), this presentation focuses only on the major results of the study. Our analysis of growth rates for each of the phonological variables provided support for our model identifying five distinct but correlated abilities. We combined the tasks measuring each variable into a unit-weighted composite based on scores that had been standardized with respect to their kindergarten means and standard deviations. This created a score for each variable at each age that was referenced to the amount of naturally occurring variability in kindergarten, and allowed us to directly compare growth rates across variables. The growth rates for each of the variables are displayed in Figure 1. Our analyses indicated that growth rates on all the variables were different from one another (with the exception of isolated naming and synthetic awareness skills), with the fastest growth occurring in serial naming and the slowest in verbal short-term memory. When we calculated growth rates for word-reading skills (combining measures involving reading of isolated real words and nonwords) and general verbal ability, growth in reading skills was very similar to that for serial naming, whereas general verbal ability grew at a rate similar to our verbal memory composite.

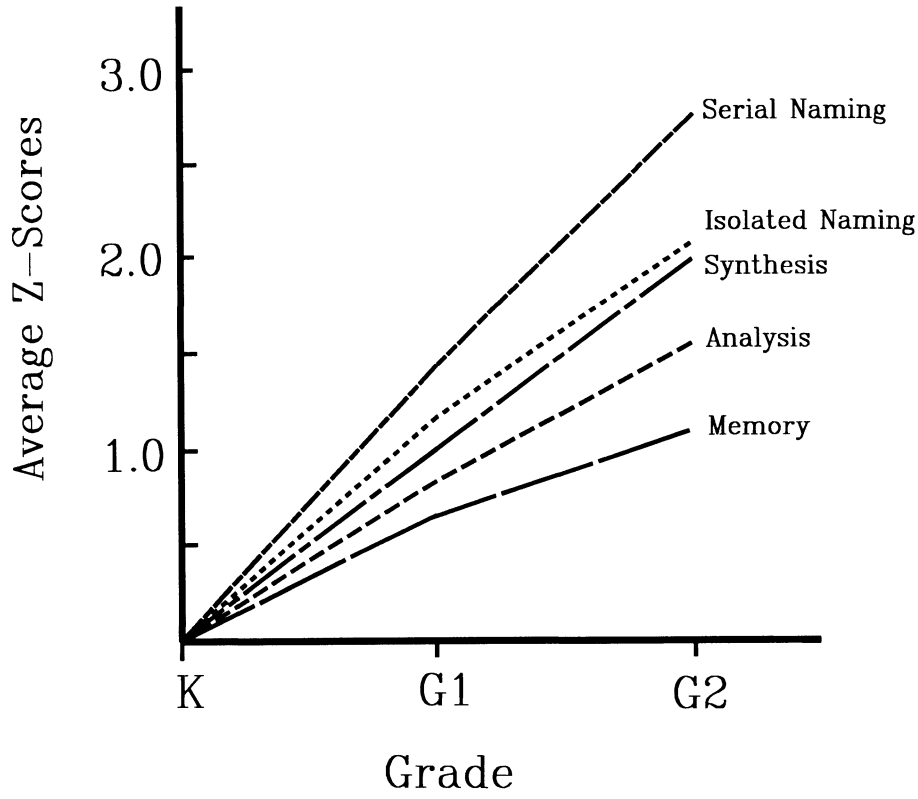

FIGURE 1. Rates of development for the five phonological variables. (*Note.* Adapted from "The Development of Reading-Related Phonological Processing Abilities: New Evidence of Bi-Directional Causality From a Latent Variable Longitudinal Study" by R. K. Wagner, J. K. Torgesen, and C. A. Rashotte, in press, *Developmental Psychology.*)

We next examined the stability of individual differences in each of the phonological processing constructs across the period from kindergarten to second grade. When latent variables were used to stand for each of the constructs (remember that latent variables represent the common variance among several different measures of the same construct, so they provide measurement uncontaminated by task-specific or error variance), the correlations between measures of each construct given in kindergarten and first grade were .87, .71, 1.0, .78, and .81 for analysis, synthesis, phonological memory, isolated naming, and serial naming, respectively. The correlations between kindergarten and second-grade testing for the same variables were .66, .49, 1.0, .65, and .62, respectively. These correlations indicate that individual differences in reading-related phonological skills are remarkably stable during the period in which children are receiving early reading instruction. When this evidence is considered in conjunction with the fact that the structure of these abilities (their relationships among themselves) is also very consistent during this period, it suggests that these abilities are an enduring aspect of children's cognitive endowment and are not simply a reflection of knowledge and skill they acquire as a result of learning to read. In other words, these reading-related

phonological processing skills should be considered to be important human abilities in their own right, similar to the intellectual abilities assessed on measures of general intelligence.

Table 1 shows the simple correlations between the various phonological abilities (measured as latent variables) and reading measured at several points in time. These data are remarkably consistent with an earlier longitudinal study reported by Felton and Wood (1989), in which analytic phonological awareness and rapid serial naming emerged as two of the most powerful predictors of subsequent reading achievement in a sample of 485 children tested during first grade. The primary difference between our data and Felton and Wood's is that we found analytic awareness to be more strongly related to reading than serial naming, whereas they found the opposite pattern to be true. One advantage of using latent variables in comparing relative strengths of relationships among variables is that all variables are measured with essentially the same reliability, so that possible differences in reliabilities among various measures cannot affect the pattern of relationships.

Although the pattern of simple correlations reported in Table 1 is interesting in light of the results from previous research, we were primarily interested in a causal analysis of the relationships between phonological skills and reading that was uncontaminated by possible effects of prior reading skills and general verbal ability. When we examined the causal relations between each phonological processing variable and subsequent reading, including in our models the effects of prior reading and general verbal ability, we found that each phonological variable had a statistically significant causal influence on first-grade word-reading skill. The causal coefficients were .67, .39, .21, .27, and .37 for analysis, synthesis, memory, isolated naming, and serial naming, respectively. The pattern of relationships between phonological skills measured in first grade and reading in second grade was very similar, except that synthesis had a stronger causal relationship than analysis.

After establishing that each of the five phonological processing abilities had a significant causal relationship to subsequent reading development when they were considered in isolation, the next logical question was, Do these abilities each account for unique variance in reading skill or are their causal effects redundant? To answer this question, we used a structural equation model in which the five phonological variables (measured in kindergarten), along with verbal ability and kindergarten reading skills, were allowed to be simultaneous causes of variation in word-reading ability measured in first grade. The results of this analysis are contained in Figure 2. In this figure, which is a simplified representation of the causal model, latent variables are represented by ellipses, and observed variables are represented by rectangles. The finding of primary importance is that only one of the phonological variables—phonological analysis—had a significant causal influence on word-reading skill when all five variables were considered simultaneously. When we considered this fact, along with the finding that each phonological variable had a significant causal effect when considered individually, we were led to conclude that the causal influences of phonological skills on reading development are redundant. Notice also that prior reading skill operates as a significant cause of subsequent reading skill independent of phonological processing skills. We found essentially the same pattern of results when we considered the influence of phonological skills in first grade on reading in second grade, except that the only significant phonological variable was phonological synthesis (causal coefficient = .22). In addition, the effect of first-grade reading skill on second-grade reading skill (causal coefficient = .47) was stronger than when these two variables were measured in kindergarten and first grade.

Because other research has indicated that causal relationships between phonological processing skill and reading may be reciprocal, our analyses would be incomplete without a consideration of possible causal influences of individual differences in reading skill on subsequent development of phonological processing abilities. For a variety of reasons, in this analysis we used children's knowledge of letters as our measure of reading (actually, prereading) skill in kindergarten. The analysis indicated that prereading skill in kindergarten did in fact have a significant causal effect on subsequent development of phonological skill, although this effect was moderate when compared to the effect of phonological skills on reading. The effect was strongest for phonological awareness, moderately reliable for rapid naming skills, and nonexistent for phonological memory.

TABLE 1
Correlations Between Latent Phonological Processing Abilities and Word Decoding

	Grade level	
Phonological variable	**K phonological (1st decoding)**	**1st phonological (2nd decoding)**
Analysis	.82	.82
Synthesis	.59	.78
Memory	.42	.52
Isolated naming	.45	.48
Serial naming	.66	.70

Note. All correlations were significant at $p < .001$. K = kindergarten; 1st = first grade.

Implications for Conceptualization of Reading Disabilities

Two of the findings from our longitudinal study have special implications for understanding the emergence of reading disabilities in young children. It should be pointed out that both of these findings derive uniquely from the longitudinal nature of our study; they could not have been obtained without repeated assessment of the same group of children at several points in their development. The first point is related to the stability of individual differences in phonological skills over time. If either the structure of phonological abilities or the patterns of individual differences in those abilities varied substantially from kindergarten to first or second grade, their viability as an explanation for reading disabilities would be seriously undermined. Although some recent research (Shaywitz, Escobar, Shaywitz, Fletcher, & Makuch, 1992) has found considerable instability in diagnoses of children as reading disabled across the early elementary grades, there is relatively broad evidence that poor readers in first grade tend to remain poor readers in subsequent grades (Juel, 1988; Stanovich, 1986). If continuing difficulty in reading is to be considered the consequence of something other than consistently poor teaching in reading, or lack of motivation to learn (which may be the case for some children), those causal factors should be relatively stable themselves across the period in question. The findings from our longitudinal research provide powerful support for the conceptualization of phonological skills as stable, enduring individual-difference characteristics, at least across the early elementary period. A practical consequence of this stability, along with their strong relationships to the acquisition of reading skills, is that phonological variables should clearly be included in test batteries used to identify children at risk for reading failure (Berninger, Thalberg, DeBruyn, & Smith,

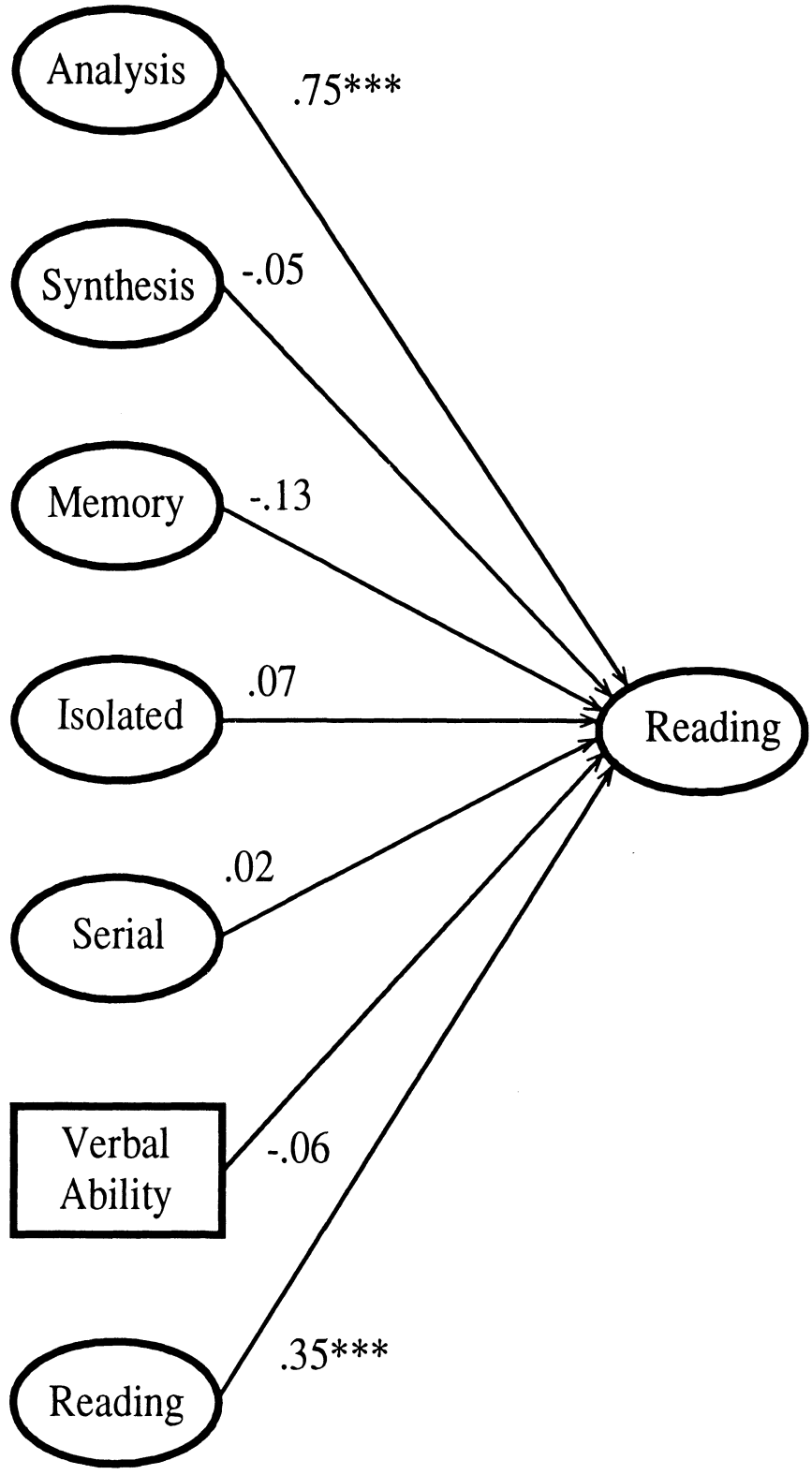

FIGURE 2. Causal influences of phonological abilities in kindergarten on first-grade decoding.

1987; Mann, 1993; Torgesen, Wagner, Bryant, & Pearson, 1992).

The findings from the analysis of causal relations between phonological skills and reading have important implications for causal theories of reading disabilities. In fact, they support what is perhaps the dominant and most completely developed theory in our field today: The theory of phonologically based reading disabilities (Stanovich, 1988; Torgesen, 1993) suggests that phonological processing disabilities are the cause of a substantial proportion of reading disabilities in young children, adolescents, and adults. By providing strong support for the idea that individual differences in phonological skill in kindergarten (before reading instruction began) are *causally* related to individual differences in subsequent growth of reading skills, we provide important confirmation of phonological deficits as a possible cause of early reading failure.

Although our longitudinal analysis indicated that phonological awareness was the phonological variable most strongly related to subsequent reading skill, it would be a misinterpretation of the simultaneous model to conclude that it was the *only* phonological skill causally related to reading. When variables that are correlated with one another (as were all the phonological variables) are included in a simultaneous causal equation, a predictor that is only slightly more strongly related to the criterion can receive a substantial coefficient, while a second, correlated predictor receives a coefficient near zero because it does not make a causal contribution that is unique from the first predictor. This does not mean that the second variable is not causally related to the criterion; it simply means that the causal contributions of the two variables are redundant. Thus, all of the phonological abilities were causally related to subsequent reading growth when considered individually, but only one emerged as a significant causal agent when they were considered together. Perhaps if we had included a more fine-grained analysis of different types of reading skill (e.g., accuracy as opposed to fluency), we may have been able to show that the five phonological skills contribute differentially, depending upon the type of reading skill to be explained.

Where Do We Go From Here?

As a result of our research, as well as that of others, we have become interested in the potential impact of intensive training in phonological awareness coupled with systematic instruction in word-level reading skills as a possible method to reduce the incidence of reading disabilities among young children. Although programs designed to train phonological awareness in young children have been generally successful (Wagner, Torgesen, & Rashotte, 1993), we have learned from our research (Torgesen, Morgan, & Davis, 1992; Torgesen, Davis, & Wagner, 1993) and others' (Lundberg, 1988) that it is not as easy to significantly improve the phonological awareness of at-risk children as one might guess from an examination of group effects in training studies.

In our first training study (Torgesen, Morgan, et al., 1992), we found that about 30% of our at-risk sample showed no measurable growth in phonological awareness following an 8-week training program that produced significant growth in awareness in the majority of children. In a second training study (Torgesen et al., 1993), we provided a 12-week training program in both analytic and synthetic phonological awareness to a group of 60 kindergarten children who were at risk for reading failure. This was a minilongitudinal study in which analytic and synthetic skills were measured at three points in time (beginning, middle, and end of training) so that we could calculate individual growth curves for each child. Our objective was to examine the extent of individual differences in response to training in phonological awareness, and to determine which pretest variables were the best predictors of this variability.

In the second study, training was administered in small groups (3 to 4 children), in 20-minute sessions four times a week, for a period of 12 weeks. Training included explicit instruction in both blending (synthetic) skills and segmenting (analytic) skills using a variety of games and activities to stimulate and maintain the children's interest. Instruction in analytic skills included activities involving comparison of words on the basis of specific phonemes (same first, middle, or last sounds), identifying the position of specific phonemes within words, and pronunciation of individual phonemes within words. During the last 3 weeks of training, children were taught how to use their segmenting and blending skills in reading a small number of real words.

When the posttest segmenting and blending performance of children in the training group was compared with that of a group of 40 similar children who had not received special training in phonological awareness, there were obvious group differences in performance. For example, the untrained group's scores on the segmenting task were only 29% as high as those for the trained group (effect size = 1.35 standard deviation units), and the difference on the blending task was even larger (scores were 24% as high; effect size = 1.84 standard deviation units). However, substantial variability was found in response to the training among children in the experimental group. About 30% of the children in the training group obtained a score of 2 or less on the segmenting posttest, while 10% showed a similarly small improvement on the blending test. As both analytic and synthetic skills are involved in reading acquisition (Torgesen, Morgan, et al., 1992), it is clear that a substantial number of children in the training group, after our 12-week training program, remained relatively weak in the phonological

awareness skills that are important for learning to read.

When we used performance on our pretest measures to predict individual differences in response to the phonological awareness training, two tasks emerged as the best predictors. One was a measure of invented spelling, which requires both phonological awareness and knowledge of letter-sound correspondences (Mann, 1993), and the other was a measure of rapid serial naming of digits.

These findings have important implications for the idea that phonological awareness training prior to reading instruction may be one way to significantly reduce the incidence of reading disabilities among young children. Because we know that children with reading disabilities access phonological representations more slowly than nondisabled children (Wolf, 1991), and we also know that they have special difficulties reading and spelling novel words (Rack, Snowling, & Olsen, 1992), it is likely that they would enter any phonological awareness training program relatively low on the variables that predict successful response to the training. We could thus expect a large proportion of children with reading disabilities to fall in the group of children who do not profit significantly from this training.

Given all that we now know about the relationship between phonological awareness and the acquisition of alphabetic reading skills (Liberman et al., 1989; Wagner et al., in press), we strongly recommend that training in phonological awareness be included in any preventive or remedial program for children either at-risk for or identified with reading disabilities. However, our experience in training groups of at-risk children suggests that training procedures that are more explicit or more intense than those typically found in the research literature may be required in order to have a substantial impact on the phonological awareness of many children with severe reading disabilities.

ABOUT THE AUTHORS

Joseph K. Torgesen *received his PhD in developmental and clinical psychology from the University of Michigan in 1976, and he is currently a professor of psychology, and director of the Cognitive and Behavioral Science Program, at Florida State University (FSU). He is a member of the Professional Advisory Board of the Learning Disabilities Association of America, and he is the editor of a recent volume titled The Cognitive and Behavioral Characteristics of Children with Learning Disabilities, published by PRO-ED. He was recently awarded a 5-year grant from NIMH to study the prevention and remediation of reading disabilities in young children.* ***Richard K. Wagner*** *received his PhD in cognitive psychology from Yale University and is also a professor of psychology at FSU. He is the coauthor of a recent book titled The Psychology of Reading: An Introduction, published by Oxford University Press. Dr. Wagner's research interests include the study of practical intelligence and the development of reading skills in young children. He was recently awarded a 5-year grant from NIMH to continue studying the development of phonological and reading skills in young children.* ***Carol A. Rashotte*** *received her PhD in school psychology from Florida State University and is currently a senior research associate at FSU. Her research interests include the study of reading and phonological development in young children, as well as issues in the application of technology to education. Address: Joseph K. Torgesen, Psychology Department, Florida State University, Tallahassee, FL 32312-1051.*

AUTHORS' NOTE

This research was supported in part by Grant #HD23340 from the National Institute of Child Health and Human Development.

REFERENCES

Adams, M. J. (1990). *Beginning to read: Thinking and learning about print.* Cambridge, MA: MIT Press.

Alexander, A., Anderson, H., Heilman, P. C., Voeller, K. S., & Torgesen, J. K. (1991). Phonological awareness training and remediation of analytic decoding deficits in a group of severe dyslexics. *Annals of Dyslexia, 41,* 193–206.

Baddeley, A. D. (1986). *Working memory.* New York: Oxford University Press.

Ball, E. W., & Blachman, B. A. (1991). Does phoneme awareness training in kindergarten make a difference in early word recognition and developmental spelling? *Reading Research Quarterly, 26,* 49–66.

Berninger, V., Thalberg, T., DeBruyn, I., & Smith, R. (1987). Preventing reading disabilities by assessing and remediating phonemic skills. *School Psychology Review, 16,* 554–565.

Blachman, B. A., & James, S. L. (1985). Metalinguistic abilities and reading achievement in first-grade children. In J. Niles & R. Lalik (Eds.), *Issues in literacy: A research perspective* (pp. 127–163). Rochester, NY: National Reading Conference.

Bowers, P. G., Steffy, R., & Tate, E. (1988). Comparison of the effects of IQ control methods on memory and naming speed predictors of reading disability. *Reading Research Quarterly, 23,* 304–319.

Bradley, L., & Bryant, P. E. (1978). Difficulties in auditory organization as a possible cause of reading backwardness. *Nature, 221,* 746–747.

Bradley, L., & Bryant, P. (1985). *Rhyme and reason in reading and spelling.* Ann Arbor: University of Michigan Press.

Brady, S., & Shankweiler, D. (1991). *Phonological processes in literacy: A tribute to Isabelle Y. Liberman.* Hillsdale, NJ: Erlbaum.

Bryant, B. R., & Bryant, D. L. (1983). *Test of articulation performance-screen.* Austin, TX: PRO-ED.

Byrne, B., Freebody, P., & Gates, A. (1992). Longitudinal data on the relations of word-reading strategies to comprehension, reading time, and phonemic awareness. *Reading Research Quarterly, 27,* 141–151.

Crowder, R. G., & Wagner, R. K. (1991). *The psychology of reading: An introduction.* New York: Oxford University Press.

Dempster, F. N. (1985). Short-term memory development in childhood and adolescence. In C. Brainerd & M. Pressley (Eds.), *Basic processes in memory development* (pp. 128–157). New York: Springer-Verlag.

Denckla, M. B., & Rudel, R. (1976). Rapid automatized naming (R.A.N.): Dyslexia differentiated from other learning disabilities. *Neuropsychologia, 14,* 471–479.

Felton, R. H., & Wood, F. B. (1989). Cognitive deficits in reading disability and attention deficit disorder. *Journal of Learning Disabilities, 22,* 3–13.

Gough, P., & Tunmer, W. (1986). Decoding, reading, and reading disability. *Remedial and Special Education, 7*(1), 6–10.

Hansen, V. L. (1989). Phonology and reading: Evidence from profoundly deaf readers. In D. Shankweiler & I. Y. Liberman (Eds.), *Phonology and reading disability: Solving the reading puzzle* (pp. 69-90). Ann Arbor: University of Michigan Press.

Hulme, C. (1988). Short-term memory development and learning to read. In M. Gruneberg, P. Morris, & R. Sykes (Eds.), *Practical aspects of memory: Current research and issues; Vol 2. Clinical and educational implications* (pp. 234-271). Chichester, England: Wiley.

Jorm, A. F. (1983). Specific reading retardation and working memory: A review. *British Journal of Psychology, 74,* 311-342.

Jorm, A., Share, D., Maclean, R., & Matthews, R. (1986). Cognitive factors at school entry predictive of specific reading retardation and general reading backwardness: A research note. *Journal of Child Psychology and Psychiatry, 27,* 45-54.

Juel, C. (1988). Learning to read and write: A longitudinal study of 54 children from first through fourth grades. *Journal of Educational Psychology, 80,* 437-447.

Liberman, I. Y., Shankweiler, D., & Liberman, A. M. (1989). The alphabetic principle and learning to read. In D. Shankweiler & I. Y. Liberman (Eds.), *Phonology and reading disability: Solving the reading puzzle* (pp. 1-33). Ann Arbor: University of Michigan Press.

Lundberg, I. (1988). Preschool prevention of reading failure: Does training in phonological awareness work? In R. L. Masland & M. W. Masland (Eds.), *Prevention of reading failure* (pp. 163-176). Parkton, MD: York Press.

Lundberg, I., Frost, J., & Peterson, O. (1988). Effects of an extensive program for stimulating phonological awareness in pre-school children. *Reading Research Quarterly, 23,* 263-284.

Mann, V. A. (1993). Phoneme awareness and future reading ability. *Journal of Learning Disabilities, 26,* 259-269.

Mann, V. A., & Liberman, I. Y. (1984). Phonological awareness and verbal short-term memory. *Journal of Learning Disabilities, 17,* 592-599.

Morais, J., Alegria, J., & Content, A. (1987). The relationships between segmental analysis and alphabetic literacy: An interactive view. *Cahiers de Psychologie Cognitive, 7,* 414-438.

Perfetti, C. A., Beck, I., Bell, L., & Hughes, C. (1987). Phonemic knowledge and learning to read are reciprocal: A longitudinal study of first grade children. *Merrill-Palmer Quarterly, 33,* 283-319.

Rack, J. P., Snowling, M. J., & Olsen, R. K. (1992). The nonword reading deficit in developmental dyslexia: A review. *Reading Research Quarterly, 27,* 29-53.

Shankweiler, D., & Liberman, I. Y. (1989). *Phonology and reading disability.* Ann Arbor: University of Michigan Press.

Shaywitz, S. E., Escobar, M. D., Shaywitz, B. A., Fletcher, J. M., & Makuch, R. (1992). Evidence that dyslexia may represent the lower tail of a normal distribution of reading ability. *The New England Journal of Medicine, 326,* 145-150.

Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly, 21,* 360-406.

Stanovich, K. E. (1988). Explaining the differences between the dyslexic and the garden-variety poor reader: The phonological-core variable-difference model. *Journal of Learning Disabilities, 21,* 590-604.

Stanovich, K. E., Cunningham, A. E., & Cramer, B. B. (1984). Assessing phonological awareness in kindergarten children: Issues of task comparability. *Journal of Experimental Child Psychology, 38,* 175-190.

Torgesen, J. K. (1985). Memory processes in reading disabled children. *Journal of Learning Disabilities, 18,* 350-357.

Torgesen, J. K. (1993). Variations on theory in learning disabilities. In G. R. Lyon, D. B. Gray, J. F. Kavanagh, & N. A. Krasnegor (Eds.), *Better understanding of learning disabilities: New views from research and their implications for education and public policies* (pp. 153-170). Baltimore: Brookes.

Torgesen, J. K., Davis, C., & Wagner, R. K. (1993, April). *Individual difference variables that predict response to training in phonological awareness.* Paper presented at the annual meeting of the American Educational Research Association, Atlanta, GA.

Torgesen, J. K., Kistner, J. A., & Morgan, S. (1987). Component processes in working memory. In J. Borkowski & J. D. Day (Eds.), *Memory and cognition in special children: Perspectives on retardation, learning disabilities, and giftedness* (pp. 49-86). Norwood, NJ: Ablex.

Torgesen, J. K., & Morgan, S. (1990). Phonological synthesis tasks: A developmental, functional, and componential analysis. In H. L. Swanson & B. Keogh (Eds.), *Learning disabilities: Theoretical and research issues* (263-276). Hillsdale, NJ: Erlbaum.

Torgesen, J. K., Morgan, S., & Davis, C. (1992). The effects of two types of phonological awareness training on word learning in kindergarten children. *Journal of Educational Psychology, 84,* 364-370.

Torgesen, J. K., Wagner, R. K., Bryant, B. R., & Pearson, N. (1992). Toward development of a kindergarten group test for phonological awareness. *Journal of Research and Development in Education, 25,* 113-120.

Wagner, R. K., Balthazor, M., Hurley, S., Morgan, S., Rashotte, C., Shaner, R., Simmons, K., & Stage, S. (1987). The nature of prereaders' phonological processing abilities. *Cognitive Development, 2,* 355-373.

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its casual role in the acquisition of reading skills. *Psychological Bulletin, 101,* 192-212.

Wagner, R. K., Torgesen, J. K., Laughon, P., Simmons, K., & Rashotte, C. (1993). The development of young readers' phonological processing abilities. *Journal of Educational Psychology, 85,* 83-103.

Wagner, R. K., Torgesen, J. K., & Rashotte, C. (1993, April). *The efficacy of phonological awareness training for early reading achievement: A meta-analysis.* Paper presented at the annual meeting of the American Educational Research Association, Atlanta, GA.

Wagner, R. K., Torgesen, J. K., & Rashotte, C. (in press). The development of reading-related phonological processing abilities: New evidence of bi-directional causality from a latent variable longitudinal study. *Developmental Psychology.*

Wolf, M. (1991). Naming speed and reading: The contribution of the cognitive neurosciences. *Reading Research Quarterly, 26,* 123-141.