Intelligence, cognitive skills, and early reading progress

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FIFTY-SIX first-grade children were administered measures of general intelligence, decoding speed, phonological awareness, and listening comprehension. All four types of measures were moderately related to end-of-year reading comprehension. Decoding speed accounted for the largest amount of unique variance. The hypothesis that reading is strongly related to general intelligence once differences in decoding ability have been accounted for was not supported. Other relationships among the variables were explored via multiple regression, factor analysis, and path analysis. Developmental comparisons were made with groups of third- and fifth-grade children. The relationships between decoding, intelligence, and reading comprehension found in the first-grade sample were replicated in the fifth-grade sample but were somewhat different in the third-grade sample. The interrelationships between the various subskills of reading and intelligence increased with age, probably due to mutual facilitation.

Intelligence, compétences cognitives et progrès de lecture précoce

ON A ADMINISTRÉ à cinquante six enfants de cours primaire des mesures d'intelligence générale, de vitesse de décodage, de conscience phonologique et de compréhension d'écoute. Les quatre facteurs étaient modérément reliés à une mesure de compréhension de lecture de fin d'année. La vitesse de décodage rendait compte de la plus large quantité d'écart unique. L'hypothèse qui veut que la lecture soit fortement reliée à l'intelligence générale après avoir tenu compte des différences de compétence de décodage, n'a pas été soutenue. On a exploré d'autres rapports parmi les écarts à travers une régression multiple, une analyse de facteur et une analyse de parcours. On a établi des comparaisons de développement avec des groupes d'enfants de neuvième et septième. Les rapports entre décodage, intelligence, et compréhension de lecture trouvés dans l'échantillon de cours primaire sont répétés dans l'échantillon de la septième mais ont été quelque peu différents dans celui de la neuvième. Les rapports étroits entre les différentes sous-compétences de lecture et intelligence ont augmenté avec l'âge, ceci étant probablement dû à une facilitation réciproque.

Inteligencia, destrezas cognitivas y progreso adelantado en lectura

SE ADMINISTRARON medidas de inteligencia general, velocidad de descifre, conocimiento fonológico y escuchar y comprender. Los 4 factores estaban moderadamente relacionados a una medida de comprensión de lectura de fin de año escolar. La velocidad de descifre dio cuenta del mayor número de variabilidad singular. No recibió apoyo la hipótesis de que la destreza de lectura está fuertemente relacionada a inteligencia general, una vez que se han considerado las diferencias de habilidad de descifre. Otras relaciones entre variables fueron exploradas por medio de regresión múltiple, análisis factorial y análisis de trayecto. Se hicieron comparaciones de desarrollo con grupos de alumnos de tercer y quinto grado. La relación entre descifre, inteligencia y comprensión de lectura encontrada en la muestra del primer grado, fue repetida en el quinto grado, pero resultó algo diferente en la muestra del tercer grado. La correlación entre las varias subdestrezas de lectura e inteligencia aumentó con la edad, probablemente debido a facilitación mútua.

The nature of the relationship between reading ability and performance on intelligence tests is an old problem that has been much researched (see Barnes, 1955; Birch & Belmont, 1965; Chall, 1967; Samuels & Dahl, 1975; Singer, 1977; White & Jacobs, 1979). However, several recent provocative statements and hypotheses published by Jensen (1980, 1981a, 1981b) have served to reopen the discussion regarding the theoretical meaning of the relationship. For example, in a table on page 31 of his book *Straight Talk About Mental Tests,* a correlation of .68 is given as an example of the magnitude of the relationship between reading comprehension and intelligence. Reading researchers may want to question whether this correlation is intended to be representative, since it appears that it is a little on the high side (although the age of the sample is not reported). Also, given Jensen's commitment ot the theoretical concept of g as conceived by the British school of intelligence theorists, reading researchers may also wish to examine critically the interpretation of the relationship that Jensen wishes to popularize.

The answers to both of these questions are in Jensen's 1980 book *Bias in Mental Testing* (since *Straight Talk* is a book intended for the layman, a citation for the .68 correlation is not given). On page 325 of that book there is a section on "IQ and Learning to Read" that appears to be the source of the .68 correlation. The correlation is termed "typical" and it is taken from a 1969 study by Krebs where the kindergarten WPPSI (Wechsler Preschool and Primary Scale of Intelligence) Full Scale scores of a group of children were correlated with first-grade Reading Comprehension scores on the Stanford Achievement Tests. It is extremely puzzling that the Krebs study, an unpublished doctoral dissertation, was chosen to illustrate the typical relation, because there is a large published literature on the IQ-reading relationship (see Table 1). Thus, it is necessary to clear up the technical point regarding the representativeness of the .68 correlation.

In a meta-analysis of studies published in the archival literature, Hammill and McNutt (1981) found that the median of 34 correlations between reading ability and the Wechsler Intelligence Scale for Children (WISC) Full Scale score was .44. The median of 33 correlations between reading ability and Stanford-Binet score was .46. However, the Hammill and McNutt data is not broken down by the age of the sample. A wide (but certainly not exhaustive) sampling of relatively recent studies is presented in Table 1. The studies listed employed a variety of IQ tests, reading achievement tests, age levels, and subject populations (while some of the studies may suffer from restriction of range, this is not a problem in the majority of cases). It is clear that the correlations fall within a rather wide range of values. Most are within the range of .3-.7. Note also that the data in Table 1 appear to indicate a somewhat lower IQ-reading correlation in the earlier stages of reading acquisition that were the focus of the Krebs study. It would appear that a typical value in the early elementary grades would fall in the .3-.5 range (figures consistent with Chall's 1967 review of the earlier literature) and in the .45-.65 range for the middle grades. The value of .68 is only typical of adult performance patterns. The difference between correlation values of .68 and .50 should not be considered trivial since it represents nearly a twofold difference in reading variance accounted for by IQ (46% versus 25%). Interestingly, on the page preceding the "IQ and Reading" section in his 1980 book Jensen cites a study of his own (Jensen, 1974) where the Lorge-Thorndike Verbal IQs of a group of children in Grades 4-6 displayed a correlation of .52 with their scores on the Reading Comprehension subtest of the Stanford Achievement Tests. Nonverbal IQ displayed a correlation of .47 (although these correlations

Table 1 Obtained correlations between intelligence and reading ability in several relatively recent studies

Study	Correlation
Grade 1 (age 6-7)	
Barnes (1955)	.31
Birch and Belmont (1965)	.56
Bond and Dykstra (1967)	.42
Bond and Dykstra (1967)	.52
Bond and Dykstra (1967)	.56
Bond and Dykstra (1967)	.43
Bond and Dykstra (1967)	.48
Bond and Dykstra (1967)	.52
Brekke and Williams (1975)	.53
Brown (1976)	.31
Bruinicks and Lucker (1970)	.32
Butler, Marsh, Sheppard and Sheppard (1982)	.38
Feshbach, Adelman, and Fuller (1977)	.32
Feshbach, Adelman, and Fuller (1977)	.42
Henderson, Fay, Lindemann, and Clarkson (1973)	.46
Kaufman (1973)	.51
Kaufman (1973)	.36
Kaufman and Kaufman (1972)	.48*
Muehl and DiNello (1976)	.32
Sewall (1979)	.48
Sewall (1979)	.41
Sewall and Severson (1974)	.55
Shipp and Loudon (1964)	.42*
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.20*
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.41*
Wallbrown, Engin, Wallbrown, and Blaha (1975)	.46*
Whaley and Kibby (1981)	.45*
White and Jacobs (1979)	.58*
Yule and Rigley (1982)	.59*
Grade 2 (age 7-8)	
Barnes (1955)	.56
Birch and Belmont (1965)	.53
Butler, Marsh, Sheppard, and Sheppard (1982)	.39
de Hirsch, Jansky, and Langford (1966)	.31*
Feshbach, Adelman, and Fuller (1977)	.40
Feshbach, Adelman, and Fuller (1977)	.48
Hartlage and Steele (1977)	.59
Hendeson, Butler, and Goffeney (1969)	.43
Lieblich and Shinar (1975)	.63*
Muehl and DiNello (1976)	.38*
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.28*
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.28*
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.75
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.57
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.76
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.43
Yule and Rigley (1982)	.61*
Yule and Rigley (1982)	.45*
Grade 3 (age 8-9)	
Barnes (1955)	.56
Birch and Belmont (1965)	.48
Butler, Marsh, Sheppard, and Sheppard (1982)	.46
Feshbach, Adelman, and Fuller (1977)	.45

Feshbach, Adelman, and Fuller (1977)	.45
Muehl and DiNello (1976)	.37*
Silberberg, Iversen, and Silberberg (1969)	.30
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.19*
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.19*
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.71*
Stevenson, Parker, Wilkinson, Hegion, and Fish (1976)	.49*
Yule, Rutter, Berger, and Thompson (1974)	.62
Yule, Rutter, Berger, and Thompson (1974)	.36
Grades 4-8 (ages 9-14)	
Ames and Walker (1964)	.57*
Barnes (1955)	.62
Birch and Belmont (1965)	.27
Birch and Belmont (1965)	.69
Birch and Bemont (1965)	.83
Bruinicks and Lucker (1970)	.60*
Hartlage and Boone (1977)	.41
Hartlage and Boone (1977)	.68
Hartlage and Boone (1977)	.48
Hartlage and Boone (1977)	.70
Ivanoff and Tempero (1965)	.62
Muehl and DiNello (1976)	.31*
Muehl and DiNello (1976)	.41*
Muehl and DiNello (1976)	.50*
Muehl and DiNello (1976)	.51*
Rae (1977)	.67
Roberge and Flexer (1981)	.58
Sexton and Treloar (1982)	.51*
Spiegel and Bryant (1978)	.66
Sterritt and Rudnick (1966)	.78
Thompson, Alston, Cunningham, and Wakefield (178)	.59
Tremans-Ziremba, Michayluk, and Taylor (1980)	.65
Yule, Rutter, Berger, and Thompson (1974)	.61
Yule, Rutter, Berger, and Thompson (1974)	.57
Yule, Rutter, Berger, and Thompson (1974)	.61
Yule, Rutter, Berger, and Thompson (1974)	.57
Yule, Rutter, Berger, and Thompson (1974)	.61
Yule, Rutter, Berger, and Thompson (1974)	.64
Yule, Rutter, Berger, and Thompson (1974)	.50
Grades 9 and above (age 14 and above)	
Andrew (1978)	.71
Glossop, Appleyard, and Roberts (1979)	.82
Guterman (1979)	.64
Trotman (1977)	.55*
Trotman (1977)	.69*
Yule, Gold, and Busch (1981)	.61

Note. Multiple values are listed for studies that employed more than one subject sample and for studies that employed multiple measures of intelligence or reading ability. Asterisks indicate that intelligence was measured at an earlier point of time.

do not actually appear in the paper cited, it can probably be assumed that the data on which they were based came from the subject group described in that article). Clearly, in light of the data presented in Table 1, these correlations are more typical than the .68 figure, and thus it is even more puzzling that it was the latter figure that was chosen for presentation in a book intended for the general public. Also, the .68 figure would seriously mislead elementary school teachers (a likely audience for a nontechnical book like *Straight Talk*) if applied to their population of interest.

Moving beyond the issue of the representativeness of the correlation to the interpretation of the relations, we find Jensen advocating very strong positions, such as "In the general school population, reading comprehension is highly g loaded" (Jensen, 1981a, p. 31), or "When elementary school children (all of the same age) are matched on decoding skill, their rank on a test of reading comprehension is practically the same as on IQ" (Jensen, 1980, p. 325), or "The vast majority of poor readers, however, are poor readers not because they lack decoding skill but because they are deficient in comprehension, which, as measured by standard tests of reading comprehension is largely a matter of g" (Jensen, 1980, p. 325). Certainly most reading researchers will find that these statements fail to reflect the complexity of the process analyses of reading performance that have been carried out by educational researchers and by cognitive, developmental, and educational psychologists (Just & Carpenter, 1980; Kieras, 1981; LaBerge & Samuels, 1974; Lesgold & Perfetti, 1981; Mitchell, 1982; Singer, 1982; Thibadeau, Just, & Carpenter, 1982), nor do they reflect the complex patterns of individual differences in the cognitive processes of reading that have been revealed by recent research (e.g., Carr, 1981; Curtis, 1980; Doehring, Trites, Patel, & Fiedorowicz, 1981; Perfetti & Lesgold, 1977, 1979; Singer & Crouse, 1981; Stanovich, 1980, 1982a, 1982b; Stevenson, Parker, Wilkinson, Hegion, & Fish, 1976; Vellutino, 1979). No doubt most reading researchers will find the suggestion that the explanation of reading ability variance be assigned to a global trait rather than to specific processing subskills a distinct step backward. Nevertheless, since Jensen's views are widely disseminated in both scholarly publications and in the popular press, it is perhaps advisable that reading researchers devote some attention to them. Since remarkably little actual data is cited to justify the strong claims made, the adequacy of Jensen's position needs to be evaluated empirically. One of the purposes of the present study was to provide data that contribute to such an evaluation. However, our research was also designed to yield data relevant to many other issues in the area of the development of reading ability, so a brief introduction to the structure of the entire study will precede a description of the methods.

Overview of Design and Tasks

Using first-grade children, we examined the relationships between four important determinants of reading comprehension ability: phonological awareness, decoding speed, listening comprehension, and general intelligence. Two converging measures of each of these four determinants were employed, and a reading comprehension test was administered. Our third- and fifth-grade samples were also administered converging measures of decoding speed and general intelligence, as well as a reading comprehension test. These two groups were administered only one measure of listening comprehension and did not complete the measures of phonological awareness (due to the fact that the important effects of the latter skill occur at an earlier developmental period). Thus, we were able to examine the relationships between reading comprehension, decoding speed, and intelligence in all three age groups. This was particularly important because Jensen's statements on the intelligence-reading relationship contain no indication that developmental factors may be important. That is, there is no recognition that relationships between decoding, comprehension, and intelligence may change as reading ability develops. The conjecture that there is a high correlation between reading comprehension and intelligence when word decoding is partialled out clearly needs an age specification, since that particular relationship seems a likely candidate for developmental change. Thus, it is important to note that our subjects ranged from children at the earliest stages of reading acquisition to those who had moved well beyond the initial decoding stages.

In addition to the specific hypothesis regarding the intelligence-reading relationship, the tasks administered in the present investigation allowed for the examination of many other important relationships between reading achievement and various cognitive subskills. Children in all three age groups were administered two converging measures of decoding speed and a measure of listening comprehension ability. Two intelligence measures, Raven's Progressive Matrices (RPM) and the Peabody Picture Vocabulary Test (PPVT), were also administered to all subjects. The "culture-reduced" RPM is sometimes used in conjunction with the "culture-loaded" PPVT to provide converging measures of general intelligence (Hall & Kaye, 1980). Taken together, they should account for virtually all of the reading achievement variance that can reasonably be apportioned to general intelligence.

Three additional tasks were administered to the first-grade subjects. A timed, listening cloze task was administered as a converging measure of listening comprehension. Two tasks designed to tap phonological awareness were also administered. These were included because much recent research has linked phonological awareness to early success in reading acquisition (Bradley & Bryant, 1978, 1983; Calfee, Lindamood, & Lindamood, 1973; Ehri, 1979; Fox & Routh, 1980; Golinkoff, 1978; Lewkowicz, 1980; Liberman & Shankweiler, 1979; Rozin & Gleitman, 1977; Stanovich, 1982a, 1982c; Treiman & Baron, 1981, 1983; Williams, 1980). The two phonological awareness measures were designed to tap a different subskill than the two decoding measures. The latter were timed tasks designed to assess the speed with which the subject can use phonological and visual/orthographic codes (Baron, 1979; Stanovich, 1982c) to recognize previously learned words. The former tasks are most likely tapping the phonological analysis and segmentation skills that are important in the beginning stages of reading acquisition, because they are necessary if the child is to learn to decode unknown words.

Our first-grade sample, in addition to completing more tasks, was also over twice as large as the third- and fifth-grade samples. This bias in the focus of our investigation was intentional, resulting from our interest in individual differences in the cognitive skills that are related to early reading acquisition. In light of this emphasis it is worthwhile to point out that early reading acquisition is predictive of later reading ability (Butler, Marsh, Sheppard, & Sheppard, 1982; Durkin, 1966; Stevenson et al., 1976; Thorndike, 1973-1974; Watson, Watson, & Fredd, 1982), and that the Krebs (1969) study which was apparently the source of Jensen's .68 figure employed first-grade subjects.

Finally, it should be noted that our use of Raven's Progressive Matrices as one measure of general intelligence was particularly important for assessing the conjecture that reading is "largely a matter of g," since the test is widely recognized as being highly "g-loaded" (Bingham, Burke, & Murray, 1966; Burke & Bingham, 1969; Jensen, 1980) and has often been referred to as one of the purest measures of g (Burke, 1958; Jensen, 1969, 1980; Spearman & Wynn Jones, 1950; Zaidel, Zaidel, & Sperry, 1981). Although g is not defined by performance on a single task, it seems fairer to assess the hypothesis outlined above with a test like the RPM, rather than with an omnibus aptitude measure that directly taps either the reading process itself or subskills that are critical components of reading.

There have been a few previous studies that have assessed the relationship between performance on the RPM and reading achievement, and they are not supportive of an especially strong linkage. Testing fourth-grade subjects, Kirby and Das (1977) and Knief and Stroud (1959) found correlations of .40 and .36, respectively. With sixth-grade samples, Singer and Crouse (1981) and Spiegel and Bryant (1978) found correlations of .41 and .47. Correlations as low as .20 (Weaver & Rosner, 1979) have been observed as well as correlations of .22, .24, .44, and .45 in first-grade samples (Carr, 1981; Sewall, 1979; Sewall & Severson, 1974). In a study by Tulkin and Newbrough (1968), where a sample was broken down by social class and race, values ranging from .14 to .40 were observed, although the range of the samples may have been restricted due to stratification. The largest correlations have been observed in a longitudinal study by Hall and Kaye (1980) on children in the 6-10 age range.

Across several different age comparisons, the correlations fell in the range of .46-.61 and averaged .54. In short, currently available evidence does not support the conjecture of a strong zero-order relationship between g (as measured by the RPM) and reading ability. However, little data exists relevant to the hypothesis that the relationship is strong once that decoding ability has been partialled out. Thus, this was one of the issues upon which the present research was focused.

Method

Subjects

Subjects from all three grades were recruited from classrooms in a predominantly middle-class elementary school. All testing was done in late May and early June. There were 56 first-grade subjects (32 males and 24 females). The mean age of this group in May was 6 years, 8 months. There were 18 third-grade subjects (10 males and 8 females; mean age 9 years, 1 month) and 20 fifth-grade subjects (10 males and 10 females; mean age 11 years, 3 months). All children were group administered the form of the Reading Survey test of the Metropolitan Achievement Tests that was appropriate for their age level (Form JS, Primary 1 for the first-grade children, Form JS, Elementary for the third-grade children, and Form JS, Intermediate for the fifth-grade children). The raw score on this measure was used in all of the analyses that follow. The Reading Survey test of the Metropolitan is a test of reading comprehension and does not directly test word decoding. That is, no direct tests of word analysis skills enter into the total score. The mean raw score and mean grade equivalent for the first-grade children was 41.1 and 2.6, for the third-grade children 43.5 and 4.4, and for the fifth-grade children 44.1 and 7.5. The first-grade children were also administered the Comprehension Subtest (Form 2, Primary Level A) of the Gates-MacGinitie Reading Tests. Since the results obtained with this measure were virtually identical with those obtained with the Metropolitan, it will not be discussed further. The children in the first grade received a reading program consisting of a basal series (Harcourt, Brace, Jovanovich, 1979), phonics program with a workbook (Modern Curriculum Press, 1970), and a spelling and writing program developed by their teachers.

Tasks[1]

General intelligence. The Peabody Picture Vocabulary Test was administered to the children of all three groups. Raven's Colored Progressive Matrices was administered to the first- and third-grade children, and Raven's Standard Progressive Matrices was administered to the fifth-grade children. A 60-minute time limit was used for the RPM. The raw scores on the PPVT and the RPM were used in the analyses that follow. The split-half reliabilities (Spearman-Brown corrected) of the RPM scores were .85, .85, and .94 for the first-grade, third-grade, and fifth-grade subjects, respectively.

Decoding speed. The speed with which subjects could name words and pseudowords was assessed. A pseudoword is a nonword that conforms to the orthographic and phonological structure of English. The time taken to name such stimuli is a relatively pure measure of the speed with which a subject can apply spelling-to-sound correspondence rules or analogies, since a visual or "whole-word" strategy will not be effective with pseudowords. Word naming time, on the other hand, is a more complex measure of decoding skill. It presumably reflects a combination of the skills that subjects use to decode on both a phonological and a whole-word or visual-orthographic basis. The experimental stimuli employed were 15 pseudowords (*lat, wuck, mip, pish, jun, breep, fob, rill, luss, trink, bope, sut, zock, bink, nust*) and 20 words (*go, the, in, to, stop, up, good, and, big, it, boy, look, girl, sun, red, you, what, one, down, green*). Three pseudowords (*ged, dar, cath*) and four words (*cat, went, two, was*) served as stimuli on practice trials that preceded the experimental trials which were blocked and were presented in a fixed random order. Vocal reaction time was assessed as described in Stanovich (1981). Subjects were told which stimuli type would appear and were told that their task was to name the stimuli as fast as possible. Trials on which the subject named the stimulus incorrectly were removed from the analysis, as were response times that were extreme outliers (greater than 3,000 msec or more than three standard deviations above the mean for that subject). The split-half reliabilities (Spearman-Brown corrected) of the naming times for pseudowords were .80, .96, and .92, for the first-grade, third-grade, and fifth-grade subjects, respectively. The corresponding reliabilities for the word naming times were .94, .90, and .91.

Listening comprehension. All three groups of subjects completed a task in which they answered questions about paragraphs that had been presented auditorally. The stimuli for each group were three paragraphs taken from the 1972 Revised Edition of the Diagnostic Reading Scales. Subjects received 1 point for each question answered correctly, and each subject's score on this task was the total number of correct answers summed across the three paragraphs. The maximum possible score was 23 for the first- and third-grade subjects, and 24 for the fifth-grade subjects. The three paragraphs were all tape recorded and presented in a fixed order of increasing difficulty. Following the presentation of each paragraph the tape recorder was turned off, the experimenter read the questions to the subject one by one, and the subject's oral responses were written down verbatim. The split-half reliability (Spearman-Brown corrected) of the listening comprehension scores was .68 for the first-grade subjects, .71 for the third-grade subjects, and .83 for the fifth-grade subjects.

The first-grade children were given an additional test of listening comprehension that involved measuring the speed with which they produced a cloze response to a single incomplete sentence. The stimuli employed in the task were 63 sentences that had been used in studies of context effects on word recognition speed (Stanovich, West, & Feeman, 1981; West & Stanovich, 1978). The subjects were told that the experimenter would be reading sentences to them, that the sentences would have their last word missing, and that the last word they would hear would be *the*. Their task was to try to produce the missing word as fast as they could after hearing the word *the*. They were told that their word must make the sentence "make sense" and that their time was being recorded, so they should respond as soon as possible. The mean reaction time of each subject's appropriate completions was calculated (i.e., the reaction times of inappropriate completions [20% of the responses] were not included in the calculation of the mean response time). The split-half reliability (Spearman-Brown corrected) of the cloze production time was .67. Production time was used as the dependent measure from this task rather than the number of appropriate completions for two reasons. First, the latter measure was not more highly correlated with reading ability, so predictive power was not sacrificed. Second, it was thought that the former measure was more likely to tap skills different from the listening comprehension measure, since it emphasized the ability to use context to generate meaningful interpretations rapidly and immediately. In contrast, the listening comprehension measure taps memory for information that was comprehended at an earlier point in time.

Phonological awareness. The first-grade subjects completed two tasks designed to assess the degree of their phonological awareness. The strip initial consonant task (derived from the work of Calfee, Chapman, & Venezky, 1972) employed nine words as stimuli on the experimental trials (*pink, man, nice, win, bus, pitch, car, hit, pout*). The children were told to listen closely to the experimenter who would pronounce one word. Subjects were told that if they would remove the first sound of the word pronounced by the experimenter who would pronounce one word. Subjects were told that if they would remove the first sound of the word pronounced by the experimenter they would find that a new word remained. The example, *ball-all* was provided and explained. Following three further practice trials the nine experimental trials were administered and the subject's responses were recorded. The total number of correct responses was the subject's score on this task. The split-half reliability (Spearman-Brown corrected) of the scores on the task was .81.

The second task was a phonological oddity task. The procedure and stimuli were similar to those used in a study by Bradley and Bryant (1978). The experimental stimuli were 18 sets of four words. Within each set of words three words contained a common sound that the fourth word lacked. The subject was to name the odd word in the set. Six sets had words that shared the same initial phoneme (e.g., *girl, give, pat, go*), six sets had a common medial phoneme (e.g., *bet, nut, get, let*), and six sets had a common final phoneme (e.g., *bend, mend, lend, sent*). Following a demonstration and several practice trials the 18 experimental trials were administered. Trials were blocked according to the part of the word that contained the common sound, and subjects were instructed prior to each block as to which part of the word would contain the common sound. The words were presented on a tape recorder which was turned off after each trial while the subject's response was written down. The subject's score on this task was the total number of correct responses. The split-half reliability (Spearman-Brown corrected) of the scores on the task was .60.

General Procedure

The tasks were administered in separate sessions on separate days with the following exceptions: All subjects completed the word and pseudoword naming tasks in the same session. The first-grade subjects completed the strip initial consonant and cloze production time tasks in the same session. All tasks were individually administered except the RPM, which was given in groups of four. All of the children had completed other cognitive tasks that were part of another investigation.

Results

First-Grade Children

Table 2 displays the correlations between all of the tasks administered to the first-grade subjects. Note when interpreting Table 2 that superior performance on the timed measures (pseudoword naming, word naming, and cloze production) is indicated by lower scores, and thus their correlations with Metropolitan scores will be negative. Scores on the Metropolitan Achievement Test were significantly correlated with all of the variables except cloze production time. Pseudoword naming time had the highest correlation with the Metropolitan, followed by the two phonological awareness measures (the oddity and strip initial consonant tasks). The RPM displayed a correlation of .33 with Metropolitan. The two measures of phonological awareness and the two measures of decoding speed displayed moderate correlations (.52 and .54, respectively). The correlation between

Table 2 Intercorrelations of all variables for the first-grade subjects

Variables	1	2	3	4	5	6	7	8	9
1. Metropolitan		.33*	.34*	.43**	.44**	-.52**	-.39**	.37**	-.18**
2. RPM			.22	.29*	.29*	-.15	-.15	.09	-.16
3. PPVT				.20	.07	-.21	-.27*	.33*	-.11
4. Strip initial consonant					.52**	-.24	-.39**	.35**	-.24
5. Phonological oddity task						-.33*	-.35**	.20	-.34*
6. Pseudoword naming time							.54**	-.13	.37**
7. Word naming time								-.18	.27*
8. Listening comprehension									-.26
9. Cloze production time									
Mean	41.1	22.1	68.9	7.7	12.5	1939.7	912.0	15.3	972.7
Standard Deviation	11.5	4.9	6.6	2.4	3.4	617.7	219.3	4.3	432.6

*$p < .05$
**$p < .01$

the RPM and the PPVT was .22 and the correlation between listening comprehension and cloze production time was -.26.

The relationships among the variables were explored via a series of grouped hierarchical multiple regression analyses (Cohen & Cohen, 1975). The predictor variables were paired and analyzed as sets. The oddity and strip initial consonant tasks were conceptualized as measures of phonological awareness (PA), the pseudoword and word naming tasks as measures of decoding speed (DS), the listening comprehension and cloze production time tasks as measures of general language comprehension ability (LCA), and the RPM and PPVT as measures of general intelligence (GI). These sets of variables were entered in several different fixed orders into a series of multiple regression analyses with Metropolitan scores as the criterion variable. The results of these analyses are presented in Table 3.

The results of a "bottom-up" regression sequence are illustrated in Order A. Here, the more specifically reading-related sets of variables are entered before the more global measures. Phonological awareness measures were entered first and not surprisingly, given previous research, produced a substantial multiple correlation (.494). This skill probably partially determines the child's initial success at breaking the spelling-to-sound code and thus his or her ability to identify unknown words. The decoding speed variables explained a significant amount of additional variance (14.2%) beyond that accounted for by phonological awareness. This finding supports previous theoretical explanations that the speed of decoding, in addition to accuracy, is important due to short-term memory and other processing limitations that place constraints on how rapidly word meanings must be identified in order to sustain adequate comprehension (LaBerge & Samuels, 1974; Lesgold & Perfetti, 1978; Perfetti & Hogaboam, 1975; Perfetti & Lesgold, 1977, 1979; Stanovich, 1980, 1981, 1982a). After the phonological awareness and decoding speed measures were entered, the language comprehension variables accounted for 6.5% of the variance ($.05 < p < .10$) and the general intelligence variables accounted for an additional 4.3% of the variance (not significant).

In Order B the general intelligence variables are entered before the specifically reading-related measures. The former have a multiple correlation of .431 with Metropolitan scores. The phonological awareness and decoding speed measures made sizable and significant contributions to explaining reading comprehension variance after general

Table 3 Summary of hierarchical multiple regressions by sets for first-grade subjects

Order		Pair of Variables	R	Increase in R^2
A	1.	PA	.494	.244**
	2.	DS	.621	.142**
	3.	LCA	.671	.065
	4.	GI	.703	.043
B	1.	GI	.431	.186**
	2.	PA	.579	.149**
	3.	DS	.666	.109*
	4.	LCA	.703	.050
C	1.	GI	.431	.186**
	2.	LCA	.510	.074
	3.	PA	.605	.105*
	4.	DS	.703	.129**
D	1.	PA	.494	.244**
	2.	DS	.621	.142**
	3.	GI	.666	.058
	4.	LCA	.703	.050
E	1.	GI	.431	.186**
	2.	DS	.614	.190**
	3.	PA	.666	.068
	4.	LCA	.703	.050
F	1.	DS	.534	.285**
	2.	GI	.614	.091*
	3.	LCA	.666	.068
	4.	PA	.703	.050
G	1.	LCA	.380	.144*
	2.	PA	.546	.153**
	3.	DS	.671	.153**
	4.	GI	.703	.043
H	1.	LCA	.380	.144*
	2.	GI	.510	.115*
	3.	PA	.605	.106
	4.	DS	.703	.129**

Note. PA = phonological awareness measures
DS = decoding speed measures
GI = general intelligence measures
LCA = language comprehension ability measures
*$p < .05$
**$p < .01$

intelligence had been accounted for. The proportion of variance in Metropolitan scores uniquely explained by the language comprehension measures was .050.

Order C illustrates that even after both the general intelligence and language comprehension variables are entered into the equation, the phonological awareness and decoding speed variables still made significant and sizable contributions to predictive accuracy. Order D illustrates the independent contribution of general intelligence (.058) when entered after phonological awareness and decoding speed measures were already in the equation. Orders E and F help to elucidate the relationship between measures of general intelligence and decoding speed as predictors of reading comprehension. When the former are entered first the latter account for an additional 19.0% of the variance. When the decoding speed measures are entered first, general intelligence variables account for an additional 9.1% of the variance. From Order F a measure of the unique reading comprehension variance associated with phonological awareness (.050) is also obtained. This is similar to the unique variance associated with general intelligence (.043) and language comprehension ability (.050). However, the unique variance associated with decoding speed is much larger (.129), indicating that these measures are explaining a considerable proportion of reading variance that is not being tapped by any of the other sets of variables. This result suggests the importance of assessing decoding speed, as well as accuracy, when examining the subskills that determine reading achievement. Finally, Orders G and H help to elucidate the relationships among the variables when the language comprehension measures are entered first.

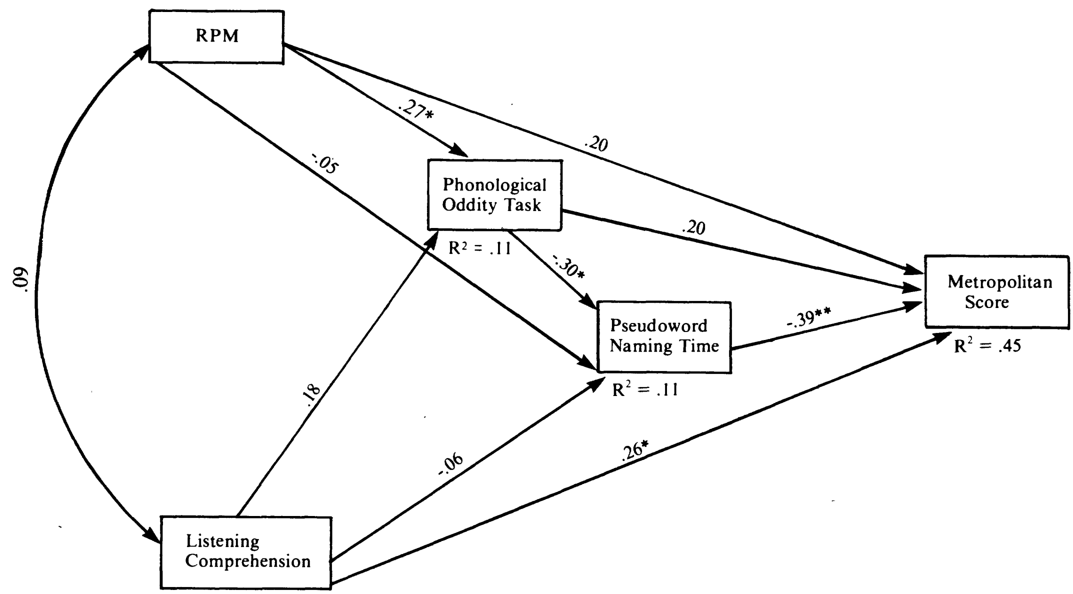
Figure 1 displays a path diagram in which Metropolitan scores are predicted from performance on the pseudoword naming, phonological oddity, RPM, and listening comprehension tasks. Path analysis is not a technique for *discovering* causal relationships but instead is a procedure that helps the researcher explore the implications of a previously specified causal model (Kenny, 1979; Kerlinger & Pedhazur, 1973; Wolfle, 1980). That is, given a theoretically derived causal model, path analysis allows the investigator to elucidate the structure of the relationships among the variables in the model. In the model displayed in Figure 1 the RPM and listening comprehension measures are purely exogenous variables considered causally prior to the phonological awareness measure, which was considered causally prior to pseudoword decoding speed. The standardized path coefficients are estimated from a series of multiple regressions in which each variable in turn becomes the criterion variable for all variables that are causally prior in the model. The final regression indicated that only pseudoword naming time and listening comprehension made significant independent contributions to predicting Metropolitan scores. Performance on the phonological oddity task made a significant independent contribution to predicting pseudoword naming time, and RPM performance was a significant predictor of phonological oddity scores. Thus, within this model, decoding speed and listening comprehension appear to have direct influences on reading comprehension, but the effect of phonological awareness appears to be indirect, through its influence on decoding speed (see Lomax, 1982, for a similar finding).

In order to assess the hypothesis that reading comprehension is strongly related to general intelligence once children are matched on decoding ability, several partial correlations were calculated. The correlation between reading comprehension and the general intelligence set with decoding speed measures partialled out was .36. With both phonological awareness and decoding speed measures partialled out (which should leave the reading variance "free" of decoding factors) the partial correlation was .31. The partial correlations employing the RPM alone were .30 and .21. These results do not support the practice of equating reading ability with g, even when the considerable variance associated with decoding is removed.

As a further method of exploring the nature of the relationships among the variables for the first-grade children, several methods of factor analysis were carried out on the data.

Figure 1

Path analysis predicting metropolitan performance from scores on the pseudoword naming, phonological oddity, RPM, and listening comprehension tasks. R^2 = percent of variance accounted for on each criterion measure by all preceding predictor variables. Standardized beta weights are shown on each path. * = $p < .05$; ** = $p < .01$.



Different techniques of commonality estimation (including a principal-components solution) were tried, and several orthogonal and oblique rotations were computed. The results of a typical solution are displayed in Table 4. In this analysis, the number of factors to be extracted from the unreduced correlation matrix was determined by the eigenvalue greater than one criterion. Squared multiple correlations were then used as commonality estimates, iteration to a stable solution was carried out, and a varimax rotation was employed. The three factors retained accounted for 46.3% of the total variance. The general pattern of factor loadings obtained by other factoring methods was highly similar to that displayed in Table 4. The only moderate discrepancy concerned the RPM, which in principal-components analyses and in oblique rotations tended to load relatively more highly on Factor 1 (that is, with the phonological awareness variables). Note also that the values of the timed variables have been multiplied by -1 for the analysis displayed in Table 4, so that the loadings would be positive and thus easier to interpret.

Metropolitan performance loaded moderately on all three factors. The loadings of the other eight variables seemed to point to a meaningful interpretation of the three factors. Factor 1 appears to reflect phonological awareness, loading highly on the strip initial consonant and phonological oddity tasks. Factor 2 clearly appears to be decoding speed. The third factor has the highest loadings on the PPVT and listening comprehension. This grouping suggests Factor 3 as a general receptive language ability or a general verbal

Table 4 Factor loadings for all variables after varimax rotation

Variable	Factor 1	2	3
Metropolitan	.407	.387	.443
RPM	.320	.093	.227
PPVT	.028	.149	.658
Strip initial consonant	.640	.138	.291
Phonological oddity task	.780	.237	.014
Pseudoword naming time	.132	.983	.107
Word naming time	.306	.479	.239
Listening comprehension	.265	.056	.473
Cloze production time	.306	.292	.099
Percent of total variance accounted for	17.35	17.10	11.86
Percent of common variance retained by the factors	37.46	36.93	25.61

comprehension ability (see Sternberg & Powell, 1983). Thus, the factor analysis partitioned the variables slightly differently than the pairings that were the basis of the regression analyses. While the factor analysis uncovered phonological awareness and decoding speed as factors, the loadings of the two intelligence measures (RPM and PPVT) did not converge at all. Likewise, cloze production time did not load with listening comprehension, but had its highest loading on the phonological awareness factor. Of course, as in all multivariate analyses of this type, the structure of the relationships among the variables is partially determined by the variables included in the analysis (for example, the "problem-solving" aspects of the phonological awareness tasks may have partially contributed to the fact that the RPM loaded most heavily on Factor 1) and the different reliabilities of the tasks. Nevertheless, a tentative conclusion may be that a common interpretation of the PPVT as a measure of receptive vocabulary (i.e., as a language variable, see Johnson, 1981) appears to be a more useful interpretation of the present results, rather than its alternative (although certainly not mutually exclusive) interpretation as a highly g-loaded test (Jensen, 1980). Such an interpretation is similar to Carr's (1981) discussion of the multivariate study of Singer and Crouse (1981), where the RPM (interpreted as a measure of predictive reasoning) and decoding skill were viewed as determinants of vocabulary knowledge, which was in turn interpreted as a predictor of reading comprehension.

A new hierarchical regression analysis by sets was run grouping the PPVT and listening comprehension as measures of general verbal comprehension ability. Entering phonological awareness measures, decoding speed measures, and verbal comprehension measures sequentially produced R^2 increments of .244, .142, and .068. These six variables produced a multiple correlation with reading comprehension of .673. Entering the RPM produced an additional nonsignificant R^2 increment of .020.

Third-Grade Children

Table 5 displays the correlations between all of the tasks administered to the third-grade subjects. The PPVT had the highest correlation with Metropolitan scores, followed by listening comprehension. The correlation between the RPM and the Metropolitan (.42) and between pseudoword naming time and the Metropolitan (-.41) were both marginally significant ($p < .10$). The two measures of decoding speed were highly correlated (r = .70). The PPVT was significantly correlated with both listening comprehension (r = .65) and the RPM (r = .52).

The relationships among the variables were explored via a series of hierarchical multiple regression analyses involving the RPM, the listening comprehension task, and the pseudoword naming task (i.e., measures of general intelligence, listening comprehension, and decoding speed) as predictor variables and the Metropolitan scores as the criterion variable. Regression Order A indicates that after the RPM is entered into the equation, pseudoword decoding speed accounts for an additional 18.5% of the variance, and listening comprehension 6.5% of the variance when entered last. Order B indicates that after pseudoword naming time is entered, listening comprehension accounts for an additional 18.8% of the variance, and the RPM 6.7% of the variance when entered

Table 5 Intercorrelations of all variables for the third-grade subjects

Variable	1	2	3	4	5	6
1. Metropolitan		.42	.59*	-.41	-.32	.52*
2. RPM			.52*	.04	-.01	.45
3. PPVT				-.01	.00	.65**
4. Pseudoword naming time					.70**	-.26
5. Word naming time						-.24
6. Listening comprehension						
Mean	43.5	27.7	78.8	991.7	689.9	14.5
Standard Deviation	8.1	3.3	10.6	315.4	123.8	4.6

*$p<.05$
**$p<.01$

last. Order C illustrates that the RPM accounts for 18.9% of the variance after pseudoword decoding time is entered into the equation. From Order D it is apparent that 14.2% of the variance in reading comprehension that is independent of RPM is explained by listening comprehension, and that the unique variance associated with pseudoword decoding time (10.9%) is somewhat larger than that associated with listening comprehension (6.5%) or the RPM (6.7%). Orders E and F illustrate the predictive contributions of RPM and pseudoword decoding after the variance explained by listening comprehension has been accounted for.

With pseudoword naming time partialled out, the correlation between Metropolitan scores and RPM was .48, the same correlation that was obtained for Metropolitan scores and listening comprehension. With the RPM partialled out, the correlation between Metropolitan scores and pseudoword naming time was -.47, and the correlation between Metropolitan scores and listening comprehension was .42. With listening comprehension partialled out, the correlation between Metropolitan scores and pseudoword naming time was .33, and the correlation between Metropolitan scores and RPM performance was .24.

A hierarchical regression analysis by sets was conducted in which the RPM and PPVT were entered first as measures of general intelligence and accounted for 36.7% of the variance. Word and pseudoword naming time were then entered as measures of decoding speed and accounted for an additional 17.3% of the variance. When the order was reversed, the decoding measures initially accounted for 17.1% of the variance, and the general intelligence measures an additional 36.9%. The pattern of results in these analyses is predictable from the correlations in Table 5, where it is apparent that the general intelligence and decoding measures are independent of

Table 6 Summary of hierarchical multiple regression analyses for third-grade subjects

Order	R	Increase in R^2
A 1. RPM	.417	.174*
2. PDS	.599	.185*
3. LC	.651	.065
B 1. PDS	.411	.169*
2. LC	.597	.188*
3. RPM	.651	.067
C 1. PDS	.411	.169*
2. RPM	.599	.189*
3. LC	.651	.065
D 1. RPM	.417	.174*
2. LC	.562	.142*
3. PDS	.651	.108
E 1. LC	.525	.276**
2. PDS	.597	.081
3. RPM	.651	.067
F 1. LC	.525	.276**
2. RPM	.562	.040
3. PDS	.651	.108

Note. RPM = Raven's Progressive Matrices
PDS = Pseudoword Decoding Speed
LC = Listening Comprehension
*$p<.10$
**$p<.05$

each other. Finally, a hierarchical regression was run where listening comprehension was entered first, and accounted for 27.6% of the variance. The two general intelligence measures (PPVT and RPM) explained an additional 11.7% of the variance, and the unique variance explained by the decoding speed measures was 14.7%.

Fifth-Grade Children

Table 7 displays the correlations between all of the tasks administered to the fifth-grade subjects. Scores on the Metropolitan Achievement Test were significantly correlated with all of the variables. Pseudoword naming time had the highest correlation with Metropolitan scores, followed by word naming time. The correlation between the RPM and the Metropolitan was .56. The two measures of decoding speed were highly correlated (r = .85). The PPVT was significantly correlated with both listening comprehension (r = .63) and the RPM (r = .52).

The relationships among the variables were explored via a series of hierarchical multiple regression analyses involving the RPM, the listening task, and the pseudoword naming task as predictor variables (see Table 8). Orders A and B illustrate that the listening comprehension and the RPM account for little additional variance after pseudoword naming time is entered into the equation (perhaps a not surprising outcome given the high correlation between the latter variable and Metropolitan scores). Order C indicates that, when entered after the RPM, pseudoword naming time accounts for an additional 37.8% of the variance, and that listening comprehension adds virtually nothing after the other two variables are entered. Listening comprehension accounts for an additional 12.8% of the variance after the RPM is entered, and pseudoword naming time explains a statistically significant 25.2% of the variance not accounted for by the other two variables (see Order D). In the last two orders, where listening comprehension is entered first, pseudoword naming time accounts for an additional 34.2% of the variance, and the RPM accounts for an additional 9.1% of the variance.

With pseudoword naming time partialled out, the correlation between Metropolitan scores and the RPM was -.06 and the correlation between Metropolitan scores and listening comprehension was .08. With the RPM partialled out, the correlation between Metropolitan scores and pseudoword naming time was -.74 and the correlation between Metropolitan scores and listening comprehension was .43. With listening comprehension partialled out, the correlation between Metropolitan scores and pseudoword naming time was -.73, and the correlation between Metropolitan scores and RPM performance was .37.

A hierarchical regression analysis by sets was conducted in which the RPM and PPVT were entered first as measures of general

Table 7 Intercorrelations of all variables for the fifth-grade subjects

Variables	1	2	3	4	5	6
1. Metropolitan		.56*	.58**	-.83**	-.73**	.59**
2. RPM			.52*	-.70**	-.50*	.51*
3. PPVT				-.64**	-.61**	.63**
4. Pseudoword naming time					.85**	-.67**
5. Word naming time						-.51*
6. Listening comprehension						
Mean	44.1	38.4	87.2	734.7	576.4	12.0
Standard Deviation	11.1	6.4	7.2	192.9	81.3	5.8

*$p < .05$
**$p < .01$

Table 8 Summary of hierarchical multiple regression analyses for fifth-grade subjects

Order		R	Increase in R^2
A	1. PDS	.831	.691**
	2. LC	.832	.002
	3. RPM	.833	.001
B	1. PDS	.831	.691**
	2. RPM	.832	.001
	3. LC	.833	.002
C	1. RPM	.560	.314*
	2. PDS	.832	.378**
	3. LC	.833	.002
D	1. RPM	.561	.314*
	2. LC	.664	.128
	3. PDS	.833	.252**
E	1. LC	.592	.351**
	2. PDS	.832	.342**
	3. RPM	.833	.001
F	1. LC	.592	.351**
	2. RPM	.664	.091
	3. PDS	.833	.252**

Note. RPM = Raven's Progressive Matrices
PDS = Pseudoword Decoding Speed
LC = Listening Comprehension
*$p < .025$
**$p < .01$

intelligence and accounted for 42.5% of the variance. Word and pseudoword naming time were then entered as measures of decoding speed and accounted for an additional 27.2% of the variance. When the order was reversed, the decoding measures initially accounted for 69.2% of the variance, and the general intelligence measures an additional 0.5%. Finally, a hierarchical regression was run where listening comprehension was entered first and accounted for 35.1% of the variance. The two general intelligence measures explained an additional 12.3% of the variance, and the unique variance explained by the decoding speed measures was 22.4%.

General Discussion

Reading Comprehension, Intelligence, and Decoding

We will first evaluate the implications of our results for hypotheses concerning the zero-order relationship between general intelligence and reading comprehension, and then consider how these conclusions are modified by taking decoding skill into account. Consistent with previous research (Hall & Kaye, 1980; Kirby & Das, 1977; Knief & Stroud, 1959; Sewall, 1979; Singer & Crouse, 1981; Spiegal & Bryant, 1978; Tulkin & Newbrough, 1968), the relationship between the RPM and reading comprehension was modest. The correlations were .33, .42, and .56 for the first-grade, third-grade, and fifth-grade subjects, respectively, and thus appeared to increase with age (although no pair of correlations was significantly different). The magnitudes of these correlations do not justify the statement that "Scores on reading comprehension are very highly correlated with IQ, even with purely nonverbal IQ" (Jensen, 1981b, p. 236).

Although the RPM is the "purest" single measure of g, a more comprehensive assessment of the construct is achieved by combining several intelligence measures. The RPM and PPVT, included in our battery of tasks, are an ideal pair of measures because they tap two very different points on the "culture-reduced"/"culture-loaded" intelligence test spectrum (also, according to the conceptualization of Cattell, 1963, the tasks tap two somewhat different aspects of general intelligence: fluid and crystalized intelligence). These two measures of general intelligence accounted for 18.6% of the variance in reading comprehension ability in the first-grade sample, 36.7% of the variance in the third-grade sample, and 42.5% of the variance in the fifth-grade sample. In summary, while there is no question that general intelligence is a moderate predictor of reading ability, the strength of the relationship clearly does not justify the conclusion that reading comprehension is "largely a matter of g." The latter statement implies a degree of relationship that is inconsistent with the results obtained in the present study,[2] ignores developmental trends and, particularly as regards early reading acquisition, fails to recognize the importance of many critical subskills that are only weakly related to measures of general intelligence.

Several of the findings relate to the hypothesis that differences in reading comprehension are totally determined by g once decoding differences are controlled. The correlation between the RPM and Metropolitan scores with pseudoword naming time partialled out was .30 in the first-grade sample (similar correlations were obtained when the phonological awareness measures were also partialled, and when the pair of general intelligence measures were correlated with reading comprehension), .48 in the third-grade sample, and -.06 in the fifth-grade sample. After the two decoding speed measures were entered into the regression equation, the two general intelligence measures (RPM and PPVT) accounted for an additional 9.1% of the variance in the first grade, an additional 36.9% in the third grade, and an additional 0.5% in the fifth grade. Thus, the hypothesis receives some support from the data of the third-grade children, but is a completely inaccurate conceptualization of the relationships among the predictors of reading ability in the first- and fifth-grade samples.

The Relative Uniqueness of Decoding Speed

One striking finding that appeared in the data of all three groups of children was the relative ability of the decoding speed measures to account for reading comprehension variance not explained by the other measures. In the first-grade data 12.9% of the variance in reading comprehension was uniquely asssociated with decoding speed. Not only is this uniqueness figure over twice as large as that of any of the other pairs of variables, but it is remarkably high when one considers what is already in the regression equation. Two standardized, reliable measures of general intelligence (RPM and PPVT) had been entered along with two listening comprehension measures, one involving recall of information and the other the production of a meaningful response. In addition, two different measures of phonological awareness had been entered. These latter tasks were presumably tapping skills relevant to developing decoding accuracy, but were far from direct measures of the *speed* with which a known word could be decoded (correlations with the decoding speed measures averaged -.33). Thus, not only is decoding speed relatively independent of general intelligence (average correlation -.20) and listening comprehension (average correlation of .24 disregarding sign) at this age, but it is not accurately tapped by nonspeeded phonological awareness tasks.

These findings from the first-grade sample are particularly supportive of theories that hypothesize that the ability to rapidly decode a word into a phonological code that can be held in short-term memory will be a determinant of reading comprehension proficiency (e.g., Lesgold & Perfetti, 1978; Perfetti & Lesgold, 1977). Such theories hypothesize that during reading, sequences of words must be held in short-term memory while comprehension processes operate on the words to integrate them into a meaningful conceptual structure that can be stored in long-term memory. Comprehension will break down if codings of newly perceived words are not provided to short-term memory before representations of words with which they are to be integrated have been lost.

From the analyses of the third- and fifth-grade data presented in Tables 6 and 8 it is clear that pseudoword naming time accounted for more unique variance than listening comprehension or the RPM. Also, after the listening comprehension task and the two general intelligence measures were entered into the regression equation, the two decoding speed measures accounted for an additional 14.7% of the variance in the third-grade metropolitan scores and an additional 22.4% of the variance in the fifth-grade metropolitan scores.

Determinants of Early Progress in Reading

A number of partially overlapping subskills and abilities contributed to early reading progress in the first-grade sample. It should be noted that the conclusions that follow are not dependent on any one particular analysis, because the results of several different multiple regressions, factor analyses, and path analyses all converged on the same set of conclusions. All of the variables except cloze production time had statistically significant correlations with Metropolitan scores. Aside from the correlations involving the Metropolitan, the highest correlations in the matrix were between tasks tapping a similar ability (the .52 correlation between the two phonological awareness tasks and the .54 correlation between the two decoding speed measures). The average correlation (ignoring sign) between measures of different abilities was .24, indicating a substantial degree of independence among the skills measured, all of which contributed to predicting variance in reading comprehension. This finding is reminiscent of the pattern of correlations obtained by Stevenson et al. (1976) using a different battery of tasks. The interpretation of early progress in reading comprehension as determined by several relatively independent abilities was also supported by the results of the factor analyses. Across several different types of analyses the patterns of factor loadings were consistent. Reading comprehension consistently loaded relatively equally on all three factors (which were interpreted as phonological awareness, decoding speed, and verbal comprehension).

The pair of decoding speed measures displayed the largest multiple correlation with the Metropolitan (.534), followed by the phonological awareness measures (.494), general intelligence (.431), and general language comprehension (.380). The decoding speed measures accounted for the largest amount of variance not explained by other variables (12.9%), and this was the only unique variance estimate to attain statistical significance. The considerable degree of specificity in the set of variables is indicated by the fact that every pair of variables (with two exceptions, language comprehension entered after general intelligence and phonological awareness), when entered second into the equation after every other pair of variables, accounted for an additional portion of the variance that was statistically significant. The three factors identified by the factor analyses also displayed considerable independence. When three variable sets formed by the pair of variables with the highest loading on each factor were formed and submitted to hierarchical regression analyses, the unique variance accounted for by each was at least marginally significant. Phonological awareness (the strip initial consonant and oddity tasks) accounted uniquely for 6.6% of the variance ($p < .10$), decoding speed (word and pseudoword naming time) for 11.1% of the variance ($p < .05$), and verbal comprehension (PPVT and listening comprehension) for 6.7% of the variance ($p < .10$).

In summary, there is evidence for the importance of three relatively independent abilities in predicting early reading progress. The results support multiple-factor theories of individual differences in reading ability (see Carr, 1981; Singer, 1982; Stanovich, 1982a, 1982b) rather than univariate or single-factor approaches. Even at this early stage of the acquisition of reading skill, there is evidence for the importance of verbal comprehension ability, a general ability that will increase in importance as reading skill develops (Curtis, 1980; Daneman & Carpenter, 1980; Jackson & McClelland, 1979). Phonological awareness also emerged as a separate predictor, explaining components of reading skill that were independent of those accounted for by general verbal comprehension ability. It is likely that phonological awareness underlies the ability to segment and analyze the speech stream, and the latter processes are important in determining early success at decoding unknown words (Calfee et al., 1972, 1973; Fox & Routh, 1980; Goldstein, 1976; Gough & Hillinger, 1980; Helfgott, 1976; Liberman, 1973; Liberman, Shankweiler, Fischer, & Carter, 1974; Lomax, 1982). However, in addition to the mere knowledge of the spelling-to-sound correspondence rules, it appears to be important to develop the ability to rapidly apply the rules, because decoding *speed* emerged as a separate predictor independent of phonological awareness. This finding appears to provide strong support for reading theories that place emphasis on the notion of limited capacity (e.g., LaBerge & Samuels, 1974; Lesgold & Perfetti, 1978; Perfetti & Lesgold, 1977; Perfetti & McCutchen, 1982; Stanovich, 1980), that is, theories that emphasize that words must be recognized rapidly (in order to provide sufficient word meanings for comprehension processes operating on activated information in short-term memory) and automatically (to free cognitive capacity for allocation to comprehension processes, rather than to lower level recognition processes).

Finally, while the general intelligence measures were significantly correlated with reading comprehension, their multiple correlation (.431) was quite moderate, and was not as high as that displayed by the pair of phonological awareness variables and the pair of decoding speed variables. The intelligence measures did not appear to have a predictive advantage over other variables that are more intepretable in terms of current process models of reading. It appears that our understanding of early reading progress will not be enhanced by substituting notions of general intelligence for a process analysis of individual differences in reading ability. This would be particularly inappropriate at the present time, when research programs based on the latter paradigm have begun to yield a convergence of ideas on the causes of early reading failure (Carr, 1981; Doehring et al., 1981; Stanovich, 1980, 1982a, 1982b; Vellutino, 1979).

Developmental Trends

One trend that is apparent in comparing Tables 2, 5, and 7 is that the skills and abilities measured in the present study become increasingly interrelated as the age of the children increases. As mentioned in the previous section, measures of different abilities were relatively independent in the first grade. By the third grade, the interrelationships between the intelligence and listening comprehension measures had increased, but performance on these tasks was still relatively independent of performance on the decoding speed tasks. In the fifth grade, performance on all of the tasks was moderately to highly correlated. While it is true that the reliabilities of both the experimental tasks and the standardized tests increase slightly from first to fifth grade, the developmental trend toward increasing interrelationships among the tasks could not have been entirely due to changes in the reliabilities of the tasks. A similar developmental trend is reported by Curtis (1980; also compare Stevenson et al., 1976, to Jackson & McClelland, 1979), and Guthrie (1973) reported that the intercorrelations in a battery of tasks given to groups of skilled and less skilled readers were much higher in the former. One might hypothesize, as did Guthrie (1973), that at the more advanced levels of reading skill, mutual facilitation among the subskills of reading may increase the correlations between them.

The correlations of reading comprehension with the PPVT, RPM, and listening comprehension task increased from first to third and from third to fifth grade. The results from the latter task are consistent with the trends reported by Curtis (1980) and with the theoretical arguments of Sticht (1979). The results from the two decoding speed tasks displayed a different pattern. The correlations with reading comprehension decreased from first to third grade and then increased markedly in fifth grade. The decrease in the third grade is not due to changes in task reliabilities or to subject variability, so the explanation for it is not immediately apparent.

The developmental trend in the relationships between intelligence and decoding speed as predictors of reading comprehension is reasonably predictable from the trends in the zero-order correlations. In the first and fifth grade the general intelligence measures account for little additional variance after decoding speed measures have been entered into the regression equation, but in the third grade the additional variance explained by general intelligence is substantial. A similar pattern is apparent in the correlation between the RPM (or the multiple correlation with both intelligence measures) and reading comprehension with the decoding speed measures partialled out. This correlation was .30, .48, and -.06 across increasing grade levels. Thus, when differences in decoding speed are removed, the remaining variance in reading comprehension is fairly strongly correlated with intelligence in the third grade, but not in the first and fifth grades (of course, in the case of the fifth grade, the reliable variance remaining after decoding speed is partialled is probably not great).

Combining the conclusions of this section with those of the previous section we might outline the following tentative hypothesis: While reading is dependent on listening comprehension ability at all ages, this relationship becomes stronger at the higher levels of reading skill. At the early stages of reading acquisition there are other independent and equally important determinants of initial reading progress, factors that may initiate a causal chain of achievement deficits. For example, phonological awareness is probably causally related to the early acquisition of decoding skills (Bradley & Bryant, 1978, 1983; Fox & Routh, 1976; Goldstein, 1976; Lomax, 1982; Mann, 1981; Perfetti, Beck, & Hughes, 1981; Stanovich, 1982a, 1982c; Treiman & Baron, 1981, 1983). Inadequate decoding skills result in unrewarding early reading experiences that lead to less involvement in reading-related activities (a substantial practice differential between skilled and less skilled readers is apparent as early as January of the first-grade year, see Biemiller, 1977-1978). Lack of exposure and practice on the part of the less skilled readers leads to a failure to develop automaticity and speed at the word recognition level. Slow and capacity-draining word recognition processes require capacity that should be allocated to comprehension processes (Blanchard, 1980; Stanovich, 1980). As a result, reading for meaning is hindered, unrewarding reading experiences multiply, practice is avoided or merely tolerated without real cognitive involvement, and the downward spiral continues. Additionally, since reading as a specific language ability is probably linked with other language skills in relationships characterized by reciprocal causation, the interactive facilitation of verbal abilities fails to occur.

Concluding Speculations, Caveats, and Cautions

The speed of early reading acquisition is substantially correlated with reading performance later in life (e.g., Butler et al., 1982; Durkin, 1966; Satz, Taylor, Friel, & Fletcher, 1978; Stevenson et al., 1976; Thorndike, 1973-1974; Watson, Watson, & Fredd, 1982; Yule, 1973). Thus, uncovering the early determinants of reading acquisition will contribute to the explanation of reading failure át the more advanced levels of schooling, a problem that has drawn national attention. The data presented here (and other converging data, see Carr, 1981; Curtis, 1980; Singer, 1982; Stanovich, 1982a, 1982b; Stevenson et al., 1976) suggest that early reading acquisition is related to several different sets of skills that are relatively independent of each other and of general intelligence measures at that age. Thus, "single-factor" theories of reading failure are rejected and "multiple-cause" theories are supported (see Carr, 1981; Singer, 1982).

There are probably many different reasons why the correlation between reading comprehension and general intelligence increases with age, and none of the explanations are mutually exclusive. First, any intelligence-achievement correlation is probably characterized by reciprocal causation. Although intelligence is commonly seen as a cause of achievement, alternative explanations of the relationship are possible (Coles, 1978; Das, Kirby, & Jarman, 1979; Doehring et al., 1981; McCandless, Roberts, & Starns, 1972; McClelland, 1973; Singer, 1977), and some investigators have explicitly emphasized the "boot strapping" effect that achievement (particularly in a skill like reading) may have on intelligence (Baron, 1978; Chall, 1983; Doehring et al., 1981; Feuerstein, 1979; Staats & Burns, 1981; Stevenson et al., 1976). The data presented here lend some credence to the latter interpretation. In the first grade general intelligence was not a strong predictor of reading comprehension. Comprehension ability was accurately predicted (multiple R = .671) by three subskills that were not highly correlated with the intelligence measures. However, by fifth grade the typical .5-.6 intelligence-achievement correlation was present. Perhaps part of the relation is due to effects that early reading acquisition has on intellectual development. The possibility of reciprocal causation should always be acknowledged (as it is not in the phrasing "reading is largely a matter of g," which attributes all of the causal power to g), and the temptation to reify the general factor as the ultimate cause of cognitive performance differences should probably be avoided (Bell & Staines, 1981; Cronbach, 1969; Das et al., 1979; Feuerstein, 1979; Kempthorne & Wolins, 1982). The failure to observe this caution may explain the tendency on the part of some investigators to ignore or downplay the growing literature on the relationship between time on task and academic achievement (see Lerner, 1981, pp. 1060-1061).

An alternative explanation (see Sticht, 1979) derives from the fact that reading comprehension at the higher levels begins to invoke more of the same skills that determine listening comprehension (e.g., use of real-world knowledge, inferential skills, memory strategies, vocabulary). Because many of the latter are directly represented in the subtests of many intelligence tests (e.g., the Wechsler information, comprehension, vocabulary, and similarity subscales), it is not surprising that moderate correlations are obtained (see Singer, 1977).[3] What is interesting is that intelligence tests like the Raven, which do not directly tap a recognized subskill of reading, but are instead measures of the abstract reasoning ability or "mental energy" that supposedly is the quintessence of g (Jensen, 1969, 1980; Spearman, 1927), are generally poor predictors of reading ability (for evidence on this issue that converges with the data of the present study see Hall & Kaye, 1980; Kirby & Das, 1977; Knief & Stroud, 1959; Sewall, 1979; Sewall & Severson, 1974; Singer & Crouse, 1981; Tulkin & Newbrough, 1968).

Of course, the results presented here are subject to several crucial caveats. The sizes of the third- and fifth-grade samples were small, rendering tentative any conclusions from the results of these groups. However, our confidence in the results is bolstered by their convergence with other multivariate studies (e.g., Curtis, 1980). The one result that does remain puzzling is the drop in the correlation between reading comprehension and decoding speed in the third grade. Naturally, all of the relationships obtained depend on the reliabilities of the variables involved. However, all of the psychometric tasks and most of the laboratory tasks were characterized by reasonably high reliabilities. Although all of the component processes of reading were not represented by tasks in this research, some of the most important and theoretically meaningful variables were studied. In addition, the tasks included were particularly relevant to assessing the relationships between decoding skill, general intelligence, and reading.

Finally, our study should be viewed as focusing on intelligence only to the extent that we wished to clarify its relationship to reading performance and the cognitive subskills of reading. We have used and interpreted the psychometric tasks in standard ways and have not attempted to resolve any of the controversial issues surrounding the concept of general intelligence or the tests used to measure it. We have attempted to use rather "typical" or "general" interpretations in order to insure that the implications of our results would be as wide and generalizable as possible. This should not be taken as an endorsement of the standard interpretations, because we fully recognize that many issues in intelligence research are the subject of intense debate. For example, the theoretical status of the concept of g (Anastasi, 1983; Carroll, 1981; Carroll & Horn, 1981; Carroll & Maxwell, 1979; Das et al., 1979; Detterman, 1982; Guilford, 1982; Humphreys, 1979; Resnick, 1976; Sternberg, 1977, 1981a; Zaidel, Zaidel, & Sperry, 1981), the trainability of the mental processes tapped by such tasks as the Raven (Bethge, Carlson, & Wiedl, 1982; Bridgeman & Buttram, 1975; Fueerstein, 1979; Guinagh, 1971; Jacobs & Vandeventer, 1971; Lawson & Kirby, 1981; Sewall & Severson, 1974; Turner, Hall, & Grimmett, 1973; Willis, Blieszner, & Baltes, 1981), and the "purity" of the cognitive processes tapped by such tasks (Burke, 1958; Carroll & Maxwell, 1979; Corman & Budoff, 1974; Hunt, 1974; Kirby & Das, 1978; Lawson & Kirby, 1981; Zaidel et al., 1981) are controversial and interesting issues, but they are problems that we have not attempted to address. While the interpretation of our results may change with future developments (as is always the case in science), their general importance for current theorizing on the psychology of reading is not dependent on a specific resolution of any of these particular issues.

Finally, our general conclusions should not be read as an attack on the use of the concept of intelligence itself. Rather, we have concluded that in the area of reading it is a theoretical mistake to think that a posited global trait can substitute for a process analysis of the task. Such a substitution gives an inaccurate description of our data on the skills related to early acquisition. Instead the performance relationships that we have obtained support an argument outlined by Detterman (1982; see also Carr, 1981; Sternberg, 1981b). He argues that higher order constructs like g or "executive capacity" inevitably result when complex systems involving many interrelated components are studied. However, while measures of such higher order constructs may provide rough estimates of overall system functioning they are of little help in explaining the processes by which the system functions. Such estimates can never substitute for an analysis of the system's primary processing parameters. An analogous argument appears to be applicable to the problem of analyzing the reading process.

REFERENCES

AMES, L., & WALKER, R. (1964). Prediction of later reading ability from kindergarten: Rorshach and IQ scores. *Journal of Educational Psychology, 55,* 309-313.

ANASTASI, A. (1983). Evolving trait concepts. *American Psychologist, 38,* 175-184.

ANDREW, J. (1978). Why can't delinquents read? *Perceptual and Motor Skills, 47,* 640.

BARNES, P. (1955). Prediction of achievement in grades 1 through 4 from Otis Quick Scoring Mental Ability Tests: Alpha Short Form. *Educational and Psychological Measurement, 15,* 493-494.

BARON, J. (1978). Intelligence and general strategies. In G. Underwood (Ed.), *Strategies in information processing.* London: Academic Press.

BARON, J. (1979). Orthographic and word-specific mechanisms in children's reading of words. *Child Development, 50,* 60-72.

BELL, P., & STAINES, P. (1981). *Reasoning and argument in psychology.* London: Routledge & Kegan Paul.

BETHGE, H., CARLSON, J., & WIEDL, K. (1982). The effects of dynamic assessment procedures on Raven Matrices Performance, visual search behavior, test anxiety and test orientation. *Intelligence, 6,* 89-97.

BIEMILLER, A. (1977-1978). Relationships between oral reading rates for letters, words, and simple text in the development of reading achievement. *Reading Research Quarterly, 13,* 223-253.

BINGHAM, W., BURKE, H., & MURRAY, S. (1966). Raven's Progressive Matrices: Construct validity. *Journal of Psychology, 62,* 205-209.

BIRCH, H., & BELMONT, L. (1965). Auditory-visual integration, intelligence, and reading ability in school children. *Perceptual and Motor Skills, 20,* 295-305.

BLANCHARD, J.S. (1980). Preliminary investigation of transfer between single-word decoding ability and contextual reading comprehension by poor readers in grade six. *Perceptual and Motor Skills, 51,* 1271-1281.

BOND, G., & DYKSTRA, R. (1967). The cooperative research program in first-grade reading instruction. *Reading Research Quarterly, 2,* 5-142.

BRADLEY, L., & BRYANT, P.E. (1978). Difficulties in auditory organization as a possible cause of reading backwardness. *Nature, 271,* 746-747.

BRADLEY, L., & BRYANT, P. (1983). Categorizing sounds and learning to read—A causal connection. *Nature, 301,* 419-421.

BREKKE, B., & WILLIAMS, J. (1975). Conservation as a predictor of reading achievement. *Perceptual and Motor Skills, 40,* 95-98.

BRIDGEMAN, B., & BUTTRAM, J. (1975). Race differences on nonverbal analogy test performance as a function of verbal strategy training. *Journal of Educational Psychology, 67,* 586-590.

BROWN, N. (1976). Non-cognitive characteristics in the prediction of reading readiness. *Educational and Psychological Measurement, 36,* 537-542.

BRUINICKS, R., & LUCKER, W. (1970). Change and stability in correlations between intelligence and reading test scores among disadvantaged children. *Journal of Reading Behavior, 2,* 295-305.

BURKE, H. (1958). Raven's Progressive Matrices: A review and critical evaluation. *Journal of Genetic Psychology, 93,* 199-228.

BURKE, H., & BINGHAM, W. (1969). Raven's Progressive Matrices: More on construct validity. *Journal of Psychology, 72,* 247-251.

BUTLER, S., MARSH, H. SHEPPARD, M., & SHEPPARD, J. (1982). Early prediction of reading achievement with the Sheppard School Entry Screening Test: A four-year longitudinal study. *Journal of Educational Psychology, 74,* 280-290.

CALFEE, R., CHAPMAN, R., & VENEZKY, R. (1972). How a child needs to think to learn to read. In L. Gregg (Ed.), *Cognition and learning in memory* (pp. 139-182). New York: Wiley.

CALFEE, R.C., LINDAMOOD, P., & LINDAMOOD, C. (1973). Acoustic-phonetic skills and reading—Kindergarten through twelfth grade. *Journal of Educational Psychology, 64,* 293-298.

CARR, T.H. (1981). Building theories of reading ability: On the relation between individual differences in cognitive skills and reading comprehension. *Cognition, 9,* 73-113.

CARROLL, J. (1981). Ability and task difficulty in cognitive psychology. *Educational Researcher, 10,* 11-21.

CARROLL, J.B., & HORN, J.L. (1981). On the scientific basis of ability testing. *American Psychologist, 36,* 1012-1020.

CARROLL, J., & MAXWELL, S. (1979). Individual differences in cognitive abilities. *Annual Review of Psychology, 30,* 603-640.

CATTELL, R. (1963). Theory of fluid and crystallized intelligence: A critical experiment. *Journal of Educational Psychology, 54,* 1-22.

CHALL, J. (1967). *Learning to read: The great debate.* New York: McGraw-Hill.

CHALL, J. (1983). *Stages of reading development.* New York: McGraw-Hill.

COHEN, J., & COHEN, P. (1975). *Applied multiple regression/correlation analysis for the behavioral sciences.* Hillsdale, NJ: Erlbaum Associates.

COLES, G. (1978). The learning disabilities test battery: Empirical and social issues. *Harvard Educational Review, 48,* 313-340.

CORMAN, L., & BUDOFF, M. (1974). Factor structures of retarded and nonretarded children on Raven's Progressive Matrices. *Educational and Psychological Measurement, 34,* 407-412.

CRONBACH, L. (1969). Heredity, environment, and educational policy. *Harvard Educational Review, 39,* 338-347.

CURTIS, M.E. (1980). Development of components of reading skill. *Journal of Educational Psychology, 72,* 656-669.

DANEMAN, M., & CARPENTER, P.A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19,* 450-466.

DAS, J., KIRBY, J., & JARMAN, R. (1979). *Simultaneous and successive cognitive processes.* New York: Academic Press.

DEHIRSH, K., JANSKY, J., & LANGFORD, W. (1966). *Predicting reading failure.* New York: Harper & Row.

DETTERMAN, D. (1982). Does "g" exist? *Intelligence, 6,* 99-108.

DOEHRING, D.G., TRITES, R.L., PATEL, P.G., & FIEDOROWICZ, C.A.M. (1981). *Reading disabilities: The interaction of reading, language, and neuropsychological deficits.* New York: Academic Press.

DURKIN, D. (1966). *Children who read early.* New York: Teachers College Press.

EHRI, L.C. (1979). Linguistic insight: Threshold of reading acquisition. In T. Waller & G. MacKinnon (Eds.), *Reading research: Advance in research and theory* (Vol. 1, pp. 63-114). New York: Academic Press.

FESHBACH, S., ADELMAN, H., & FULLER, W. (1977). Prediction of reading and related academic problems. *Journal of Educational Psychology, 69,* 299-308.

FEUERSTEIN, R. (1979). *The dynamic assessment of retarded performers.* Baltimore, MD: University Park Press.

FOX, B., & ROUTH, D.K. (1976). Phonemic analysis and synthesis as word-attack skills. *Journal of Educational Psychology, 68,* 70-74.

FOX, B., & ROUTH, D.K. (1980). Phonemic analysis and severe reading disability. *Journal of Psycholinguistic Research, 9,* 115-119.

GLOSSOP, J., APPLEYARD, R., & ROBERTS, C. (1979). Achievement relative to a measure of general intelligence. *British Journal of Educational Psychology, 49,* 249-257.

GOLDSTEIN, D.M. (1976). Cognitive-linguistic functioning and learning to read in preschoolers. *Journal of Educational Psychology, 68,* 680-688.

GOLINKOFF, R.M. (1978). Phonemic awareness skills and reading achievement. In F. Murray & J. Pikulski (Eds.), *The acquisition of reading* (pp. 23-41). Baltimore, MD: University Park Press.

GOUGH, P.B., & HILLINGER, M.L. (1980). Learning to read: An unnatural act. *Bulletin of the Orton Society, 30,* 171-196.

GUILFORD, J. (1982). Cognitive psychology's ambiguities: Some suggested remedies. *Psychological Review, 89,* 48-59.

GUINAGH, B. (1971). An experimental study of basic learning ability and intelligence in low-socioeconomic-status children. *Child Development, 42,* 27-36.

GUTERMAN, S. (1979). IQ tests in research on social stratification: The cross-class validity of the tests as measures of scholastic aptitude. *Sociology of Education, 52,* 163-173.

GUTHRIE, J.T. (1973). Models of reading and reading disability. *Journal of Educational Psychology, 65,* 9-18.

HALL, V., & KAYE, D. (1980). Early patterns of cognitive development. *Monographs of the Society of Research in Child Development, 45* (2, Serial No. 184).

HAMMILL, D., & MCNUTT, G. (1981). *The correlates of reading.* Austin, TX: Pro-Ed.

HARTLAGE, L., & BOONE, K. (1977). Achievement test correlates of Wechsler Intelligence Scale for Children and Wechsler Intelligence Scale for Children-Revised. *Perceptual and Motor Skills, 45,* 1283-1286.

HARTLAGE, L., & STEELE, C. (1977). WISC and WISC-R correlates of academic achievement. *Psychology in the Schools, 14,* 15-18.

HELGOTT, J.A. (1976). Phonemic segmentation and blending skills of kindergarten children: Implications for beginning reading acquisition. *Contemporary Educational Psychology, 1,* 157-169.

HENDERSON, N., BUTLER, B., & GOFFENEY, B. (1969). Effectiveness of the WISC and Bender-Gestalt Test in predicting arithmetic and reading achievement for white and nonwhite children. *Journal of Clinical Psychology, 25,* 268-271.

HENDERSON, N., FAY, W., LINDEMANN, S., & CLARKSON, Q. (1973). Will the IQ test ban decrease the effectiveness of reading prediction? *Journal of Educational Psychology, 65,* 345-355.

HUMPHREYS, L. (1979). The construct of general intelligence. *Intelligence, 3,* 105-120.

HUNT, E. (1974). Quoth the Raven? Nevermore! In L. Gregg (Ed.), *Knowledge and cognition* (pp. 129-157). Potomac, MD: Erlbaum Associates.

IVANOFF, J., & TEMPERO, H. (1965). Effectiveness of the Peabody Picture Vocabulary Test with seventh-grade pupils. *Journal of Educational Research, 58,* 412-415.

JACKSON, M., & MCCLELLAND, J.L. (1979). Processing determinants of reading speed. *Journal of Experi-*

mental Psychology: General, 108, 151-181.
JACOBS, P., & VANDEVENTER, M. (1971). The learning and transfer of double-classification skills: A replication and extension. *Journal of Experimental Child Psychology, 12,* 240-257.
JENSEN, A. (1969). How much can we boost IQ and scholastic achievement? *Harvard Educational Review, 39,* 1-123.
JENSEN, A. (1974). Interaction of Level I and Level II abilities with race and socioeconomic status. *Journal of Educational Psychology, 66,* 99-111.
JENSEN, A. (1980). *Bias in mental testing.* New York: Free Press.
JENSEN, A. (1981a). Raising the IQ: The Ramey and Haskins study. *Intelligence, 5,* 29-40.
JENSEN, A. (1981b). *Straight talk about mental tests.* New York: Free Press.
JOHNSON, C. (1981). *The diagnosis of learning disabilities.* Boulder, CO: Pruett Pub. Co.
JUST, M.A., & CARPENTER, P.A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review, 87,* 329-354.
KAUFMAN, A. (1973). Comparison of the WPPSI, Stanford-Binet, and McCarthy scales as predictors of first-grade acheivement. *Perceptual and Motor Skills, 36,* 67-73.
KAUFMAN, A., & KAUFMAN, N. (1972). Tests built from Piaget's and Gesell's tasks as predictors of first-grade achievement. *Child Development, 43,* 521-535.
KEMPTHORNE, O., & WOLINS, L. (1982). Testing reveals a big social problem. *Behavioral and Brain Sciences, 5,* 327-336.
KENNY, D. (1979). *Correlation and causality.* New York: Wiley.
KERLINGER, F., & PEDHAZUR, E. (1973). *Multiple regression in behavioral research.* New York: Holt, Rinehart and Winston.
KIERAS, D. (1981). Component processes in the comprehension of simple prose. *Journal of Verbal Learning and Verbal Behavior, 20,* 1-23.
KIRBY, J., & DAS, J. (1977). Reading achievement, IQ, and simultaneous-successive processing. *Journal of Educational Psychology, 69,* 564-570.
KIRBY, J., & DAS, J. (1979). Skills underlying Coloured Progressive Matrices. *Alberta Journal of Educational Research, 14,* 94-99.
KNIEF, L., & STROUD, J. (1959). Intercorrelations among various intelligence, achievement, and social class scores. *Journal of Educational Psychology, 50,* 117-120.
KREBS, E. (1969). *The Wechsler Preschool and Primary Scale of Intelligence and prediction of reading achievement in first grade.* Unpublished doctoral dissertation, Rutgers State University.
LABERGE, D., & SAMUELS, S.J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology, 6,* 293-323.
LAWSON, M., & KIRBY, J. (1981). Training in information processing algorithms. *British Journal of Educational Psychology, 51,* 321-335.
LERNER, B. (1981). The minimum competence testing movement: Social, scientific, and legal implications. *American Psychologist, 36,* 1057-1066.
LESGOLD, A.M., & PERFETTI, C.A. (1978). Interactive processes in reading comprehension. *Discourse Processes, 1,* 323-336.
LESGOLD, A., & PERFETTI, C. (Eds.). (1981). *Interactive processes in reading.* Hillsdale, NJ: Erlbaum Associates.
LEWKOWICZ, N.K. (1980). Phonemic awareness training: What to teach and how to teach it. *Journal of Educational Psychology, 72,* 686-700.
LIBERMAN, I.Y. (1973). Segmentation of the spoken word and reading acquisition. *Bulletin of the Orton Society, 23,* 65-77.
LIBERMAN, I.Y., & SHANKWEILER, D. (1979). Speech, the alphabet, and teaching to read. In L. Resnick & P. Weaver (Eds.), *Theory and practice of early reading* (Vol. 2, pp. 109-132). Hillsdale, NJ: Erlbaum Associates.
LIEBERMAN, I., SHANKWEILER, D., FISCHER, F., & CARTER, B. (1974). Explicit syllable and phoneme segmentation in the young child. *Journal of Experimental Child Psychology, 18,* 201-212.
LIEBLICH, A., & SHINAR, M. (1975). The predictive validity of the WPPSI with Israeli children. *Educational and Psychological Measurement, 35,* 473-475.
LOMAX, R. (1982). Causal modeling of reading acquisition. *Journal of Reading Behavior, 14,* 341-345.
MANN, V.A. (1981, March). *Reading and language skill.* Paper presented at the meeting of the Society for Research in Child Development, Boston, MA.
MCCANDLESS, B., ROBERTS, A., & STARNES, T. (1972). Teacher's marks, achievement test scores, and aptitude relations with respect to social class, race, and sex. *Journal of Educational Psychology, 63,* 153-159.
MCCLELLAND, D. (1973). Testing for competence rather than for "intelligence." *American Psychologist, 28,* 1-14.
MITCHELL, D.C. (1982). *The process of reading: A cognitive analysis of fluent reading and learning to read.* New York: John Wiley.
MUEHL, S., & DINELLO, M. (1976). Early first-grade skills related to subsequent reading performance: A seven year followup study. *Journal of Reading Behavior, 8,* 67-81.
PERFETTI, C., BECK, I., & HUGHES, D. (1981, March). *Phonemic knowledge and learning to read.* Paper presented at the meeting of the Society for Research in Child Development, Boston, MA.
PERFETTI, C.A., & HOGABOAM, T. (1975). Relationship between single word decoding and reading comprehension skill. *Journal of Educational Psychology, 67,* 461-469.
PERFETTI, C.A., & LESGOLD, A.M. (1977). Discourse comprehension and sources of individual differences. In M. Just & P. Carpenter (Eds.), *Cognitive processes in comprehension* (pp. 141-183). Hillsdale, NJ: Erlbaum Associates.
PERFETTI, C.A., & LESGOLD, A.M. (1979). Coding and comprehension in skilled reading and implications for reading instruction. In L.B. Resnick & P. Weaver (Eds.), *Theory and practice of early reading* (Vol. 1, pp. 57-84). Hillsdale, NJ: Erlbaum Associates.

PERFETTI, C., & MCCUTCHEN, D. (1982). Speech processes in reading. In N. Lass (Ed.), *Speech and language: Advances in basic research and practice* (Vol. 7, pp. 237-269). New York: Academic Press.

RAE, G. (1977). Relation of auditory-visual integration to reading and intelligence. *Journal of General Psychology, 97,* 3-8.

RESNICK, L. (1976). *The nature of intelligence.* Hillsdale, NJ: Erlbaum Associates.

ROBERGE, J., & FLEXER, B. (1981). Re-examination of the covariation of field independence, intelligence, and achievement. *British Journal of Educational Psychology, 51,* 235-236.

ROZIN, P., & GLEITMAN, L.R. (1977). The structure and acquisition of reading II: The reading process and the acquisition of the alphabetic principle. In A. Reber & D. Scarborough (Eds.), *Toward a psychology of reading* (pp. 55-141). Hillsdale, NJ: Erlbaum Associates.

SAMUELS, S., & DAHL, P. (1975). Relationships between IQ, learning ability, and reading achievement. In J. Johns (Ed.), *Literacy for diverse learners* (pp. 31-38). Newark, DE: International Reading Association.

SATZ, P., TAYLOR, H., FRIEL, J., & FLETCHER, J. (1978). Some developmental and predictive precursors of reading disabilities: A six year follow-up. In A. Benton & D. Pearl (Eds.), *Dyslexia: An appraisal of current knowledge* (pp. 315-347). New York: Oxford University Press.

SEXTON, L., & TRELOAR, J. (1982). Cognitive and perceptual measures as predictors of fourth-grade achievement. *Psychology in the Schools, 19,* 122-128.

SEWALL, T. (1979). Intelligence and learning tasks as predictors of scholastic achievement in black and white first-grade children. *Journal of School Psychology, 17,* 325-332.

SEWALL, T., & SEVERSON, R. (1974). Learning ability and intelligence as cognitive predictors of achievement in first-grade black children. *Journal of Educational Psychology, 66,* 948-955.

SHIPP, D., & LOUDON, M. (1964). The Draw-A-Man Test and achievement in first grade. *Journal of Educational Research, 57,* 518-521.

SILBERBERG, N., IVERSEN, M., & SILBERBERG, M. (1969). A model for classifying children according to reading level. *Journal of Learning Disabilities, 2,* 634-643.

SINGER, H. (1977) IQ is and is not related to reading. In S. Wanat (Ed.), *Papers in applied linguistics: Linguistics and reading series* (Vol. 1, pp. 43-63). Arlington, VA: Center for Applied Linguistics.

SINGER, M. (1982). *Competent reader, disabled reader: Research and application.* Hillsdale, NJ: Erlbaum Associates.

SINGER, M.H., & CROUSE, J. (1981). The relationship of context-use skills to reading: A case for an alternative experimental logic. *Child Development, 52,* 1326-1329.

SPEARMAN, C. (1927). *The abilities of man.* New York: Macmillan.

SPEARMAN, C., & WYNN JONES, L. (1950). *Human ability.* London: Macmillan.

SPIEGEL, M., & BRYANT, N. (1978). Is speed of processing information related to intelligence and achievement? *Journal of Educational Psychology, 70,* 904-940.

STAATS, A., & BURNS, G. (1981). Intelligence and child development: What intelligence is and how it is learned and functions. *Genetic Psychology Monographs, 104,* 237-301.

STANOVICH, K.E. (1980). Toward an interactive-compensatory model of individual differences in the development of reading fluency. *Reading Research Quarterly, 16,* 32-71.

STANOVICH, K. (1981). Relationships between word decoding speed, general name-retrieval ability, and reading progress in first-grade children. *Journal of Educational Psychology, 73,* 809-815.

STANOVICH, K.E. (1982a). Individual differences in the cognitive processes of reading I: Word decoding. *Journal of Learning Disabilities, 15,* 485-493.

STANOVICH, K.E. (1982b). Individual differences in the cognitive processes of reading II: Text-level processes. *Journal of Learning Disabilities, 15,* 549-554.

STANOVICH, K.E. (1982c). Word recognition skill and reading ability. In M. Singer (Ed.), *Competent reader, disabled reader: Research and application* (pp. 81-102). Hillsdale, NJ: Erlbaum Associates.

STANOVICH, K.E., WEST, R.F., & FEEMAN, D.J. (1981). A longitudinal study of sentence context effects in second-grade children: Tests of an interactive-compensatory model. *Journal of Experimental Child Psychology, 32,* 185-199.

STERNBERG, R. (1977). *Intelligence, information processing, and analogical reasoning.* Hillsdale, NJ: Erlbaum Associates.

STERNBERG, R. (1981a). Nothing fails like success: The search for an intelligent paradigm for studying intelligence. *Journal of Educational Psychology, 73,* 142-155.

STERNBERG, R. (1981b). Toward a unified componential theory of human intelligence. In M. Friedman, J. Das, & N. O'Connor (Eds.), *Intelligence and learning* (pp. 327-344). New York: Plenum.

STERNBERG, R., & POWELL, J. (1983). Comprehending verbal comprehension. *American Psychologist, 38,* 878-893.

STERRITT, G., & RUDNICK, M. (1966). Auditory and visual rhythm perception in relation to reading ability in fourth grade boys. *Perceptual and Motor Skills, 22,* 859-864.

STEVENSON, H.W., PARKER, T., WILKINSON, A., HEGION, A., & FISH, E. (1976). Longitudinal study of individual differences in cognitive development and scholastic achievement. *Journal of Educational Psychology, 68,* 377-400.

STICHT, T.G. (1979). Applications of the Audread model to reading evaluation and instruction. In L.B. Resnick & P. Weaver (Eds.), *Theory and practice of early reading* (Vol. 1, pp. 209-226). Hillsdale, NJ: Erlbaum Associates.

THIBADEAU, R., JUST, M.A., & CARPENTER, P.A. (1982). A model for the time course and content of reading. *Cognitive Science, 6,* 157-203.

THOMPSON, B., ALSTON, H., CUNNINGHAM, C., & WAKEFIELD, J. (1978). The relationship of a measure of structure of intellect abilities and academic achievement. *Educational and Psychological Measurement, 38,* 1207-1210.

THORNDIKE, R.L. (1973-1974). Reading as reasoning. *Reading Research Quarterly, 9,* 135-147.

TREIMAN, R., & BARON, J. (1981). Segmental analysis ability: Development and relations to reading ability. In T. Waller & G. MacKinnon (Eds.), *Reading research: Advances in theory and practice* (Vol. 3, pp. 100-120). New York: Academic Press.

TREIMAN, R., & BARON, J. (1983). Phonemic-analysis training helps children benefit from spelling-sound rules. *Memory and Cognition, 11,* 382-389.

TREMANS-ZIREMBA, M., MICHAYLUK, J., & TAYLOR, L. (1980). An examination of some predictors of reading achievement in grade four children. *Reading Improvement, 17,* 260-266.

TROTMAN, F. (1977). Race, IQ, and the middle class. *Journal of Educational Psychology, 69,* 266-273.

TULKIN, S., & NEWBROUGH, J. (1968). Social class, race, and sex differences on the Raven (1956) Standard Progressive Matrices. *Journal of Consulting and Clinical Psychology, 32,* 400-406.

TURNER, R., HALL, V., & GRIMMETT, S. (1973). Effects of familiarization feedback on the performance of lower-class and middle-class kindergarteners on the Raven Coloured Progressive Matrices. *Journal of Educational Psychology, 65,* 356-363.

VELLUTINO, F.R. (1979). *Dyslexia: Theory and research.* Cambridge, MA: MIT Press.

WALLBROWN, J., ENGIN, A., WALLBROWN, F., & BLAHA, J. (1975). The prediction of first grade reading achievement with selected perceptual-cognitive tests. *Psychology in the Schools, 12,* 140-149.

WATSON, B., WATSON, C., & FREDD, R. (1982). Follow-up studies of specific reading disability. *Journal of the American Academy of Child Psychiatry, 21,* 376-382.

WEAVER, P.A., & ROSNER, J. (1979). Relationships between visual and auditory perceptual skills and comprehension in students with learning disabilities. *Journal of Learning Disabilities, 12,* 51-55.

WEST, R.F., & STANOVICH, K.E. (1978). Automatic contextual facilitation in readers of three ages. *Child Development, 49,* 717-727.

WHALEY, J.F., & KIBBY, M.W. (1981). The relative importance of reliance on intraword characteristics and interword constraints for beginning reading achievement. *Journal of Educational Research, 74,* 315-320.

WHITE, D., & JACOBS, E. (1979). The prediction of first-grade reading achievement from WPPSI scores of preschool children. *Psychology in the Schools, 16,* 189-192.

WILLIAMS, J.P. (1980). Teaching decoding with an emphasis on phoneme analysis and phoneme blending. *Journal of Educational Psychology, 72,* 1-15.

WILLIS, S., BLIESZNER, R., & BALTES, P. (1981). Intellectual training research in aging: Modification of performance on the fluid ability of figural relations. *Journal of Educational Psychology, 73,* 41-50.

WOLFLE, L. (1980). Strategies of path analysis. *American Educational Research Journal, 17,* 183-209.

YULE, W. (1973). Differential prognosis of reading backwardness and specific reading retardation. *British Journal of Educational Psychology, 43,* 244-248.

YULE, W., GOLD, R., & BUSHC, C. (1981). WISC-R correlates of academic attainment at 16 1/2 years. *British Journal of Educational Psychology, 51,* 237-240.

YULE, W., & RIGLEY, L. (1982). Predicting future reading attainment from the WPPSI. *Journal of Research in Reading, 5,* 67-74.

YULE, W., RUTTER, M., BERGER, M., & THOMPSON, J. (174). Over- and under-achievement in reading: Distribution in the general population. *British Journal of Educational Psychology, 44,* 1-12.

ZAIDEL, E., ZAIDEL, D., & SPERRY, R. (1981). Left and right intelligence: Case studies of Raven's Progressive Matrices following brain bisection and hemicortication. *Cortex, 17,* 167-186.

TEST REFERENCES

GATES-MACGINITIE READING TESTS (Primary Level A). (1978). Boston: Houghton Mifflin.

METROPOLITAN ACHIEVEMENT TESTS (Primary 1, Elementary, Intermediate). (1978). New York: Psychological Corporation.

PEABODY PICTURE VOCABULARY TEST. (1965). Circle Pines, MN: American Guidance Service.

RAVEN'S PROGRESSIVE MATRICES (Colored and Standard). (1978). New York: Psychological Corporation.

Footnotes

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[1]Due to journal space limitations the task descriptions that follow have been considerably condensed. A more complete description of the methods can be obtained by writing the senior author.

[2]The findings reported here are certainly not without precedent. In reviewing the earlier literature on related issues Chall (1967, pp. 141-149) pointed to the fact that letter knowledge in Grade 1 was a better predictor of reading acquisition than intelligence tests.

[3]It is for just this reason that overall correlations between reading comprehension and full scale IQs tell us little about reading as a process, and thus are of little use to the reading theorist. Full scale IQs (or g, measured as the factor score on the first principal component of a battery of tasks) represent an amalgam of subskills that must be analyzed if theories of the cognitive processes responsible for individual differences in reading are to be constructed.