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ABSTRACT

This review of psychometric research in reading analyzes the factors which seem related to reading comprehension skills. Experimental analysis of reading comprehension by L. E. Thorndike revealed two major components: knowledge of word meanings and verbal reasoning abilities. Subsequent analysis of experimental studies of reading comprehension confirmed Thorndike's conclusions and added the skills of (1) obtaining literal sense meaning from a passage, (2) following the structure (syntax) of the passage, and (3) recognizing the literary techniques used by an author. Other tests of reading speed and comprehension also confirm these conclusions. Statistical techniques of substrata analysis and regression analysis are criticized for their lack of validity and their misleading conclusions. Thorndike's conclusions are pronounced confirmed and sound, and suggestions are made for applications of these conclusions to techniques and materials for reading instruction. References are cited. (AL)

PSYCHOMETRIC RESEARCH IN READING

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Psychometric research in reading began early in the century and has resulted in the publication of hundreds of studies involving the measurement of various aspects of reading. In this paper, I shall limit myself to a relatively few studies of the process of comprehension in reading and shall try to point out some of the practical consequences of those studies.

The first systematic experimental analysis of comprehension was reported in 1917 by Professor Edward Lee Thorndike (1917a, 1917b, 1917c). He presented short paragraphs to elementary-school pupils and asked them to write answers to simple questions based on those paragraphs. The pupils were given unlimited time and allowed to refer to the paragraphs as often as they wished while they were composing or writing their responses. Thorndike found that, even when the pupils understood the meanings of the individual words or phrases in a paragraph, many of them made errors in answering the questions about it. He carefully classified the responses of the children and analyzed the nature of the errors that they made. The resulting data led him to conclude that the pupils were unable to fit together the separate ideas expressed in a paragraph and to give individual words or separate word groups the proper amount of emphasis in relation to one another. For example, the pupils were unable to use connective words or phrases (such as "but" or "on the contrary") to link ideas together in the proper relationships. He wrote:

> Understanding a paragraph is like solving a problem in mathematics. It consists in selecting the right elements of the situation and putting them together in the right relations, and also with the right amount of

weight or influence or force for each (1917b, p. 329).

> Understanding a ... printed paragraph is then a matter of habits, connections, mental bonds, but these have to be selected from so many others, and given weights so delicately, and used together in so elaborate an organization that "to read" means "to think" as truly as does "to evaluate" or "to invent" or "to demonstrate" or "to verify" (1917c, p. 114).

The last quotation formed the kernel of a vast literature on the teaching of reading as a process of thinking. It should be noted, however, that in his analysis of comprehension Thorndike fully recognized the importance of association, or memory, in evoking meanings attached to words or phrases as well as the importance of reasoning with these to achieve understanding of ideas expressed by an author. We may say that, in his informal "factor analysis" of reading, Thorndike identified two major components: (1) Knowledge of word meanings, and (2) Verbal reasoning ability. As a practical consequence, the teaching of reading came more and more to emphasize understanding and less and less to emphasize word calling; that is, decoding words by pronouncing them correctly regardless of whether they had meaning for the "reader."

One of the first factor analyses of reading tests was reported by Feder (1938). He analyzed scores from tests, originally devised by Adler (1936), that included acquisition of facts, drawing inferences, appreciating passages, and speed of reading easy materials. He found that the factual-information tests loaded heavily on a factor different from the inference tests. The appreciation test appeared to be most closely associated with the inference tests and the speed-of-reading test appeared to measure functions different from the others.

In 1939, Davis (1940) compiled a list of hundreds of skills of comprehension in reading that had been suggested by previous investigators. Once the skills that appeared to be highly overlapping had been combined, the outline of skills of comprehension that is shown in Table 1 emerged. This list reflects rather plainly the influence of an experiment performed by I. A. Richards pertaining to the comprehension of poetry. These data and their implications were discussed in Practical Criticism by Richards (1929). Davis's (1940) outline formed the list of criterion skills measured by the Cooperative Reading Comprehension Tests, Forms Q through Z (Davis, et al., 1940-1950). In practice, two of the skills did not lend themselves to measurement with multiple-choice items and had to be dropped. The remainder were grouped for convenience into nine skills and are so identified in Table 1. Every item in the twelve forms of the Cooperative Reading Comprehension Tests was classified as measuring principally one of these skills. The validity of the tests was thus established in the same way as the validity of criterion-referenced tests, as they are often called nowadays.

About fifteen years later, the Taxonomy of Educational Objectives (Bloom, et al., 1956) listed many of the same skills, though under different names, as major objectives in the cognitive domain. To show the resemblance of the two sets of objectives in comprehension, the Bloom categories are cross-referenced to the Davis list of nine skills in Table 1.

Davis (1941, 1944) published the results of a principal-components analysis of a matrix of variances and covariances obtained by administering the nine basic skills of comprehension, as measured by items in the lower and higher levels of Form Q of the Cooperative Reading Comprehension Tests, to 421 college freshmen. Because the items had been constructed with the intention of making them measure

as separately as possible the various skills of comprehension listed in Table 1, the analysis was done in such a way as to retain in the results the unique elements, if any, of the skills measured. As is well known, five or six of the skills were found to have unique nonchance elements at a rather high level of statistical significance. The practical significance of the findings was that comprehension should not be regarded as a unitary trait. Consequently, the teaching of reading should presumably involve systematic instruction in various skills and any assessment of level of comprehension should involve the measurement of these different skills in combination. As a matter of fact, tests of comprehension in reading constructed since 1940 have tended to reflect these findings.

Although Davis's 1941 experimental findings were not designed to ascertain the relative importance of different skills in comprehension, the results suggested that knowledge of word meanings and reasoning in reading were of greatest importance. Three or four additional skills were shown to be present in amounts that could not readily be explained by chance but they are apparently of far less general utility in the reading of materials customarily encountered by pupils in grades 7 - 12.

It should be noted that Davis's rather extensive experimental study essentially confirmed the insightful conclusions of Professor E. L. Thorndike in 1917 that (1) Knowledge of word meanings and (2) Reasoning with these meanings are the major components of comprehension. To these were added: (3) Getting the literal sense meaning of a passage; (4) Following the structure (the syntax) of a passage; and (5) Recognizing the literary techniques used by an author.

To check up on these conclusions, Davis (1968) conducted a much more elaborate study that was published in full in the summer issue of the Reading

Research Quarterly. This made rather difficult reading for laymen, but its results are shown in a simple way in Table 2. Here we see two estimates of the per cent of the true variance of each of eight comprehension skills that are unique. It will be noted that, in a sample of 988 high-school seniors, the largest of these are:

1. Recalling word meanings;
2. Drawing inferences from the content (reasoning);
3. Following the structure of a passage;
4. Recognizing a writer's purpose, attitude, tone, and mood;
5. Finding answers to questions answered explicitly or in paraphrase; that is, getting the literal sense meaning.

Four of these were judged significant in Davis's earlier study (Davis, 1941, 1944). Thus, considerable overlap in the results is shown despite the fact that different passages and items, different techniques of analysis, and examinees at different grade levels were used in the 1941 and 1968 studies. A component analysis of the 1968 data, first published in 1971 in The Literature of Research in Reading, With Emphasis on Models (Davis, 1971), confirms Components I and V of the 1941 study and splits Component II of that study into two separate factors. The first of these emphasizes Making inferences from the content (Skill 5) and the second emphasizes Finding answers to questions answered explicitly or in paraphrase (Skill 3) and Weaving together ideas in the content (Skill 4). This material is scheduled to appear in the 1972 Summer issue of the Reading Research Quarterly.

As you know, research methodologists refer to a conceptualization of a phenomenon (its elements and their inter-relations as a working model of the phenomenon) as a model. Davis's outline in 1939 constituted a model of the comprehension process in reading. Since that time, Davis has tested the separate reality (or uniqueness) of its elements and their relative importance in the process of comprehension among secondary-school and college

students. Only one other model, or conceptualization of the reading process, has been subjected to experimental verification. This is Holmes's substrata-factor theory of reading (Holmes, 1948, 1954), which will be discussed next. At this point it may be noted that arm-chair models or partial models of the comprehension process in reading that have not been subjected to comprehensive experimental verification include those by Albright (1927); Barrett (1968, pp. 19-23); Barton (1930); Berry (1931); Bloom, et al. (1956); Cleland (1965); Gates (1935); Gray (1919, 1960); Kingston (1961); Robinson (1966); Smith (1960); Spache (1962, 1963); Strang (1938); and Yoakum (1928). At present, Chapman (1969) is engaged in experimental verification of three models that she has proposed.

Holmes suggested (1948, 1954) the use of multiple-regression analysis to identify the relative contributions of a wide selection of variables to the variance of speed and power of reading. Experiments to carry out these proposals were conducted by Holmes (1948), by Singer (1965a, 1965b), and by Holmes and Singer (1966). These experiments were designed to test only a limited part of the so-called substrata-factor theory of reading, a rather diffuse statement which would be difficult to put to experimental test.

By "power of reading" Holmes (1948) meant the ability to comprehend rather difficult textbook material in generous time limits. This variable has commonly been called "level of comprehension" and will be so referred to in this paper. Holmes measured it in his 1948 experiment, which involved the analysis of data based on testing 126 college students, by using the sum of comparable scores on five untimed comprehension subtests in the Diagnostic Examination of Silent Reading Abilities (Dvorak & Van Wagenen, 1939).

The criterion variable of speed of reading was obtained by averaging standard

scores on the Minnesota Speed of Reading Test for College Students (Eurich, 1936) and the Rate of Comprehension Test of the Diagnostic Examination of Silent Reading Abilities. Both of these tests measure the ability of an examinee to detect an absurd word inserted near the end of a rather short, easy passage. This ability is not called into play in natural reading situations and may lead test-wise examinees to alter their normal reading habits to an unacceptable degree. In any case, high scores on these tests are obtained by marking items correctly as rapidly as possible during a short time limit. Therefore, both comprehension and speed of covering material are measured. This variable is commonly referred to as "speed of comprehension" and will be so referred to in this paper to distinguish it from mere speed of reading (in number of words covered per minute, for example). Unfortunately, the validity of this criterion variable is open to question because it is not ordinarily called into play in natural reading situations and may lead test-wise examinees to alter their normal reading habits to an unacceptable degree.

The predictor variables, for which it was desired to obtain estimates of the proportion of the variances of "level of comprehension" and of "speed of comprehension" that they constitute, consisted of 20 measures that had correlations with the two criterion variables such that they gave preliminary promise of making independent contributions to the variance of level of comprehension and speed of comprehension. When the partial regression coefficients were obtained, the level-of-comprehension criterion score was added to the 20 predictors of speed of comprehension; vice versa, the speed-of-comprehension criterion score was added to the 20 predictors of level of comprehension. The Wherry-Doolittle procedure was used to obtain partial regression coefficients for only the four

variables that contributed most to the variance of the two criteria. This limitation may have been wise, considering that there were only 126 examinees in a study involving 21 predictors. But more meaningful results could have been obtained if a large number of examinees had been used and if all 21 partial regression coefficients per criterion variable had been obtained. In any event, the results showed that somewhat over half of the variance of speed of comprehension was attributable to three measures: tests of accuracy and speed of word perception and word meaning, and recognition span (a measure obtained by eye-movement photography).

About 80 per cent of the variance of level of comprehension was attributable to measures of level of vocabulary, reasoning ability (as measured by the Otis Quick-Scoring Mental-Ability Tests), verbal relationships, and the number of fixations per 100 running words. The latter has a negative sign on the regression coefficient, indicating that the smaller the number of fixations per 100 words, the greater the examinee's level of comprehension tends to be. (The zero-order correlation coefficient between these two variables was actually .10, which is not significantly different from zero.) This analysis provides a very limited amount of information about the underlying elements of speed of comprehension by suggesting that the latter is based largely on accuracy and speed of word perception and on level of vocabulary. Generally speaking, it is believed that accuracy of eye movements and span of recognition are influenced by the comprehension levels of individuals rather than the reverse.

With respect to comprehension, the analysis appears to reiterate the Thorndike and Davis conclusions that knowledge of word meanings and verbal reasoning are

the two major components of comprehension in reading.

The reader familiar with Holmes's practice of using the most important predictor variables as the criteria for regression analyses that use the other variables in the set as predictors may wonder why I have not discussed these so-called substrata analyses in the interpretation of Holmes's study. The answer lies in the fact that, legitimate though these analyses may be in and of themselves, it is not legitimate to use the regression coefficients from a second-level analysis (say, of the level-of-vocabulary scores that account for about 40 per cent of the variance of level of comprehension) with the first-level analysis of the level-of-comprehension criterion variable directly to show what proportion of the latter is accounted for by some of the original 21 predictor variables for which regression coefficients were not computed in the original analysis. If you want such data (and Holmes seemed to want them), you should use a large number of subjects and compute the partial regression coefficients for all of the variables (which can be done on large computers in a small fraction of a second). I have discussed this matter at some length (Davis, 1971, pp. 8-22 to 8-24) and Carroll (1968) earlier drew attention to it, diagrammed the situation, and took the same dim view of Holmes's substrata analysis technique that I take, and for the same reasons as nearly as I can tell. In fact, if you haven't read that article by Carroll, which was a review of a monograph entitled Speed and Power of Comprehension in Reading by Holmes and Singer (1966), it will pay you to locate volume 2 of the journal called Research on the Teaching of English in which the review appeared.

I have pointed out (Davis, 1971, pp. 8-23 to 8-24) that the independent contributions to criterion-score variance identified mathematically by a multiple-

regression analysis cannot usually be properly identified simply by assigning to each of these independent parts of the criterion-score variance the name of one of the predictor variables. Each packet of predictor-score variance that is said to "account for" a portion of the criterion-score variance usually represents only one of several different elements that together make up the variance of the predictor score. The beta weight associated with a predictor score usually reflects the presence of one element of criterion-score variance in more than one predictor test. To make inferences about the psychological nature of the elements of the variance of predictor tests that make significant contributions to the predictable variance of a criterion variable is a complex and delicate process that requires intimate knowledge of the skills involved in each predictor variable and insightful understanding of what is yielded by multiple-regression analyses. The interpretation of the results of factor analyses and component analyses is equally complex and difficult. My own feeling is that, broadly speaking, the statistical technique of substrata analysis that was suggested by Holmes (1948, 1954) does not properly lead to the identification of substrata factors as he envisaged that it would. Furthermore, the interpretations made by Holmes of data obtained in the course of his substrata analyses of the nature of the reading process are not statistically sound and may have led to misleading conclusions. Finally, his investigations cannot be said to have either supported or to have denied support to his basic substrata theory of reading.

The second large-scale regression analysis of comprehension was made by Singer (1965a, 1965b). The plan of the study was similar to that of Holmes's (1948) study, but the variables were somewhat different and were administered to about 250 pupils in each of grades 3, 4, 5, and 6 in Alvord, California.

The two criterion variables were speed of comprehension, as measured by the speed-of-reading subtest in the Gates Reading Survey (Gates, 1953, 1958), and level of comprehension, as measured by the subtest of that name in the Gates Reading Survey.

After discussing the contributions of specific tests to the variance of the speed-of-comprehension criterion scores, Singer concludes that these skills shift from a predominance of visual-perception abilities at the third-grade level to a more equal balance with knowledge of word meanings at the sixth-grade level. This may, however, reflect an increasing speed component from grade to grade in the vocabulary test used.

The largest proportion of the variance of the level-of-comprehension criterion variance was accounted for by scores on the same vocabulary test. Without detailed personal knowledge of the elements measured by other predictor variables, it is difficult to determine the nature of the criterion variance predicted by the three or four tests with fairly large regression coefficients.

A third large-scale regression study was reported by Holmes and Singer (1966). They used a sample of 400 pupils in grades 9-12 of the University of California Demonstration Summer School of 1953. The procedures used in selecting the sample and the wide age and grade range in it raise serious problems about generalizing the findings of the study to any representative group of American secondary-school pupils.

As in the two previous studies reported by Holmes (1948, 1954) and Singer (1965a, 1965b), measures of speed of comprehension and level of comprehension served as criterion variables. Careful examination of these measures leaves

doubt about their validity. In fact, the names given to some of the predictor tests may be misleading. For example, test 8 is labelled "Vocabulary in Context." Yet the sample item reads:

He felt very sad.

1 timid

2 happy

3 weary

4 sorrowful

5 hungry

The so-called context provided for the word "sad" is entirely superfluous; the item can be answered with complete confidence by an examinee who knows that the word "sad" means "sorrowful." So this test measures knowledge of words presented in isolation, as do the sample items for Tests 1 and 9, although these tests are labelled "Visual Verbal Meaning Test" and "Vocabulary in Isolation Test," respectively. It should be noted that Test 1 was speeded (4 minutes allowed for 50 four-choice items) while Tests 8 and 9 were essentially unspeeded.

The variance of the speed-of-comprehension criterion variable has fairly large components that may, perhaps, be regarded as:

1. Knowledge of word meanings;
2. Reasoning facility;
3. Visual memory for word forms;
4. General information;
5. Interest in literary rather than computational interests.

The variance of the level-of-comprehension criterion variable has fairly large components that may, perhaps, be regarded as:

1. Knowledge of word meanings;
2. Reasoning facility;

3. General information;

4. Interest in literary rather than mechanical activities.

These interpretations of the data differ markedly from those given by Holmes and Singer (1966, pp. 62-78), whose interpretations seem to be based on an impression that each of their predictor tests is made up of homogeneous variance that is adequately described by the title of the test.

In addition to the regression analyses reported above, Holmes and Singer also performed a centroid factor analysis of the common variance of the two criterion variables and the 54 predictor variables. Nine factors were extracted and rotated by the normalized varimax procedure. Of these, six measure variables essentially irrelevant to either of the two criterion variables. This result is a little surprising when it is recalled that these 54 predictor variables were chosen in the light of the substrata-factor theory to be relevant to an analysis of speed and power in reading. The rotated factor that accounted for the largest percentage of the variance (27 per cent) appears to measure general verbal facility. The second largest factor appears to measure the reporting of problems in personal adjustment and is not relevant to the criterion measures of reading. The third largest factor seems, after reflection of signs, to be a music aptitude and appreciation variable. It has little relationship to reading. The fourth largest factor appears, after reflection of signs, to measure visual-perception ability. The fifth largest factor probably measures speed of mental operation, especially in taking tests. The remaining factors have no appreciable relationship to speed or level of comprehension in reading. Three of them appear to be interest factors and the fourth is not defined clearly enough to warrant interpretation. To conclude from this study that comprehension in reading involves general verbal

facility, speed of mental operation, and some skill in visual-perception is probably correct but does not seem particularly helpful in understanding the processes of comprehension or of developing skill in them. It would appear that this effort to test certain aspects of the substrata theory of reading was not rewarding, perhaps because of an unfortunate selection of criterion and predictor tests and partly because of statistical procedures.

Let me complete this paper by saying that after a half century of psychometric research on comprehension I believe that Professor Thorndike's 1917 model of comprehension as mainly a composite of recalling word meanings and reasoning with them has stood the test of time. Davis's studies (1941, 1968) confirmed Thorndike's findings, quantified them, and extended their application to secondary-school and college students. These studies also added several more specific skills that should be taken into account.

How should we use these findings and what research ought to come next? First, tests of comprehension for secondary schools and colleges should be referenced to Davis's list of behavioral skills shown in Table 2. This is a fundamental step in achieving content validity through the development of criterion-referenced tests at appropriate levels of difficulty.

Second, workbooks designed to develop the behavioral skills of comprehension should be developed and used to allow pupils consciously to practice these skills in useful content materials. Sample exercises of the type that might be useful in such workbooks are shown in Table 3. Third, tests should be supplied with the workbooks to aid in evaluating their usefulness and to permit informal diagnosis of the performance of individual pupils.

The next steps in research in comprehension should, in my judgment, be to apply Davis's model of the process to elementary-school pupils in grades 2-3

and to middle-school pupils in grades 4 through 6. Adaptations in the model will have to be made and new types of comprehension exercises will have to be devised. At least one doctoral dissertation is now under way in this field. Translation of the model into the language and concepts of psycholinguistic theory has already been accomplished.

Along with the extension of Davis's model of comprehension to use in grades 2-6, a new model of the process of decoding must be developed. A preliminary version of this model has already been developed, criterion-referenced tests based on it have been written, and these tests are being tried out in Title-I classes this week under the auspices of the Chicago Board of Education and the Educational Records Bureau.

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