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Human Factors and Behavioral Science:

A Study of the Match Between the Stylistic Difficulty of Technical Documents and the Reading Skills of Technical Personnel

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The reading grade level of a sample of Bell System technical documents was assessed using the Flesch Reading Ease Index, which estimates the reading skill needed to cope with a document's writing style. The reading skills of two groups of Bell System craft and management trainees were also estimated from their performance on a standardized reading test. We found that most of these employees had sufficient reading skill to deal with the writing styles of the sample documents. This observed match between readers and documents resulted because most of our students were proficient readers, not because the documents' writing styles were easy. We compared the reading skills of students as they entered and completed training to see whether less able students were eliminated during training. Results did not support training selection as an explanation of our readers' proficiency. While results indicated that many Bell System employees have the reading skills necessary to cope with the technical documents they read, others may find that the writing styles of technical documents are real barriers to success on the job. We can identify a document that may place an undue burden on its readers by estimating the likelihood of a mismatch between the document's readability and the reading skills of its users.

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I. INTRODUCTION

How well technical documents communicate with their readers depends in part on the style in which they are written, since the *way* ideas are expressed can influence how easily they are understood. Readers may find a document particularly difficult to read when its writing style places an undue burden on their reading skill. For example, use of words that are unfamiliar to readers can obscure a document's message. Also, a document can be unclear if ideas are embedded in sentences whose syntax is too complex for its readers. Other characteristics of style are described elsewhere in this issue of the *Journal*.[1]

The stylistic difficulty of written communication can be appraised with the help of readability formulas.[2,3] These formulas predict the reading difficulty that may result from a document's writing style but not from its content, organization, or format. Readability formulas estimate the reading skill needed to cope with a document's writing style, as manifested in the writer's choice of surface structures. A readability index is calculated from measures of text features that are thought to be indicators of stylistic difficulty. For example, many formulas use the average length of a text's words and sentences to calculate readability. These two text measures, word length and sentence length, function primarily as indicators of the lexical and syntactic difficulty of the text. In English, shorter words are likely to be more familiar to readers than longer words, since shorter words tend to occur more frequently. Shorter sentences are apt to be easier for readers to process than longer sentences because shorter sentences tend to be less complex syntactically.

While readability indexes are often derived from relatively simple formulas, they can provide useful estimates of sytlistic difficulty.[4] For example, readability indexes tend to agree with human judgments of text difficulty,[5] and it is usually less time-consuming and costly to calculate a readability index than to collect human judgments of reading ease. Readability indexes have also been shown to predict behavioral measures of reading ease, such as reading rate[2,6] or duration of eye fixations,[7] in experimental settings. The readability level of documents has also been related to their effective use in work situations[8,9] and will be discussed later in this section.

Readability formulas have their limitations. Formulas only provide estimates of the stylistic difficulty of texts. These formulas are derived from correlations between text measures related to style and measures of reading difficulty such as comprehension test scores. Almost all formulas have been developed using a multiple regression technique to select the linear combination of stylistic measures that best predicts the scaled difficulty levels of a set of texts. Most of the commonly

used readability formulas, such as the Flesch and Dale-Chall formulas, produce estimates that are accurate to within ±1 reading grade level.[10] The Kincaid formula[11] is slightly less accurate, having a standard error of 1.41 as compared to the Flesch, which has a standard error of 0.81.[12]

Readability formulas are often criticized because editorial revisions that produce acceptable readability indices do not necessarily result in a more readable text.[3,13,14] For example, shortening words or sentences will lower a text's readability index without necessarily making it easier to read. This should not be surprising since readability formulas are derived from *correlations* between measurable text attributes and readers' performance on comprehension tests.[3] As pointed out in the preceding paragraphs, easily quantifiable text features such as sentence length gain their predictive power by indexing underlying contributors to text difficulty that are less easily quantified. Some of the important *determinants* of reading difficulty, such as syntactic complexity and the use of the passive voice, are discussed elsewhere in this issue of the *Journal*.[1]

Just how much difficulty a particular group of readers will have with a document's style depends on their level of reading skill. If a given reader's skill matches or exceeds that required by a document, its writing style alone is not likely to cause trouble for that reader, even though the document's subject matter may be difficult. Conversely, a reader with more limited skill is likely to find that the document's writing style alone presents a challenge.[2–4] By comparing a document's readability index (an estimate of stylistic difficulty) with an estimate of reading skill, we can predict the difficulty a reader might be expected to have with a document's writing style. An estimate of overall reading competence can be obtained from a person's performance on a standardized reading test. These tests sample a reader's behavior on tasks that have been found to discriminate between skilled and unskilled readers.

Estimation of the match between a document's readability and the reading skills of its audience can be helpful in evaluating the effectiveness of technical writing that contains job-related information. Many companies, such as the Bell System, rely heavily on written communication to support job performance. When the writing style of a job-related document is too difficult for its users, job performance may suffer in a number of ways. Studies have investigated the consequences of this mismatch between document style and reading skill. Jobs may take longer than usual to perform because needed information is hard to access.[9] Errors may increase because the descriptions of work procedures are unclear.[8] Perplexed readers may turn to co-workers for help, thus reducing their co-workers' productivity.[9]

In the present study, the match between the readability of docu-

ments and the reading skills of readers was estimated for a large sample of Bell System technical documents. These documents are a major source of information about the operation and maintenance of equipment. The readability of these documents was measured by computer and compared with the reading skills of two groups of Bell System employees who use the documents. Levels of reading skill were estimated from the employees' scores on a reading test.

II. METHOD

2.1 Readability survey

2.1.1 Documents

Readability measures were obtained for the text of Bell System technical documents called Bell System Practices (BSPs). These documents are a major source of information about the operation and maintenance of equipment. They are used throughout the system by both craft and management personnel. There are well over 250,000 BSPs so only a sample of these documents were analyzed. Most of these BSPs are typeset under computer control and consequently were available in computer-readable form.

The BSPs selected for analysis were those likely to be used frequently. To meet this goal, documents were chosen from three important areas of company activity—outside plant, customer equipment, and *ESS** switching equipment. The BSPs dealing with outside plant and customer equipment were taken in a random fashion from handbooks provided to craft personnel for use on the job. The BSPs about electronic switching systems were chosen in a random fashion from those describing the operation of two different systems, 1 *ESS* and 2 *ESS* switching equipment. Table I shows the number of BSPs analyzed from each category of company activity. Altogether, readability indices were obtained for 140 BSPs consisting of a total of 378,359 words.

2.1.2 Readability measure

The Flesch Reading Ease Index[12] was chosen to measure readability. The formula for calculating this index, given in Table II, uses two features of a text to predict stylistic difficulty: (1) the average length of a text's words in syllables, and (2) the average length of its sentences in words. These two measures function primarily as indicators of the lexical and syntactic difficulty of a passage. Available evidence[2–4] suggests that formulas using these simple word and sentence measures are satisfactory predictors of the stylistic difficulty of texts. The

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Table I—Number of BSPs in the readability survey from each category of company activity

Category	Number of BSPs	Total Number of Words
Outside plant	49*	101,162*
Customer equipment	48*	83,927*
ESS maintenance	50	213,373

* Seven BSPs that were in both the outside-plant and customer-equipment handbooks were included in the totals for both categories.

Table II—Formula for the Flesch Reading Ease Index and the algorithm for converting a vowel count to a syllable estimate

1. Flesch Reading Ease Index (FL):

   $FL = 206.84 - 84.6\ WL - 1.015\ SL$

   Where
   WL* is the average length of a word in syllables
   SL is the average length of a sentence in words

2. Algorithm for estimating the syllables (SYL) in a sample of words

   $SYL = 0.998\ VOW - 0.343\ W$

   Where
   VOW is total vowels (aeiouy)
   W is total words

* WL = SYL/W.

Kincaid formula[11] also uses these two measures and is the basis for the Writer's Workbench advisory on readability.[1] The Flesch formula was chosen for the present survey because it has been more widely used than the Kincaid formula and has been shown to be one of the most accurate predictors of readability.[10]

The Flesch Index ranges from 0 to 100 with a higher index representing a more readable text. A Flesch Index can also be expressed as a reading grade level, which is the average school grade of readers who would be expected to score 75 percent on a comprehension test for the reading material. Originally, a point on the Flesch Index scale corresponded to one-tenth of a grade,[12] but Flesch found that his formula underestimated the reading grade level of more difficult passages. He proposed a nonlinear relationship between the Flesch Index and reading grade level,[15] and this relationship is used in the present study to assign a reading grade level to an index value.

The Flesch Index was calculated by computer,[16,17] since the BSPs were in computer-readable form. A program was written to compute average sentence length for (complete) sentences in the text of the BSPs. The program was able to exclude tables, headings, and titles

that were flagged in the text. To calculate the average length of a word in syllables (WL), the program estimated the number of syllables in a word sample from a count of the number of vowels in that sample. This vowel count was then converted to syllables using the formula[18] shown in Table II.

When syllables are estimated from a vowel count, the presence of words without vowels, such as abbreviations, acronyms, and numbers, may be a problem. Their inclusion in the computer's estimate of syllables can lead to an underestimation of average word length and a consequent underestimation of reading difficulty. This is a problem when analyzing technical documents. In some of the BSPs selected for the present survey, over 11 percent of the words did not contain vowels. One solution to this problem is to base the syllable estimate on words that conform to the syllable estimation algorithm's assumption that a word contains at least one vowel. This solution was adopted in the present study and has been implemented in the Writer's Workbench. Only nonnumeric words with at least one vowel were used in the estimation of syllables from a vowel count. This solution seemed to work. Flesch Indexes were computed using hand counts of syllables for 16 BSPs that had a large number of words without vowels. These manually produced indexes were compared with computer-produced indexes. When words without vowels were omitted from the computer estimation of syllables, 11 of the 16 texts were assigned the same reading grade levels by the computer-produced and manually produced indexes. When words without vowels were included in the syllable estimation, only 4 of the 16 BSPs were classified at the same readability level by the computer-produced and manually produced indexes. This solution finds precedence in Flesch's suggestion[12] that counts of syllables be based on words whose pronunciation is unambiguous.

2.2 Reading skills survey

2.2.1 Reading test

The reading skills of Bell System personnel were estimated from their performance on a standardized, commercially produced reading test, the Nelson-Denny Reading Test, Form D.[19] This test had been standardized by giving it to a sample of over fifteen thousand high school students, representing the student population of the United States in 1972. The test performance of students in this sample was used to estimate the reading skill represented by a test score. Level of reading skill is often expressed as a score's reading grade level. A test score is assigned a reading grade level that corresponds to the *average* educational level of students who made that test score in the standardization sample. Thus, a reader's reading grade level is the school grade for which his or her test score is typical. It should be emphasized

here that the educational level of a person and the reading grade level of his or her test score are not identical.

The Nelson-Denny Reading Test was chosen for three reasons: (1) it can be given in a reasonably short period of time, (2) it covers a range of reading abilities appropriate for Bell System employees, and (3) it was well constructed according to standards for norm-referenced tests.[20]

The Nelson-Denny Test is composed of a vocabulary test and a comprehension test. The vocabulary test contains 100 multiple-choice items consisting of a sentence stem and four words that can complete the sentence. The comprehension test consists of 36 multiple-choice questions that relate to five short prose passages. Readers work on the vocabulary test for 10 minutes and on the comprehension test for 20 minutes.

Performance on the test is expressed as a total score. This score is the sum of two subscores: (1) the number of correct vocabulary items, and (2) the number of correct comprehension items multiplied by two. The reading grade equivalents for total scores are given in the Examiner's Manual of the Nelson-Denny Test.[19] In terms of accuracy, the total score has a standard error of measurement* of about 5.7.[19] Translated into reading grade level, this standard error is approximately a 0.5 reading grade level.

In the present study, total scores were used in all statistical computations. However, the results were also presented as reading grade equivalents of test scores. Reading grade levels were used because: (1) they are often a more meaningful way of expressing reading skill, and (2) the readability of the technical documents was expressed as reading grade levels.

2.2.2 Subjects

The Nelson-Denny Reading Test was given to 471 technical management employees and 210 craft employees. Both groups were students at Bell System training centers. The management students were taking a variety of technical courses covering such diverse subjects as switching systems, data management, building engineering, and finance. The craft students were taking the final course in an *ESS* switching equipment training program that involves approximately 700 hours of training.

These employees were chosen because they were likely to use doc-

* The consistency of a test can be expressed in terms of the standard error of measurement. Approximately two-thirds of the hypothetical "true" scores on a test would lie within one standard error of measurement from a score obtained on the test.

uments such as the BSPs sampled in the readability survey. In addition, students at the training centers are more readily available for testing than are employees in work situations.

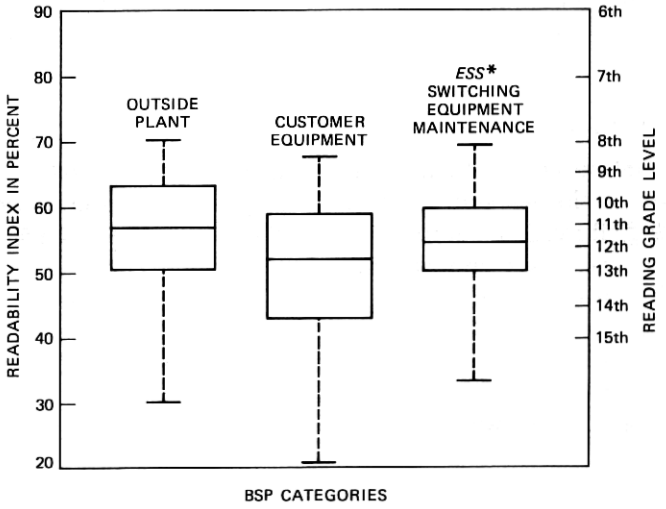
Each student took the Nelson-Denny Test and filled out a questionnaire requesting information about his or her age, sex, years of formal education, job level, years of service in the Bell System, and region of the country in which he or she worked. The study was conducted in the students' classrooms in groups ranging from 10 to 30 students. All students in the selected classes participated in the study although they were not required to do so. To ensure the anonymity of the participants, each student used a number to identify all test material and the questionnaire.

III. RESULTS

3.1 Readability survey

Figure 1 shows the distributions of Flesch Indexes for BSPs in each of the three categories: outside plant, customer equipment, and *ESS* maintenance. The distribution for each category is displayed as a box plot. The ends of a box are drawn at the upper and lower quartiles of the distribution, while the bar across the box represents the median. The extremes of the distribution are plotted as horizontal lines joined to the box by dashed lines.

Figure 1 suggests that considerable reading skill is required to cope with the writing styles of many BSPs. Thirty-three percent of all the



*TRADEMARK OF WESTERN ELECTRIC.

Fig. 1—The distributions of readability for the three categories of BSPs.

BSPs sampled had Flesch Indexes below 50. An appreciation of the stylistic difficulty of these BSPs can be gained by comparing their readability levels with those obtained by Flesch[12] for some representative magazine articles. Flesch found that academic journals such as the *American Scholar* or the *Yale Review* had Flesch Indexes ranging from 30 to 50, while quality magazines such as the *New Yorker* had Indexes ranging from 50 to 60. Over half of the customer-equipment BSPs were comparable to academic journals in their level of stylistic difficulty. The writing style of three-quarters of the *ESS* switching equipment maintenance BSPs was at least as difficult as that of quality magazines. In terms of required reading skill, the writing style of one-third of the BSPs would be likely to cause difficulty for readers with skills below the 13th reading grade level. The writing style of over half the documents (63 percent) would be likely to cause difficulty for those employees reading below the 11th reading grade level.

3.2 Reading skills survey

3.2.1 Reader characteristics

The questionnaires provided information about the students who took the reading test. Sixty-five percent of the technical management students were first-level management, 27 percent were second-level management, and the remaining 8 percent were third- (4 percent) and fifth- (4 percent) level management. As Table III shows, the technical management students represented a broader range of age, education, and years of service than did the craft students. The two groups differed primarily in educational level. More technical management

Table III—Age, formal education, and years of service

		Percentage of Students	
		Technical Management	Craft
Age Level	20–29	26	29
	30–39	39	52
	40–49	24	14
	50 or older	11	5
Educational Level	Some high school	1	3
	High school grad	30	55
	Some college	29	36
	College grad	26	6
	Some grad school	14	
Years of Service	1–5	19	9
	6–10	26	49
	11–20	30	30
	over 20	25	12

students (69 percent) than craft students (42 percent) had continued on to college after graduating from high school. There were also more women among the technical management students (30 percent) than among the craft students (9 percent).

3.2.2 Reading scores

The cumulative probability distributions of total scores on the Nelson-Denny Reading Test are shown in Fig. 2 for each group of students. The reading grade equivalents of test scores appear at the top of the figure. The median, upper, and lower quartiles of the distributions are also shown. The maximum total score is 172, while the highest reading grade level that can be assigned to a score is 15.

Test scores indicate that, on the average, both groups of students were competent readers. Mean scores were 81 and 94 for craft and technical management students, respectively. For comparison, the Nelson-Denny manual[19] gives mean scores for samples of freshmen, sophomores, juniors, and seniors in college. These scores were 75, 85, 93, and 98, respectively. Over half the craft and technical management students had test scores at or above the 14th (college sophomore) reading grade level. The reading grade levels of the mean scores were 14.0 and 14.9 for craft and technical management students, respectively, and this difference between student groups was greater than would be expected by chance ($t = 3.24$, $df = 671$, $p < 0.05$).

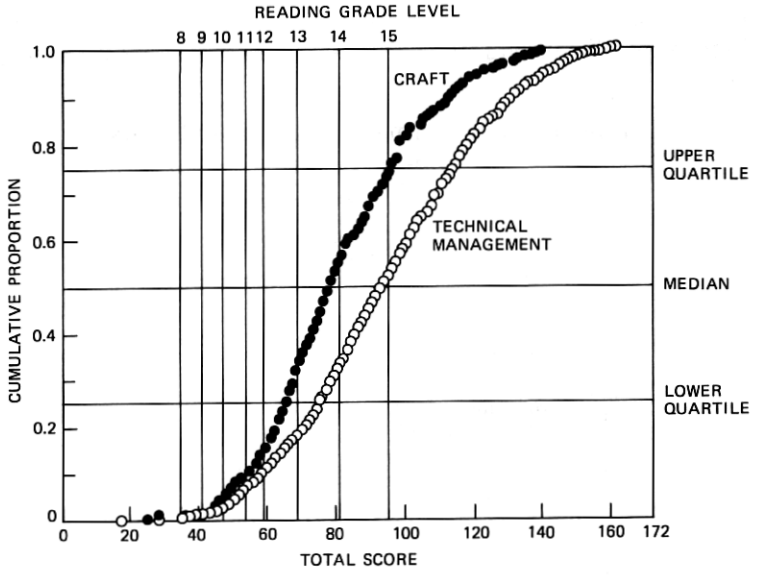


Fig. 2—Cumulative frequency distributions of reading test scores showing the median, upper, and lower quartiles of distributions.

3.3 Estimating the stylistic difficulty of BSPs

An estimate of the difficulty a group of readers may have with the writing style of a specific document can be made by finding the proportion of readers whose reading grade levels on a reading test are below the reading grade level of the document. If a document's reading grade level is 12, for example, and one third of its users have reading skills below the 12th reading grade level, then the likelihood of a mismatch is 0.33 (e.g., the probability that the users' reading skills will be below the 12th reading grade level).

This likelihood of a mismatch between audience and document can be extended to a set of documents. In this case, two measures are needed for each reading grade level represented by the set of documents:

1. The proportion of documents in the set whose reading grade levels are greater than a specified reading grade level (that is, the proportion of documents likely to be difficult for readers at that grade level);
2. The proportion of readers in the group at that reading grade level.

The likelihood of a mismatch is the sum of the products of these two estimates over all reading grade levels. This likelihood is the probability that a member of the audience will select a document from the set that exceeds his or her reading grade level.

The likelihood of a mismatch between BSPs and the technical management and craft students were calculated from the information in Table IV. This table shows the proportion of BSPs whose reading grade levels exceeded each level in the table. Also shown are the

Table IV—Proportions for calculating the likelihood of a mismatch between BSPs and two employee groups

Reading Grade Level	Proportion of Difficult BSPs	Proportion at Each Reading Grade Level	
		Technical Management	Craft
below 7.0	1.00	0.00	0.01
7.0–7.9	0.99	0.00	0.00
8.0–8.9	0.90	0.01	0.01
9.0–9.9	0.74	0.01	0.02
10.0–10.9	0.63	0.04	0.05
11.0–11.9	0.44	0.04	0.05
12.0–12.9	0.33	0.06	0.15
13.0–13.9	0.20	0.16	0.26
14.0–14.9	0.11	0.19	0.18
15 or greater	0.00	0.49	0.27

proportion of technical management and craft students at each reading grade level.

The likelihoods of a mismatch between BSPs and the student audiences was 0.14 for technical management students and 0.20 for craft students. This result suggests that technical management students were likely to have some difficulty with the writing style of about 14 percent of the BSPs in the sample, and craft students with about 20 percent. These estimates of difficulty suggest that the mismatch between students and BSPs is not great, but we do not really know how to interpret such results. For one thing, the Flesch Reading Ease Index assumes 75-percent reading comprehension. For technical documents, such as these BSPs, comprehension closer to 100 percent is probably desirable. In addition, although losses in job efficiency may result when employees have difficulty with a document, simplifying its writing style can be both costly and time-consuming. At present we know that it is useful to match documents to readers but we don't know how to calculate the benefits and costs involved in achieving this match.

IV. DISCUSSION

The results of the present study suggest that the writing style of many Bell System documents used on the job and in training requires considerable reading skill. Yet, the reading skill levels of the majority of the employees we tested matched or exceeded the estimate of required reading skill provided by the readability analysis. Our two samples of Bell System employees appeared to have fewer people with limited reading skills than might be expected from their educational levels. This was especially so for the craft students who had an average reading grade level (level 14—college sophomore) that was two grade levels *above* their average educational level (level 12—high school graduate).

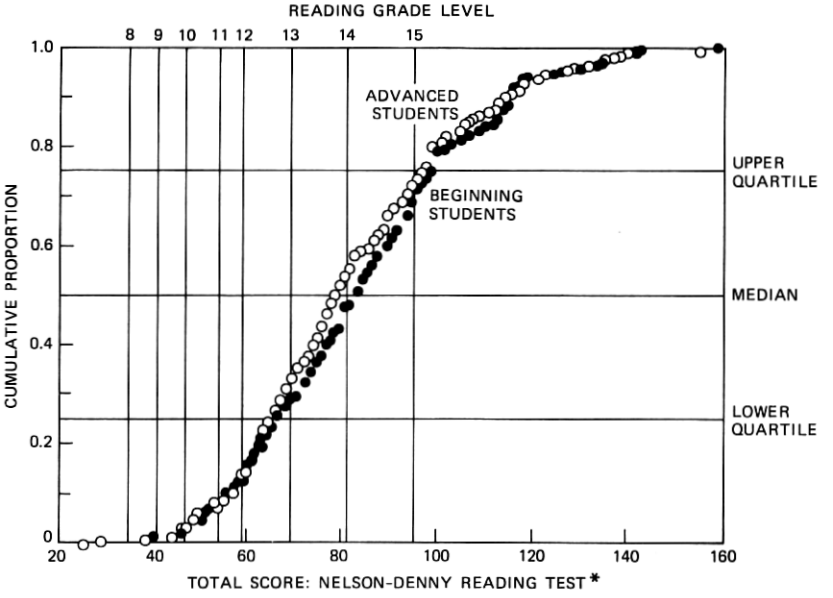
A number of selection factors may have acted to make our sample of Bell System employees such able readers. One of these factors may have been the documents that these students read during training. The craft students we tested had successfully completed a series of courses (approximately 700 hours of training) that required the use of highly technical documents, including BSPs. These technical documents may have acted as selective filters, tending to eliminate students with limited reading skills. This explanation assumes that students who have reading difficulties or who are averse to reading difficult documents will tend to leave training. If our filter explanation is correct, we would expect to find proportionately more skilled readers among students who were about to complete training than among students who were starting a training sequence. We explored this filter

explanation by comparing the reading-test performance of craft students who were just beginning an *ESS* switching equipment training sequence with students who were about to complete this sequence.

The Nelson-Denny Reading Test and a questionnaire were administered to 160 craft employees who were enrolled in introductory *ESS* switching equipment courses given at the training centers of several operating companies. Their performance was compared with that of the 210 craft students discussed earlier (Fig. 2), who were finishing their last course in the ESS training sequence.

The distributions of total scores on the reading test are shown in Fig. 3 for the beginning and advanced students. There was little difference between these two groups in their performance on the reading test. These results do not support the contention that training documents tend to filter out less able readers during *ESS* training, but rather they suggest that our sample of Bell System craft students was not biased by selective factors during *ESS* switching equipment training. Thus, their level of reading skill is likely to be representative of Bell System craft employees with similar training.

Training documents may not have worked as filters because of the procedures for selecting employees who enter *ESS* switching equip-



*MAXIMUM SCORE IS 172

Fig. 3—Cumulative distributions of reading test scores for advanced and beginning students.

ment training. These procedures, themselves, may lead to the choice of able readers. Operating companies undoubtedly choose their more able employees for *ESS* training because it is expensive and time-consuming. In addition, all those who start *ESS* training must complete a mini-course that helps to select employees who are likely to do well in *ESS* switching equipment self-instructional training. Even the perceived mental demands of operating and maintaining a complex switching system may discourage employees with limited intellectual skills. Although *ESS* trainees are not chosen explicitly for their reading skills, all the factors mentioned above could lead to the selection of competent readers as trainees.

V. CONCLUSION

In the present study, the reading skills of the majority of employees we tested were likely to be matched to the reading demands made by the writing styles of the majority of the technical documents they read. This match resulted because so many of the employees were proficient readers and not because the documents were easy to read. In many technical areas, such as *ESS* switching equipment, readers may have more reading skill than would be expected on the basis of their education. One implication of this finding is that demographic information about education may not be sufficient to predict an audience's level of reading skill. More direct estimates of reading skill may be needed, such as the Nelson-Denny Reading Test.

Although we found a reasonable match in grade levels between documents and readers in the present study, this does not ensure that the documents are easy to read. Documents can be identified as difficult but not necessarily as easy to read, because the readability index does not include such important determinants of difficulty as organization, content, or format. For this reason, our findings should not discourage Bell System writers from writing as clearly and simply as possible. For many employees, the writing styles of technical documents may be a real barrier to success on the job. Screening devices that combine information about the readability of documents and the reading skills of their audiences, such as the likelihood of a mismatch, can help identify documents that may be too difficult for their intended readers.

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