THE EFFECTS OF PICTORIAL AND VERBAL INSTRUCTIONAL MATERIALS ON THE OPERATIONAL PERFORMANCE OF DEAF SUBJECTS[1]

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The present research compared the effectiveness of pictorial and verbal information in printed instructional materials for deaf subjects. Four types of instructional formats were prepared, varying in proportion of pictorial and verbal information: (a) all pictorial; (b) predominantly pictorial, with some ancillary verbal information; (c) all verbal; and (d) predominantly verbal, with some ancillary pictorial information. Each format was given to a separate group of deaf college students. The instructional materials described sequences of operational procedures to be carried out by subjects on a complex control-display apparatus. Performance was measured by task completion time and error rate. Results showed that when both performance variables were considered, the best instructional format was predominantly pictorial, with some ancillary verbal information. The all-pictorial format produced short task completion times but relatively high error rates. The all-verbal and predominantly verbal formats generally yielded low error rates but longer task completion times. Since these results are consistent with related studies conducted with hearing subjects, the research has general implications for the development of instructional materials and job performance aids in education and rehabilitation.

A pervasive problem in education is how to design instructional materials that convey information to students efficiently and unambiguously. This is a particularly important consideration in the field of special education, where instructional methods and materials should be designed in accordance with the special needs and characteristics of students. With printed materials, the principal channels of communication are linguistic (verbal) and pictorial, and the educator must decide what kind and proportion of information should be conveyed by each channel. Such judgments most often are based on intuition or expediency rather than objective evidence. Accordingly, the present research provided an empirical evaluation of the effectiveness of printed verbal and pictorial information, as revealed by objective measures of subject performance. Although the experiment was conducted with deaf students, the results (combined with findings from related studies) have general implications for the development of instructional materials and job performance aids.

[1]This project was supported in part by research funds from Gallaudet College.

0022-4669/80/1402-0006$02.00/0

It is well known that early childhood deafness, as a rule, severely impedes the acquisition of spoken language and the development of reading (and writing) ability, thereby disrupting general educational and cultural development. Attempts to improve the quality of education for the hearing impaired generally have followed two basic approaches. One employs special techniques and materials to improve reading performance directly, while the other uses instructional formats designed to communicate more effectively within the existing language and reading skills of the hearing-impaired student. Although more effort has been directed to the former approach, results have not been encouraging. For example, the average reading-test performance of noncollege deaf students at the age of 18 is comparable to about a fourth-grade level by comparison with norms for hearing students (DiFrancesca, 1972; Furth, 1966; Jensema, 1975). As might be expected, the problems of English language development and reading are most acute for prelingually deaf individuals — those who were born deaf or became deaf before language acquisition, and who account for about 50% of the deaf population under the age of 20 (Schein & Delk, 1974). Early educational approaches for prelingually deaf children that incorporate sign language in the home and school may facilitate later acquisition of English, although further research is necessary to substantiate this (Brasel & Quigley, 1977).

Continued efforts to improve the reading ability of deaf children are essential, but in view of the discouraging lack of progress to date, it appears that greater emphasis should also be given to the design of printed instructional materials that can be comprehended more readily by deaf individuals. Improvements in instructional format design might also aid in the educational and vocational development of hearing persons with reading and language disabilities (Magee & Smith, 1976).

In recent years psychologists have shown increasing interest in the extent to which pictures convey information to people varying in age, education, language, and cultural background (Hagen, 1974; Kennedy, 1974). A theoretical basis for understanding picture perception has been provided by Gibson (1966, 1971), who describes an optic array of reflected light from a picture as structured in such a way that it contains the same *kind* of information found in an optic array reflected from the real object or environment represented in the picture. Thus, an outline drawing provides optical contrasts that may represent (correspond to) the edges of a real object or surface discontinuities of color, brightness, and texture. In fact, a picture, such as an outline drawing, cartoon, or caricature, may facilitate perceptual recognition by eliminating the superfluous and enhancing the critical features (Dwyer, 1972; Ryan & Schwartz, 1956).

The richness of information provided by pictures is a principle well known to educators concerned with the preparation of printed materials and visual aids. However, pictures alone often are not sufficient to communicate information efficiently and unambiguously. Chapanis (1965) has summarized this issue by the following questions: "How much is a picture worth? When should we use pictures rather than words? What should be the mixture of pictures and words that will give us the most understandable and most readable combination?"

Anticipating such questions, Gibson, in 1954, proposed that pictures and other "replicative surrogates" are effective in representing concrete objects, places, and events, while words and symbols are essential in conveying abstract properties, qualities, or variables. However, the relative effectiveness of pictures and words in conveying information remains to be determined empirically. This is a particularly important question in the field of deaf education.

Traditionally, pictures have been used to convey the meanings of written words and phrases in teaching reading to deaf (as well as hearing) children (Reynolds, 1976; 1978). Presenting information simultaneously through pictures and printed language has been considered by Hartman (1961) in a discussion of the instructional effectiveness of various forms of "multiple-channel communication." His review suggests that multiple-channel presentations are generally more effective than single-channel presentations, provided that the tests of comprehension and retention use the same channels employed in the presentations. The advantage of multiple-channel communications is explained by Hartman in terms of "cue summation." That is, information which may be ambiguous or absent in one channel may be supplemented by more readily comprehensible information presented in another channel.

Experiments showing performance variations as a result of different combinations of pictorial and verbal (print) information have been conducted with both hearing subjects (Booher, 1973; Dwyer, 1972) and deaf subjects (Reynolds & Rosen, 1973). The study by Reynolds and Rosen compared the effectiveness of three printed instructional formats (narrative textbook style, individualized, and pictorial) with hearing-impaired college students. Results showed that the pictorial format, which consisted of outline drawings with printed verbal labels and brief printed descriptions or explanations, produced better comprehension and retention than the textbook and individualized formats.

Booher (1973) presented proceduralized task information to Navy maintenance personnel, and found that pictorial information facilitated performance speed, but produced a relatively high error rate. Verbal information, on the other hand, tended to reduce the error rate, but at the expense of performance speed. However, a multiple-channel format with a high proportion of pictorial information combined with related verbal (print) information produced the best overall results in terms of both task performance time and accuracy.

The present study compared the effectiveness of four instructional formats, derived from Booher's materials, with a sample of deaf college students. The instructional materials described sequences of operational procedures to be carried out by subjects on a complex control-display panel. The effectiveness of instructional materials was measured by the performance variables of task completion time and error rate. In this way, the dependent variable measures were isolated from the subjects' expressive verbal abilities. Since deaf subjects generally show deficiencies in reading performance, it was expected that instructional formats consisting entirely or primarily of pictures would generally produce better task performance than would formats consisting entirely or largely of verbal (print) information. More specifically, following Booher's (1973) results, it was hypothesized that an instructional format consisting of a

high proportion of pictures and a lower proportion of related, printed verbal information would produce the best overall performance, considering both task completion time and error rate.

METHOD

Subjects

A total of 56 deaf students (20 males, 36 females) from Gallaudet College served as subjects in the experiment. Gallaudet College students generally read at a higher level than the average for the adult deaf population, with mean reading-test performance equivalent to a ninth- or tenth-grade level by comparison with norms for hearing students (Reynolds, 1976). The subjects ranged in age from 19 to 30 years, with a mean age of 23. Their average pure-tone hearing loss was 97 dB (ANSI, 1969) in the better ear, corresponding to profound deafness. All became deaf prior to 5 years of age, and the vast majority (94%) became deaf before age 3 (prior to significant acquisition of spoken language). Students were randomly assigned to four groups corresponding to the different instructional formats. Initial selection of subjects to meet audiological criteria (profound deafness and early age of onset) was based on student responses to a questionnaire. Following the experiment, when objective records were checked, several students did not meet the audiological criteria and were dropped from data analysis, producing some inequalities in group size.

Apparatus

The apparatus operated by subjects in the experiment was a Programmable Task Simulator System designed by Booher (1973, 1975) to evaluate the relative effectiveness of various instructional formats. This system, diagrammed in Figure 1, consists of three control-display panels, an experimenter control unit, a subject GO-FAIL decision unit, a programmable display matrix, and underlying electronic logic and power circuitry.

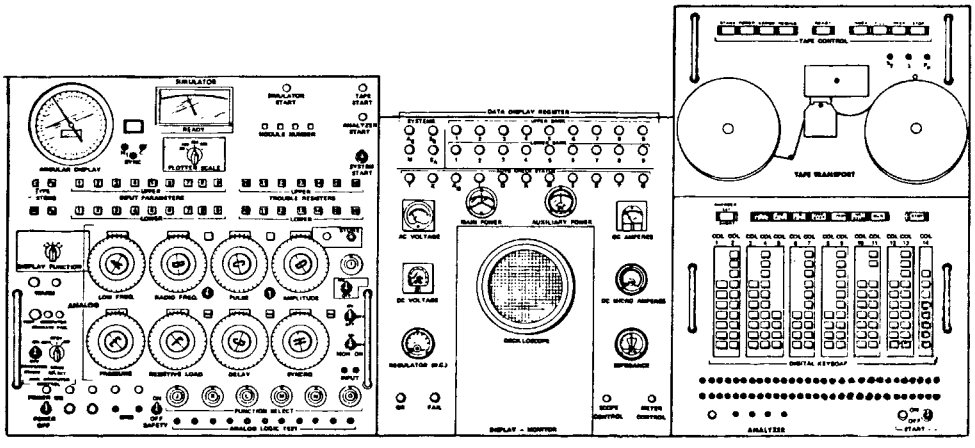

Figure 1. Programmable task simulator.

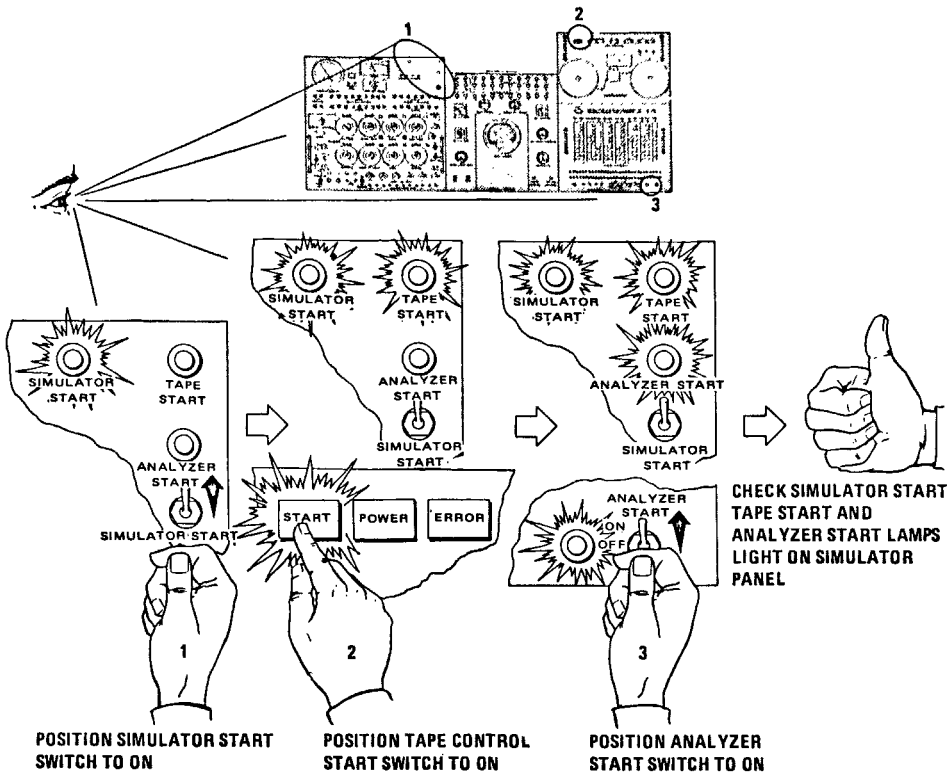

Figure 2. Sample of operational instructions from the High Pictorial–Low Verbal format.

Instructional formats. Four sets of operational instructions were prepared, varying in proportion of pictorial and printed verbal information. All instructional formats presented the same operational information, consisting of three practice procedures or tasks followed by eight experimental tasks in fixed order to be carried out with the apparatus. The tasks were divided into two categories termed "Location" problems and "Reference" problems, which were presented alternately in the instruction manual for the eight experimental tasks. Location problems required the subject to locate certain control and display components on the apparatus and to use them in executing a set of prescribed actions. Reference problems required the subject to compare information presented in tables with information displayed on the apparatus, and then to make responses based on the results of this comparison.

The four types of instructional formats are described below, with a sample frame from one format shown in Figure 2.

1. All Pictorial. This format consisted of information presented through the single channel of pictorial displays (outline drawings). No printed verbal information was used, and labels on the apparatus consisted only of alphanumeric symbols. The pictures identified the general area of the apparatus involved; the

specific controls, displays, or tables to be used; and the sequence of actions to be performed.

2. All Verbal. This format consisted entirely of printed verbal and numerical information arranged in complete, but relatively simple, sentences and paragraphs identifying the controls, displays, and tables to be used and describing the action-steps to be followed. No pictures were included. Printed verbal labels were used on the apparatus.

3. High Pictorial–Low Verbal. The same diagrams in the All-Pictorial format were used, with the addition of some related printed words and phrases (see Figure 2). This verbal information consisted of labels identifying the specific controls, displays, and tables shown in the pictures, and brief descriptions of the action-steps to be followed. Printed verbal labels were also used on the apparatus.

4. High Verbal–Low Pictorial. This format consisted primarily of the same verbal information used in the All-Verbal format, together with some related pictorial displays. The pictorial information consisted of an outline drawing of the entire apparatus with word labels connected by arrows to specific controls and displays.

Procedure

Subjects were seated individually in front of the control-display apparatus and given typed preliminary instructions that introduced the purpose of the experiment and described the various parts of the apparatus. These instructions also explained that the task was to follow a set of printed procedural instructions describing specific operations to be carried out with the apparatus. The preliminary instructions were then summarized by the experimenter in sign language, followed by an opportunity for questions.

Subjects were assigned at random to the four instructional format groups. Initially, three practice tasks were given — one Location problem and two Reference problems. These were followed by the eight experimental tasks, which alternated between Location and Reference problems. Performance was measured in terms of errors and task completion time for each problem. Each problem or task consisted of a sequence of steps, and the experimenter recorded an error for each step performed incorrectly, performed out of sequence, or omitted. Task completion time was recorded to the nearest second with the aid of a stopwatch used by the experimenter.

RESULTS

The experimental design involved randomized independent groups assigned to the four instructional format conditions, with two problem types (Location and Reference) included in each format. The total errors for each subject were recorded as a percentage of the total number of steps in the four Location problems (19 steps) and the four Reference problems (21 steps). Time data represent the average task completion time per problem to the nearest second. Mean time and error data for the four instructional formats and two problem types are presented in Table 1.

TABLE 1
MEAN PERFORMANCE TIME (SEC.) PER PROBLEM AND PERCENT ERROR RATE FOR FOUR INSTRUCTIONAL FORMATS AND TWO PROBLEM TYPES

	All Pictorial (n=15)		High Pictorial–Low Verbal (n=15)		All Verbal (n=12)		High Verbal–Low Pictorial (n=14)	
	Location	Reference	Location	Reference	Location	Reference	Location	Reference
Time (sec.)								
Mean	60.27	45.27	66.73	60.87	89.83	103.75	92.86	100.43
SD	24.57	13.18	19.83	21.30	26.64	50.72	41.18	67.38
Errors (%)								
Mean	28.77	28.25	17.22	12.07	19.74	17.07	33.46	18.04
SD	17.20	20.34	9.84	11.50	16.66	15.79	18.78	14.97

Time and error data were separately analyzed by a two-factor, mixed design analysis of variance, with repeated measures on problem type. For time scores, there were significant effects between instructional formats (F=6.32, p<.01), but the difference between problem types and the format × problems interaction were not significant. Error data yielded significance between instructional formats (F=3.47, p<.05) and problem types (F=6.12, p<.05), but a nonsignificant interaction between these factors.

These results are clarified by the graphs in Figure 3 (time) and Figure 4 (errors). Figure 3 reveals that, for both Location and Reference problems, the

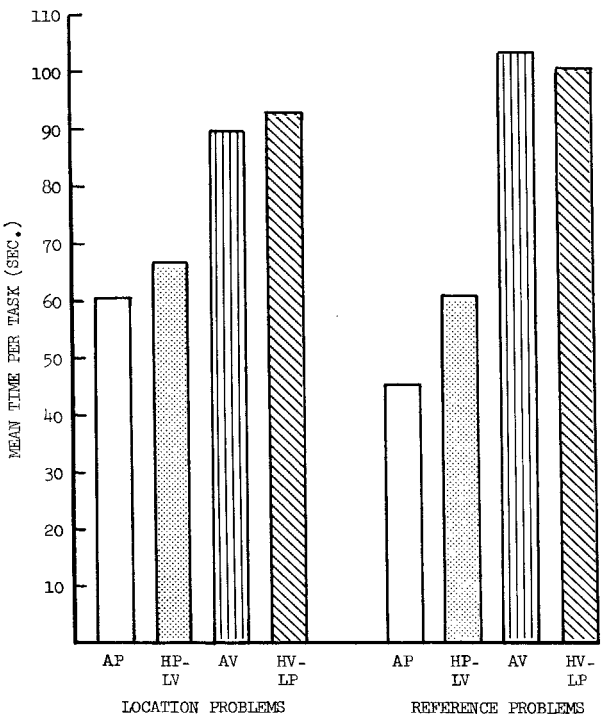

Figure 3. Mean performance time per problem for four instructional formats and two problem types. (AP, all pictorial; HP–VL, high pictorial–low verbal; AV, all verbal; HV–LP, high verbal–low pictorial.)

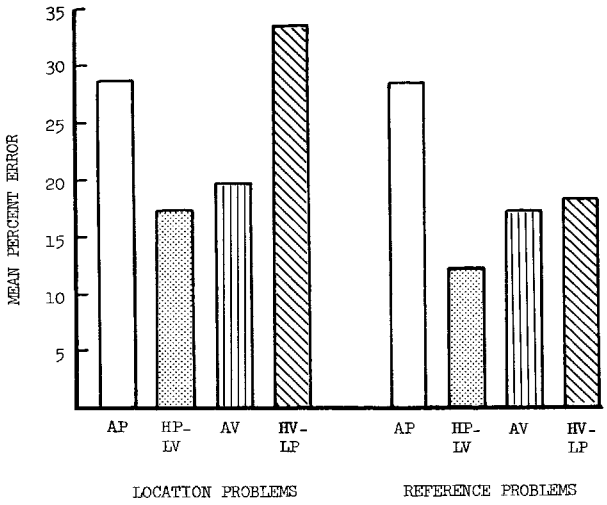

Figure 4. Mean percent error rate for four instructional formats and two problem types (abbreviations as in Figure 3).

shortest mean task completion times occurred for the All-Pictorial format, with somewhat longer times for High Pictorial–Low Verbal and substantially higher time scores for the All-Verbal and High Verbal–Low Pictorial groups. Tukey tests for multiple comparisons (Bruning & Kintz, 1977) indicated significant differences between the All-Pictorial format and the All-Verbal and High Verbal–Low Pictorial formats both for Location problems ($p<.05$) and Reference problems ($p<.01$).

Error data in Figure 4 reveal a somewhat different pattern of results. For both Location and Reference problems, the lowest error rates were produced by the High Pictorial–Low Verbal format, with slightly higher error scores for the All-Verbal format and substantially higher errors for the All-Pictorial format. The major difference in the pattern of results between the two problem types occurred for the High Verbal–Low Pictorial format, which yielded the highest error rate for Location problems, and a relatively moderate error rate for Reference problems. Tukey tests for multiple comparisons revealed significant differences between the High Pictorial–Low Verbal and High Verbal–Low Pictorial formats for Location problems ($p<.05$), and between the High Pictorial–Low Verbal and All-Pictorial formats for Reference problems ($p<.05$).

DISCUSSION

Relative effectiveness of instructional formats

Considering both time and error data, the All-Pictorial format provided the shortest mean task completion time, but a high error rate for both Location and Reference problems. By comparison, the High Pictorial–Low Verbal format produced the lowest mean error rate and the second shortest task completion time (not significantly different from the All-Pictorial format) for both problem types. Therefore, with both performance measures considered, the High Pictorial–Low Verbal format emerged as the most effective instructional design.

The advantage, in performance time, of this multiple-channel format over the predominantly verbal formats was statistically significant for both problem types for a one-tailed test, which would be justified by the directional hypothesis stated earlier. With error data, the superiority of the High Pictorial–Low Verbal format was not as strong, but the trend in that direction is evident from Figure 4.

The value of the High Pictorial–Low Verbal format is that the predominance of pictures efficiently conveys information about the layout of the apparatus, the controls and displays to which the subject must attend, and the sequence of actions which are to be carried out. The results revealed that information provided by the pictorials was effective in producing a relatively short task completion time. However, if pictures alone are employed, there may be some ambiguity about details such as the specific operations to be performed or the identity of specific controls and displays to be used. Such an interpretation was suggested by the relatively high error rate produced by the All-Pictorial format. The inclusion of a limited amount of verbal information in the High Pictorial–Low Verbal format may have served to reduce this ambiguity by specifying certain details, thereby lowering the error rate without appreciably increasing performance time. This advantage applies even though deaf students are generally deficient in reading performance by comparison with hearing students of the same age, because the verbal information in the High Pictorial–Low Verbal format is presented in relatively concise, uncomplicated form (see Figure 2). As shown by the results of Booher's (1975) research, the advantages of this format also apply to hearing subjects with presumably better reading ability.

The two formats consisting entirely or predominantly of verbal information generally produced low error rates (with one exception to be discussed later), which may be attributable to the relatively precise, unambiguous nature of printed language. The deficiency of these formats is that the reading of detailed information for comprehension is a process that lengthens task completion time, even for hearing subjects (Booher, 1975). However, it is possible that if this study were conducted with hearing subjects who are exceptionally good readers, task performance time with all verbal or predominantly verbal formats might be reduced.

Location versus Reference problems

The study included two categories of problems to increase representativeness of the experimental tasks and to determine the relative effectiveness of the instructional formats for rather different operational sequences. Of the two categories, Reference problems probably required a higher level of abstraction and attention to detail, since numerical information in tables had to be compared with information displayed on the apparatus, with the results of this comparison leading to specific responses by the subject. By comparison, Location problems entailed a more concrete identification of components on the apparatus and execution of specific responses involving those components. In spite of these differences, the pattern of results across instructional formats

was very similar for both types of problems for the performance time measure (Figure 3). With error data, the pattern of results was also similar, with the exception that the High Verbal–Low Pictorial format produced a significantly higher error rate for Location problems than for Reference problems. The explanation for this finding is obscure, since the All-Verbal format produced relatively low error scores for both problem types, and the inclusion of some pictorial information should not be expected to raise the error rate for the relatively concrete Location problems alone. Consequently, this finding may have been a spurious effect, considering the absence of this anomaly from Booher's data.

Theoretical and practical implications

The results of this study reinforce Hartman's (1961) conclusion that multiple-channel communications are generally superior to those employing a single channel. Data in Figures 3 and 4 show that both single-channel formats produced performance decrements, although on different dependent variable measures. The results also extend Hartman's conclusions, indicating that multiple-channel communications which are predominantly pictorial with supplementary verbal information can produce better performance than those which are primarily verbal, at least in an operational performance situation similar to that used in the present study.

It is also of some interest for a theory of pictorial perception that the outline drawings used in these instructional materials were so effective in facilitating performance time. Outline drawings might be considered "impoverished" pictures in which simple lines are used to represent only the edges of objects and the countours formed by discontinuities in surface color, luminance, and texture. In spite of this simplicity, research indicates that familiar objects depicted by outline drawings are readily recognized by children and adults across a wide range of educational, experiential, linguistic, and cultural backgrounds (Hagen, 1974; Kennedy, 1974). Apparently, outline drawings can preserve the essential distinctive features of shape and surface detail required for recognition, while eliminating less critical information about color, shading, and texture. Perhaps the efficiency of outline drawings contributed to the rapid assimilation of information and execution of prescribed actions in this experiment.

In general, pictorial information is advantageous because it provides an iconic representation requiring little or no decoding or interpretation by subjects. Verbal information, on the other hand, must be decoded and interpreted in order to derive meaning, a process requiring additional time. As Haber (1970) has demonstrated, the iconic nature of pictures allows more or less direct storage of the visual image in memory, with the result that recognition of pictures previously seen is extremely fast and accurate.

In addition to the educational implications, the results of this experiment have practical, vocational significance for deaf individuals and others with reading deficiencies. The present findings, together with those of Booher (1975),

suggest that properly designed information presentation formats can improve performance of both hearing and deaf persons on job-related tasks, thereby increasing the employability of reading-deficient individuals in jobs usually considered to require higher levels of reading ability.

Conclusions and recommendations for future research

The results of this study and Booher's (1975) findings suggest a number of general conclusions that should be relevant to deaf or hearing subjects who have achieved at least functional literacy (approximately fourth-grade reading level). These conclusions are applicable to the design of operational instructions, job performance aids, or task descriptions, and probably other kinds of educational materials as well.

1. If both performance time and accuracy (low error rate) are important considerations, an effective instructional format will consist predominantly of pictorial displays with some supplementary verbal information. Following Gibson's (1954) suggestion, pictures might best convey more concrete information about objects, places, procedures, and events, while more abstract or detailed information might best be communicated in verbal form.

2. If minimizing performance time is the most important consideration, and error rate is relatively unimportant, an instructional format consisting entirely of pictures may be effective, especially if the information to be communicated is not too abstract or detailed. However, the present research indicates that an all-pictorial format produces only moderately shorter task performance times than does a high pictorial–low verbal format, and this difference is not significant.

3. If performance accuracy (minimal error rate) is the overriding concern, and performance time is less important, an effective instructional format may consist entirely of verbal information, or possibly verbal material supplemented by pictorial displays. Of course the language complexity used in such a format should be appropriate for the students' reading level. Furthermore, it is likely that predominantly verbal instructional materials will be more effective for subjects with higher levels of reading proficiency.

This report has raised a number of questions and offered some tentative suggestions that might be explored through future research. For example, what is the relative effectiveness of pictorial and verbal information as a function of age and reading level of subjects? What combinations of pictures and words are best for communicating various kinds of information (e.g., abstract versus concrete; qualitative versus quantitative; simple versus complex)? How does the effectiveness of pictorial and verbal information vary as a function of the type of instructional material (e.g., operational versus didactic)? The answers to such questions will contribute to a better understanding of the informational value of pictures and to the improvement of instructional materials in the education and rehabilitation of both hearing and deaf individuals.

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