Adjunct Aids in Instructional Prose: A Multimedia Study With Deaf College Students

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A computer-based science lesson was administered to 144 deaf college students grouped into low, middle, and high reading ability levels. Five instructional conditions were compared: (1) text only, (2) text and content movies, (3) text and sign movies, (4) text and adjunct questions, and (5) all of these together (full condition). The low reading level subjects in the adjunct question and full conditions demonstrated immediate, factual learning performance comparable to that of the high reading level subjects in the text-only condition. These and other results of this investigation suggest the compensatory potential of adjunct aids and associated mathemagenic activities to improve factual learning from instructional prose for low reading ability students.

Deaf learners' difficulties in comprehending prose have long been documented. Allen (1986) reported that deaf students lag increasingly in reading comprehension relative to their hearing peers through the school years. By the time deaf students are in their late adolescence, their reading abilities approximate those of the average 8- or 9-year-old hearing student. It has been estimated that only 8% of all deaf students enrolled in college read at the 8th grade level or higher, and the estimated functional reading level for minority deaf college students is even lower (Allen, 1994).

Unfortunately, reading comprehension deficits in deaf learners have not changed much over the past thirty years. More than 30% of deaf students leaving school are functionally illiterate, compared with less than 1% of their hearing peers (Marschark, 1993). Analyses of the English grammatical knowledge of deaf students have shown delays in virtually every aspect of English syntax. English sentences that do not follow subject-verb-object word order are particularly difficult for these learners (Berent, 1988; Quigley & King, 1980; Wilbur, Goodhart, & Montandon, 1983).

For deaf learners, adjunct aids to improve learning from prose have long been recognized as useful. "Pictures," wrote deaf educator James H. Logan (1870), "besides the pleasure they give, act as definers of the text, and convey far more correct ideas than could be gained from the words alone" (p. 97). Logan lacked the tools available today for educational research. Yet, even in more recent times, few such studies have involved deaf subjects, despite the promise of adjunct aids to learners who rely primarily on vision. Since there is no comparable body of literature, a review of adjunct aids to prose learning must necessarily include findings from studies with hearing subjects. The following review focuses on three types of adjunct aids used in the present study: pictorial displays, sign representations, and adjunct questions.

Adjunct Pictorial Aids

Pictorial aids in the form of static illustrations and animation are frequently used in instructional materials. Early studies focused on illustrations used in printed books; more recent studies include computer-based instruction. Some investigations examine the importance

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of contiguity, that is, the presentation of more than one medium in an integrated frame. Studies using illustrations with text have shown how contiguity may enhance learning. Bransford and Johnson (1972), for example, found that when high school and undergraduate college students with normal hearing were presented with ambiguous text accompanied by a picture that integrated text information, they recalled information contained in the unfamiliar prose more readily than those who did not see the pictorial organizer.

Royer and Cable (1976) reported a significant increase in abstract prose comprehension for hearing undergraduate college students when an illustration was included with text material. Dean and Enemoh (1983) investigated the effect of including a pictorial organizer in comparing undergraduate college students with and without prior knowledge of the text material. They found that, when provided with the pictorial organizer prior to reading, subjects with low prior knowledge recalled information at a level comparable to those with background knowledge. The authors concluded that null findings in such studies may result from the concreteness of the text per se. That is, highly concrete text may negate the contribution of supportive pictorial aids.

In another study conducted with hearing students, Mayer (1989) administered two versions of scientific text to 34 female college students, with and without illustrations. The students who received passages that contained labeled illustrations recalled more explanative than nonexplanative information than control groups. Mayer concluded that the results support a model of meaningful learning in which illustrations can help readers to focus their attention on explanative information in text.

Two investigations of the use of illustrations with deaf college students have also revealed positive findings. Reynolds and Rosen (1973) examined the effectiveness of three printed instructional formats, including narrative textbook, individualized, and pictorial formats. They reported that the use of the pictorial format, consisting of outline drawings with printed verbal labels along with brief descriptions or explanations, produced better learning and retention of information than a textbook or individualized format. Later, Diebold and Waldron (1988) used textbook materials and randomly assigned four different printed instructional formats presenting science concepts to 60 deaf students ages 12 to 22. The use of highly pictorial content and simplified English text produced significantly higher pre- to posttest gain scores than formats with less pictorial content and more complex English patterns in the text.

Research with hearing subjects has shown animation to be less effective with adults than with children (Rieber, Boyce, & Assad, 1990). Large, Beheshti, Breuleux, and Renaud (1995) suggest that animation in multimedia research has little empirical support although it is widely used in computer-based instruction. In a study with 12-year-old children, they investigated the effects of animation and linked short textual strings (captions) on the factual recall and enactment of a procedure to find south in a science lesson using a model specifically designed for that purpose. There was no significant difference for literal recall. However, the children in the text-plus-animation group were more successful at enacting the procedure than the text-only group.

In a study with deaf adults, Kelly (1998) used silent motion pictures to examine whether adjunct movies could foster comprehension of relative clause and passive voice sentences, two of the more challenging syntactic structures for such readers. He reported that the clear action of the movies' target scenes provided meaning that, along with the printed versions of that meaning, appeared to improve comprehension of sentences. Readers of less ability, however, did not benefit as much from the video instruction. Kelly hypothesized that deaf readers may have employed more of their capacity to process routine sentences and that they may not have had the capacity necessary to handle the "additional linguistic computations" of complex sentence structures, even with the benefit of adjunct motion picture aids (p. 229).

These available studies indicate that some adjunct pictorial aids used under certain conditions may contribute to learning. Pictorial aids seem to clarify ambiguous text and focus readers' attention on explanative information in text. Animations have been shown to be useful for providing procedural demonstrations and for conveying information through action. More research is needed, however, to determine additional specific

moderating factors. For deaf learners, traditionally recognized as "visual learners," the need for additional research on pictorial aids is particularly warranted.

Adjunct Sign Representations

Several studies have examined the association between text and graphic sign representations of the text, reporting that word identification task performance was improved with the use of adjunct sign language aids (Robbins, 1983; Stoefen-Fisher & Lee, 1989). In Robbins' study, with two groups of 49 deaf elementary and 32 deaf secondary students, sign language equivalents were displayed in pictorial format above each word in one of the three editions of a reading inventory. Comprehension questions were derived from the test manual. For both groups, the results indicated significant increases in comprehension with the use of the pictorial signs. Consistent findings with younger deaf children have been reported. Stoefen-Fisher and Lee studied deaf readers 6–8 years old and collected data on word identification and immediate retention. They found that the use of pictorial signs assisted beginning deaf readers in identifying unknown words. That is, both word identification and immediate retention were significantly better when the subjects received words with signs than when they received the printed words only. More recently Wilson and Hyde (1997) found that the use of signed English pictures in association with printed text significantly enhanced learning, particularly among poor readers. In their study, conducted with 8–13-year-old deaf children, more story details were recalled in correct sequence.

These studies were somewhat limited by the static nature of the graphic representation of signs. As Stoefen-Fisher and Lee (1989) suggest, investigations utilizing interactive computer generation might shed additional light on the relevance of signs and signed language as adjunct aids for reading text. On the other hand, studies comparing text (printed and captioned) and interpreted versions of spoken content have shown greater effectiveness in communication through the printed word. These include investigations with deaf adolescents of captioned versus interpreted versions of spoken messages (Gates, 1971; Norwood, 1976) and printed versus interpreted videotaped versions of a lecture (Stinson, Meath-Lang, & MacLeod, 1981). In addition, Stinson, Stuckless, Henderson, and Miller (1988) found deaf college students assigned higher ratings of understanding to real-time captions than to interpreting. Similar findings were reported in an earlier study by Stuckless and Enders (1971).

Thus, although research with deaf adolescents has shown a preference for reception of information through the printed word over captioning, other studies have shown promise for sign representations embedded in instructional prose. While the former studies focused on comparing forms of communication, the latter deal more specifically with their interaction in support of learning. There is a crucial need for additional research to examine the impact on learning outcomes of adjunct sign representations in instructional prose. For example, current computer technology provides the means to present digital sign movies in combination with instructional prose. This would allow for a more realistic presentation of sign representations in the context of an instructional unit.

Adjunct Questions

Since the early 1960s the study of mathemagenic activities and adjunct questions with hearing college students has received a great deal of attention (Anderson & Biddle, 1975; Faw & Waller, 1976; Hamaker, 1986; Rickards, 1979; Rothkopf, 1966, 1996). Generally, mathemagenic activities are student behaviors that produce learning. Whereas this concept includes a broad range of behaviors, from opening a textbook to mentally rehearsing lesson content, the research has focused primarily on covert activities during instruction. Much of this work has been performed within the context and methodology of adjunct questions. As a result of a variety of studies, specific causal relationships among certain adjunct question characteristics and learning outcomes with hearing subjects are well known. Perhaps the most researched relationship is between question position (preceding or following the pertinent section of text) and learning outcome (identical to or independent of the adjunct question). The acquisition of information identical to adjunct questions is typically referred to as "repeated" or "direct" learning, whereas the acquisition of information indepen-

dent of adjunct questions has been termed "related" or "indirect" learning.

Questions directly preceding or following short sections of instructional text have been shown to increase *direct* learning. However, only post-questions tend to facilitate *indirect* learning. That is, adjunct questions in either position have been shown to produce direct mathemagenic activities that "are acts of rehearsal that strengthen memory" (Rothkopf, 1996, p. 885). Post-questions, however, have additionally been shown to produce *indirect* mathemagenic activities; they increase the likelihood that comparable instructional material will be processed in a certain way in the future.

We found three studies that investigated the use of adjunct questions with deaf subjects. Maeder (1980) examined the effect of higher-order post-questions on comprehension of instructional prose by secondary students. The mean grade equivalent reading score for these subjects was 4.2 and ranged from 2.2 to 7.1. No effect was found for post-questions, and the author suggested that future studies include a measure of subjects' reading ability. However, Dowaliby (1990) found a significant interaction between reading ability and adjunct question position. The study employed 78 college students, distributed fairly evenly across gender, with a median age of 21 years. The mean puretone hearing loss of these subjects in the better ear was 96.5 dB and ranged from 60 dB to 120 dB. When adjunct questions were placed before relevant text, the subjects with low reading ability demonstrated increased overall learning performance, whereas placing adjunct questions after relevant text facilitated overall learning for subjects with high reading ability. Since all subjects were administered the adjunct questions as a pretest, in effect, all conditions received massed pre-adjunct questions in addition to their prescribed treatment. This design limits interpretation of those results. In a follow-up study, Dowaliby (1992) investigated interactions among adjunct question position, reading ability, and direct versus indirect learning. Seventy-four deaf postsecondary students comparable to those used in the first study served as subjects. The mean puretone hearing loss in the better ear was 90.0 dB and ranged from 45 dB to 120 dB. Fifty-seven percent were male, and the mean age was 20.8 years. The same materials as in the previous study were employed but a pretest was not administered. Pre- and post-adjunct-questions produced significant and substantial increments in direct learning. The interaction between conditions and reading levels was not significant in this study. This study therefore yielded results consistent with the host of studies performed with hearing subjects that demonstrated increments in direct learning from adjunct questions.

These investigations suggest that the interrogative aspect of the adjunct questions cognitively activates the learner to focus on the response alternatives in the context of the question stem and to discriminate among them. The resulting induced focus and processing maintains the information in working memory, which in turn increases the probability of transfer to long-term memory.

In summary, the available research findings for both deaf and hearing subjects indicate that potential exists for adjunct aids, either alone or in combination, to improve learning from prose. Computer technologies now provide the opportunity to more effectively control such variables as titles, subtitles, abstracts, summaries, advanced organizers, pictorials, procedural drawings, adjunct questions, and still or moving displays.

Purpose of the Research

The present study examined the effectiveness of three adjunct aids on direct learning: adjunct questions, content movies, and sign movies. Each of these aids provided a redundant reproduction of the information presented by the instructional text. The content movie provided a visual example of the concept presented by the text; the sign movie presented a signed version of the instructional text; and the adjunct questions were verbatim reproductions of part or all of the lesson text in question form. However, there was an essential difference between the adjunct questions and the other two aids investigated. The unique purpose of the adjunct questions was to produce beneficial mathemagenic activities in the form of cognitive engagement with the instructional content. In contrast, each of the content movie and the sign movie adjunct aids were designed to present the same information presented by the instructional text, but without the inducement of instructionally beneficial mathemagenic activities. All

materials were presented by computer, thus allowing control over timing and the provision of feedback to adjunct question responses. Moreover, the use of computers allowed for a single presentation device for text and movies.

The purpose of the present study was to determine the contribution of each of these adjunct aids to the learning of factual information presented by text. Based on previous research, we expected that each of the investigated adjunct aids would result in significantly greater immediate factual learning performance than the text-only condition. We also expected that the instructional conditions would interact with reading ability, in that the adjunct aid conditions would have a greater (compensatory) impact on low reading ability subjects' than on high reading ability subjects' learning performance. Comparisons between the adjunct aid conditions were also planned although without specific expectations of possible differences.

Method

Participants. An initial pool of 946 students actively enrolled at the National Technical Institute for the Deaf (NTID) at Rochester Institute of Technology was identified. This number was reduced to 671 by eliminating students who were cross-registered in baccalaureate programs, those who had majored in Optical Finishing Technology (relevant to the lesson subject matter), or had visual problems (i.e., retinitis pigmentosis or color blindness). Several additional students were eliminated whose scores from Form W of the Reading Comprehension section of the California Achievement Tests (CAT) (Tiegs & Clark, 1963) were not available. Tercile cutpoints for this pool on the distribution of California reading scores were calculated to be 8.3 and 9.5. These cutpoints were employed to define each of the low, medium, and high reading levels for all conditions and to stratify the otherwise random assignment of subjects to each of the five conditions to achieve approximately equal cell sizes. One hundred forty-four paid voluntary participants were thus recruited. The one exception to this procedure was that participants assigned to either of the Sign or Full conditions were required to demonstrate sign language proficiency, as described below. The mean pure tone average hearing loss in the better ear for these subjects was 101.9 dB. Of the 144 subjects, 125 were born deaf, and the age of onset of deafness for the remainder ranged from age 1 to 5. The sample was 55 % male.

Participants in the Sign Movie and Full conditions were selected by examining their scores on the Sign Instruction Proficiency Interview (SIPI) given to students when they enter the college (Metz, Caccamise, & Gustafson, 1997). Participants with scores of 4 or higher on the SIPI range of 1–5 were selected for these conditions. Those for whom scores were not available were interviewed by one of the investigators to evaluate their ability to use sign language. The interviewer, who is deaf, has achieved a level of Superior on the Sign Communication Proficiency Interview (Caccamise & Newell, 1999) and has served as a sign language rater in the formal evaluation process at the college.

Materials. The computer-based instruction consisted of 11 lessons on the human eye. The text of the lessons consisted of unequivocal factual statements about the human eye, its function and care. The lessons ranged from one to three sentences (12 to 31 words). The grade-equivalent reading difficulty levels of the lessons were calculated with the Flesch-Kincaid technique (Flesch, 1951) and ranged from 5.5 to 12 with a mean of 7.7.

The multiple-choice adjunct questions and the correct response were verbatim reproductions of part or all of the lesson texts. These questions served as adjunct questions throughout the instruction for two of the instructional conditions and as posttest items for evaluating immediate factual learning for all conditions. As an example, Table 1 shows the lesson text, the corresponding multiple-choice question, and the feedback for each of the response alternatives for lesson 1.

The sign movies were representations of the lesson text. English-like signing with American Sign Language (ASL) features was used by a professional who has achieved the level of Superior on the Sign Communication Proficiency Interview (Caccamise & Newell, 1999). He is the son of deaf parents with 20 years' experience in educating deaf students. The duration of each sign movie ranged from 15 to 44 seconds.

Table 1 Text, adjunct question, and response alternative feedback for question 1

Adjunct question	Response alternative feedback
1. Most of the eye is filled with	
a) aqueous.	a) Aqueous is incorrect. Most of the eye is filled with a clear, jelly-like substance, known as vitreous.
b) vitreous.	b) Correct. Most of the eye is filled with a clear, jelly-like substance, known as vitreous.
c) air.	c) Air is incorrect. Most of the eye is filled with a clear, jelly-like substance, known as vitreous.
d) blood.	d) Blood is incorrect. Most of the eye is filled with a clear, jelly-like substance, known as vitreous.

The content movies were animated pictorials that exemplified the lesson content. They ranged from 2 to 21 seconds.

Instructional conditions and procedure. There were five instructional conditions presented by computer. A different interactive digital movie was developed for each of the instructional conditions using Macromedia Director.

The Text-Only condition presented only the text as instructional material. The introductory screen stated: "Following are 11 short lessons on the human eye. Each lesson will include: Instructional text. Try to learn as much as you can. You will be tested on this information." After this introduction, each lesson was presented in turn. Participants controlled the duration of each text screen by clicking on hot text at the bottom of the screen, which said: "Click here after you read the text above." Clicking on this text advanced the display to the next lesson.

The Adjunct Question condition presented a multiple-choice question following the text. The introductory screen stated: "Following are 11 short lessons on the human eye. Each lesson will include: 1. Instructional text; 2. A practice question; 3. Feedback on your response to the practice question. Try to learn as much as you can. You will be tested on this information." As in the Text-Only condition, participants controlled the duration of each text screen by clicking on hot text at the bottom of the screen to move to the adjunct question. Participants indicated their choice of the response alternatives by clicking on it, and they then had the opportunity to change their response. When they continued, they received feedback as to the correctness of their response, and the multiple-choice question and correct response were repeated as a statement. After they clicked the continue button, the text for the next lesson appeared.

The Content Movie condition presented the instructional text followed by the corresponding content movie. The introductory screen stated: "Following are 11 short lessons on the human eye. Each lesson will include: 1. Instructional text; 2. A movie showing a visual example of the information. Try to learn as much as you can. You will be tested on this information." Participants controlled the duration of each text screen by clicking on hot text at the bottom of the screen, which started the corresponding content movie. Upon completion of the movie, the text for the next lesson appeared.

The Sign Movie condition presented the instructional text followed by the corresponding sign movie. The introductory screen stated: "Following are 11 short lessons on the human eye. Each lesson will include: 1. Instructional text; 2. A movie of the text signed. Try to learn as much as you can. You will be tested on this information." Participants controlled the duration of each text screen by clicking on hot text at the bottom of the screen. The screen immediately following the text screen presented the corresponding sign movie. Upon completion of the movie, the text for the next lesson appeared.

The Full condition presented all of the adjunct aids in sequence. The introductory screen stated: "Following are 11 short lessons on the human eye. Each lesson will include: 1. Instructional text; 2. A movie of the text signed; 3. A movie showing a visual example of the information; 4. A practice question; 5. Feedback on your response to the practice question. Try to learn as much as you can. You will be tested on this information." Participants controlled the duration of each text screen by clicking on hot text at the bottom of the screen. The subsequent screens that presented the adjunct aids then appeared automatically, without participant con-

trol, in the order stated above. Participants continued with each of the 11 lessons at their own pace.

Thus, for all conditions, the only control participants had was to proceed after they had presumably finished reading the instructional text, and/or to proceed after they had (for the Adjunct Question and Full conditions) responded to the adjunct questions. This strategy allowed for the expected individual differences in reading time and therefore did not place slow readers at a disadvantage. Subjects did *not* have control over the selection or duration of the sign or content movies, nor could subjects proceed to the next screen prior to a movie playing out and naturally ending.

Design. Reading Level and Condition were fully-crossed, between-subject factors. There were three levels of reading ability, determined by the terciles calculated for the distribution of the Reading Comprehension scores (see Measures, below), and five Conditions. There were thus 15 between-subject cells in the design of this study.

Measures. Two measures were employed. The first was composed of scores from the Reading Comprehension portion of Form W of the CAT (Tiegs & Clark, 1963). This test is routinely administered as students enter this college in the fall. Those scores were employed as a measure of participants' reading ability and used to assign subjects to Reading Levels (see Design and Subjects, above). The observed range of scores was from 5 to 12 (grade equivalents).

The second measure was composed of scores from the posttest of immediate factual retention. The multiple-choice questions employed as adjunct questions were also used as the posttest questions. To prevent subjects in the Adjunct Question and Full conditions from simply learning which answer was correct for each question, both the sequence of the questions and their response alternatives were different for the adjunct question and posttest usages. With response-alternative positions thus varied, correct posttest responses would most likely reflect correct discrimination among the alternatives and would not be influenced by the positions employed for adjunct question usage. At the beginning of this posttest section of the interactive digital movie, participants were urged to "Answer each question as best as you can, like you would for a real classroom test." A continue button then showed the first test question and response alternatives. Participants indicated their choice by clicking on it, and they had the opportunity to change their response. When they then clicked the continue button, the next test question appeared. Feedback was not provided during this test phase.

Results

Preliminary analyses. Posttest responses were assigned a value of 1 if correct and 0 if incorrect. An item analysis was performed on these item scores. Item total correlations ranged from .08 to .50. The indicated gain in reliability if the lowest correlating item (.08) was deleted was .01. The next lowest item-total correlation was substantially higher, equal to .22. Deletion of this item would have decreased the reliability of the total scale. Based on this information, and the fact that the posttest consisted of only 11 items, all of the items were retained. The total scores could thus range from 0 to 11. The reliability (internal consistency) of this set of items for the entire sample was .65.

A Reading Level by Condition analysis of variance (ANOVA) was performed on the California reading scores to assess the pre-experimental comparability of conditions. The results indicated a significant effect for Reading Level, as expected, $F(2, 129) = 132.1$, $p < .001$, and for Condition, which was unexpected, $F(4, 129) = 4.5$, $p < .01$. The Reading Level by Condition interaction was not significant, $F(8, 129) = 1.26$, $p > .26$). The mean square error for these effects was .34. In view of this and since the pre-experimental comparability of the Conditions in terms of the reading scores was crucial, the strength of the association between the reading scores and the Condition factor was assessed with the omega-squared statistic. (Hays, 1963, p. 323). The results showed that the Condition factor accounted for 1.5% of the variance in the reading scores. Therefore, although this is a statistically significant relationship, it is so weak that essentially little or no confounding effects could result from it. By comparison, the Reading Level factor accounted for 83% of the variance in the reading scores. The conditions were thus judged to be pre-experimentally comparable

Table 2 California reading test means for each reading level and condition

	Reading level			
Condition	Low *M* (*SD*)	Middle *M* (*SD*)	High *M* (*SD*)	Overall *M* (*SD*)
Text	7.4 (.66)	8.8 (.32)	10.6 (.68)	8.7 (1.44)
Adjunct	7.3 (.57)	8.7 (.34)	11.0 (.74)	8.8 (1.66)
Content	6.9 (.69)	8.9 (.37)	10.1 (.31)	8.4 (1.43)
Sign	7.8 (.50)	9.0 (.31)	11.0 (.74)	9.1 (1.42)
Full	7.4 (.84)	8.9 (.39)	10.8 (.81)	9.0 (1.55)
Overall	7.3 (.69)	8.9 (.34)	10.7 (.73)	8.8 (1.50)

Table 3 Reading-by-condition analysis of variance of learning performance scores

Source of variance	*SS*	*df*	*MS*	*F*
Conditions (C)	116.57	4	29.14	10.32**
Reading level (R)	118.72	2	59.36	21.01**
C × R	48.89	8	6.11	2.16*
Error	364.39	129	2.82	

*$p < .05$.

**$p < .01$.

in terms of the reading scores. The means varied from 6.9 to 11.0 across Reading Levels and Conditions and are shown in Table 2.

Posttest analyses. A Reading Level (low, middle, high) by Condition (Text-Only, Adjunct Question, Content Movie, Sign Movie, Full) between-subject ANOVA was performed on the posttest scores. The results are summarized in Table 3 and show that the Condition, $F(4, 129) = 10.3$, and Reading Level, $F(2, 129) = 21.01$, effects were significant beyond the .01 level. Also shown, the Condition by Reading Level interaction effect, $F(8, 129) = 2.16$, was significant beyond the .05 level. Table 4 presents the corresponding means and standard deviations. In order to determine which of the conditions significantly differed, post-hoc comparisons were performed on the condition means using the Newman-Keuls procedure (Winer, 1962, p.80). The Adjunct Question and Full conditions yielded significantly greater posttest performance than each of the Text-Only, Content Movie, and Sign Movie conditions (all ps $< .05$). The magnitude of these observed differences would probably have been even greater were it not for a ceiling effect observed on the posttest scores, since this attenuating effect was disproportionately present for the Adjunct Question and Full conditions. Of the 14 participants responding correctly to all of the posttest items, 8 were in the Full condition and 4 were in the Adjunct Question condition. By comparison, 2 of the 29 in the Sign Condition responded correctly to all 11 posttest items, and none of the subjects in the Content Movie and Text Only conditions responded correctly to all of the questions. This analysis is summarized in Figure 1.

Specific analyses of the Reading Level by Condition interaction effect were performed to assess the significant components of this interaction. Comparisons were performed on the interaction set of means (see Table 4) with the Newman-Keuls procedure. Figure 2 provides a visual summary of the results of this analysis.

Note that the Adjunct Question and Full conditions yielded significantly higher posttest scores for *low Reading Level* participants than did either of the Text-Only and Content Movie conditions (ps $< .05$). The mean for the Sign Movie condition was between these extremes and did not significantly differ from other conditions (ps $> .05$).

The overall pattern of the means for the *middle Reading Level* participants was similar to that observed for the low Reading Level subjects, however, only as compared with the Sign Movie condition. That is, middle Reading Level participants in the Full and Adjunct Question conditions performed significantly higher on the posttest than middle Reading Level participants in the Sign Movie condition (ps$<.05$). Comparisons with the other conditions were non significant (ps $> .05$). None of the conditions differed significantly for the *high Reading Level* subjects (ps $> .05$).

Comparisons were also performed between Reading Levels within each of the conditions. Those results are shown in Figure 3 and indicate significant differences between Reading Levels for the Text-Only, Content Movie, and Sign Movie conditions (ps $< .05$). No significant differences were found between Reading Levels for the Adjunct Question and Full conditions (ps $> .05$). The absence of significant differences between Reading Levels within the Adjunct Question and Full conditions may have been influenced by the aforementioned ceiling effect, particularly for the high Reading Level participants in the Full condition.

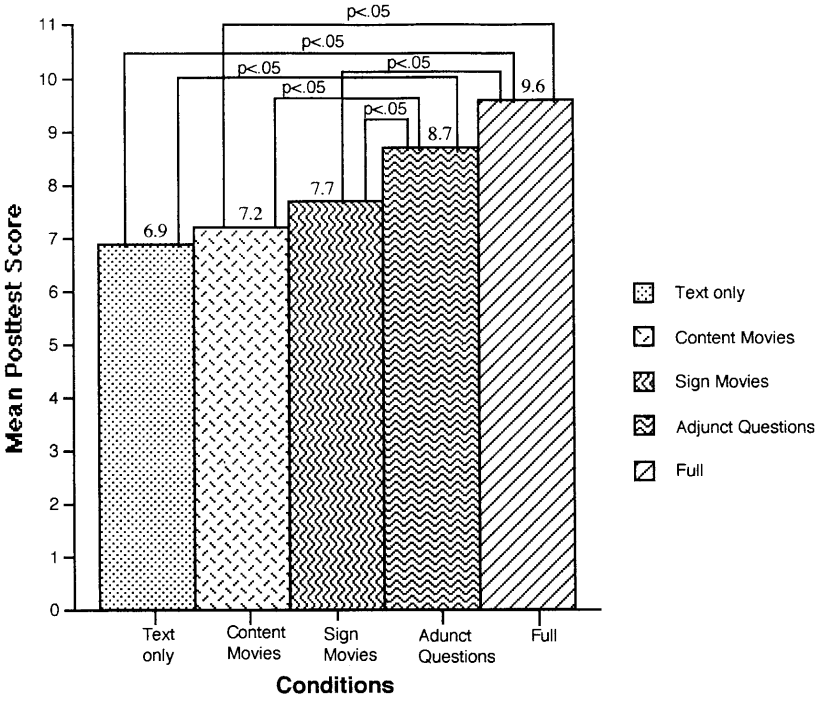

Figure 1 Mean posttest scores for conditions.

Table 4 Learning performance means, standard deviations, and numbers for each reading level and condition

	Reading level							
	Low		Middle		High		Overall	
	M (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*
Text-only	5.6 (2.0)	12	7.5 (1.8)	9	8.2 (1.9)	8	6.9 (2.2)	29
Adjunct	8.3 (1.2)	12	9.6 (1.3)	8	8.5 (1.6)	8	8.7 (1.4)	28
Content	5.6 (1.9)	13	7.9 (1.1)	10	8.7 (1.9)	9	7.2 (2.1)	32
Sign	6.8 (1.7)	11	7.0 (2.2)	10	9.7 (1.3)	8	7.7 (2.1)	29
Full	8.4 (2.4)	9	10.0 (.9)	9	10.4 (.7)	8	9.6 (1.7)	26
Overall	6.9 (2.2)	57	8.3 (1.9)	46	9.1 (1.7)	41	8.0 (2.2)	144

Comparisons were also made across Reading Levels and Conditions. Importantly, the *low* Reading Level participants in the Adjunct Question and Full conditions performed equal to the *high* Reading Level participants in the Text-Only condition. These results are shown in Figure 2. It is noteworthy that none of the subjects in these three groups demonstrated a ceiling effect.

Discussion

In a comparison of adjunct questions, sign movies, and content movies in terms of immediate factual learning, both of the conditions that included adjunct questions yielded significantly greater factual learning, overall, than any of the other conditions. Studies involving hearing subjects and a comparable study with postsecondary deaf subjects have demonstrated a similar direct learning effect from adjunct questions.

Learning performance for the Content Movie condition did not differ significantly from the Text-Only condition. This was counter to expectations, as we had hypothesized that a facilitative effect for that adjunct aid would be observed. This result is consistent, however, with findings from previous studies, which indicate that concrete text, such as that employed in the

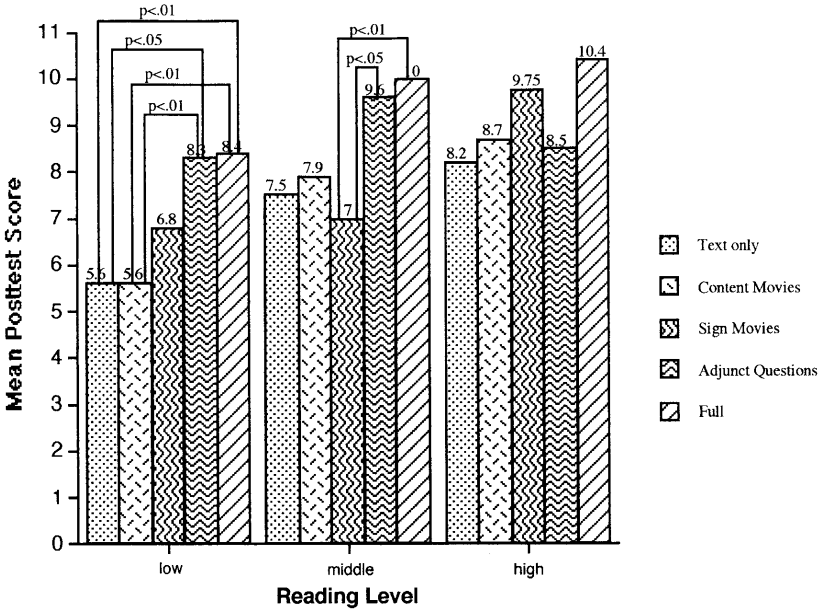

Figure 2 Mean posttest scores for reading levels and conditions: grouped by reading level.

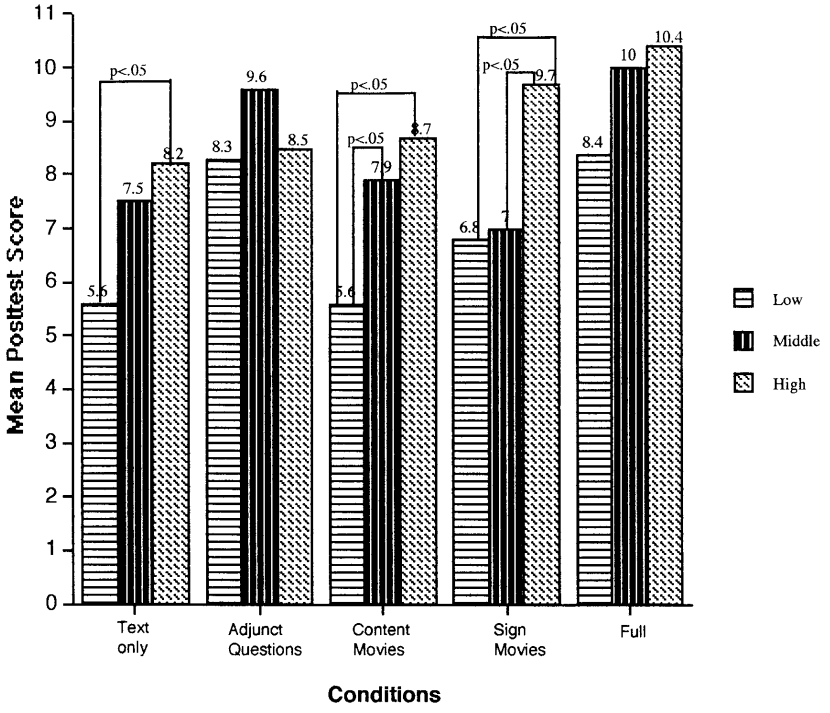

Figure 3 Mean posttest scores for reading levels and conditions: grouped by condition.

present study, can mitigate the contribution of supportive pictorial aids (e.g., Dean & Enomoh, 1983; Royer & Cable, 1976). It is also consistent with Rothkopf's (1996) work with mathemagenic activities, which emphasizes the crucial nature of learner engagement with instructional materials. Despite the visually informative characteristic of the content movies, they did not induce learner engagement, and this is probably why they did not result in factual learning greater than the text alone. As Dean and Enemoh (1983) have

stressed, it may not be enough to merely provide the pictorial organizer; one must ensure that the organizer is attended to.

The current observation that the Sign Movie condition performed comparably to the Text-Only condition was also unexpected, since former studies with static sign representations have reported learning performance benefits. However, the grade-equivalent difficulty level of the employed instructional text ranged from 5.5 to 12 with a mean of 7.7, and the mean assessed reading ability of the low ability participants in the Sign Movie condition was 7. 8. It may be that sign representations produce learning performance benefits only when the difficulty level of the text sufficiently surpasses the ability of the reader.

In view of the absence of a learning performance increment from the sign or content movies, one might infer that those aids, within the context of the Full condition, did not contribute to learning performance. However, the Full condition yielded more than twice the proportion of participants with a ceiling effect on the posttest as did the Adjunct Question condition, and the difference between these conditions approached significance ($p < .07$). These factors, taken together, suggest that either or both of the sign and content movies may have worked synergistically with the text and adjunct questions to benefit factual learning by the participants in the current study. This is an hypothesis for future research.

An important finding was the comparability of learning performance for the low Reading Level participants in the Adjunct Question and Full conditions with that of the high Reading Level participants in the Text-Only condition. This result is underscored by the fact that the high Reading Level participants in the Text-Only condition averaged three grade equivalents higher on the California Reading test than participants in either of these other two conditions. This suggeststhat adjunct questions in textual instruction could level the playing field for deaf students with varying reading comprehension abilities.

One possible explanation of the increase in learning due to the Adjunct Question and Full conditions might be that there was increased time on task for those participants. However, participants who received adjunct sign movies and those who received adjunct content movies, along with the text, also experienced increased time on task, but did not perform better than those in the Text-Only condition. Thus, increased time on task does not appear to explain the improved learning performance.

A more plausible consideration relates to differences between the instructional conditions in terms of the invocation of relevant, active processing. The Text-Only condition presented an instructional situation whereby the participants' only required activity was to advance the text to the next frame when each passage was completed. Similarly, participants in both of the movie conditions were required only to click the mouse on procedural (i.e., noncontent) text to start the movie. While those participants *may* have engaged in covert, relevant processing activities, none were required. In contrast, the participants in the Adjunct Question and Full conditions were required to actively engage with the instructional material by reading the adjunct question, examining the response alternatives, and then selecting the one they thought was correct. Those participants also had the option to change their response, and thus had the opportunity (although not required) for additional relevant processing. These differences suggest that exposure to the instructional materials per se did not increase learning performance. Rather, induced, active, criterion-relevant engagement with the instructional material seems to have been the most crucial pedagogical element of the Adjunct Question and Full conditions in the present study. The maintenance of adjunct question relevant information in working memory may be the most beneficial cognitive process resulting from confronting and answering adjunct questions, since the amount of time information is retained in working memory directly influences the likelihood of transfer to long-term memory.

The findings also support Rothkopf's (1996) postulation that mathemagenic effects would more likely be found for deficient learners. This concept of compensatory instructional effects for deficient learners is cogently expressed by Rothkopf (1996): "[B]eneficial mathemagenic effects will be produced by adjunct questions, chiefly, when the mathemagenic activities of the learner are inadequate. Good learners hardly need a boost" (p. 885).

The implications of the present study pertain to

both pedagogy and equitable access to instructional content. Adjunct aids in instructional prose that promote beneficial mathemagenic activities will more likely facilitate learning than those that merely provide information. Any intervention or practice that can produce compensatory effects of the magnitude observed in this study has the potential for leveling the playing field for readers who do not comprehend well. Future investigations should focus on adjunct aids that hypothetically produce beneficial mathemagenic activities. The findings from such studies will provide valuable information for the design of multimedia instruction.

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