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Short-Term Recall by Deaf Signers of American Sign Language: Implications of Encoding Strategy for Order Recall

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Two experiments were conducted on short-term recall of printed English words by deaf signers of American Sign Language (ASL). Compared with hearing subjects, deaf subjects recalled significantly fewer words when ordered recall of words was required, but not when free recall was required. Deaf subjects tended to use a speech-based code in probed recall for order, and the greater the reliance on a speech-based code, the more accurate the recall. These results are consistent with the hypothesis that a speech-based code facilitates the retention of order information.

For hearing persons, short-term retention of English letters and words tends to employ a speech-based code. This is true regardless of whether the input items are spoken (Baddeley, 1966; Hintzman, 1967; Wickelgren, 1965, 1966) or written (Conrad, 1962, 1964; Kintsch & Buschke, 1969; Posner, Boies, Eichelman, & Taylor, 1969). It has been hypothesized that this speech-based code may be not only well suited for representing linguistic material in short-term memory but also particularly well suited for retention of order information (Baddeley, 1978; Crowder, 1978; Healy, 1975). Whether there are properties of a speech-based code that make it particularly effective for short-term retention of words can be tested by examining short-term recall by congenitally and profoundly deaf signers of American Sign Language (ASL).

American Sign Language is the visual-gestural language used in deaf communities in North America and is acquired by children of deaf parents as a native language. It differs from English not only in the grammatical structure of sentences (Klima & Bellugi, 1979) but also in the form of lexical structure. In spoken languages, word structure is based on sequential production of phonemes. In ASL, sign structure is based on the simultaneous production of the formational parameters of handshape, movement, and place of articulation (Stokoe, Casterline, & Croneberg, 1965). These formational parameters have no direct correspondence to English phonemes or letters (graphemes).

For deaf signers of ASL, short-term retention of signs has been found to use, not a speech-based code, but a sign-based code. Bellugi, Klima, and Siple (1975) showed that intrusion errors in recall of signs are related to the formational parameters of the signs. An intrusion error for deaf subjects on recall of the sign VOTE, for example, was *teu*, a word whose corresponding sign is similar in handshape and place of articulation to the sign VOTE but differs in movement. Additional evidence for sign-based encoding of

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signs was obtained by Frumkin and Anisfeld (1977) and by Poizner, Bellugi, and Tweney (1981).

Other work has been concerned with whether sign-based encoding is used in the short-term retention of printed English words. Odom, Blanton, and McIntyre (1970) presented deaf children (mean age of 16.0 years) with lists of written words to learn. They compared the learning of a list of words having close sign correspondences with the learning of a list of "unsignable" words and found that the deaf children learned the list of signable words more easily than the list of unsignable words. The implication from these results is that the deaf children were recoding into a sign-based code when possible. With results similar to Odom et al.'s findings, Conlin and Paivio (1975), in a paired-associate task, found that deaf high school and college students learned signable pairs of words more readily than pairs of words for which there were no direct sign translations. Moulton and Beasley (1975) found that their deaf subjects (mean age of 18.0) learned pairs of words having formationally similar signs more readily than they learned pairs of words having formationally dissimilar signs. Shand (1982), testing adult signers in an ordered recall task, provided a test of speech-based as well as sign-based encoding of words. He found that lists of words having formationally similar signs were not as well recalled as were lists of words having formationally dissimilar signs. This finding was consistent with earlier work indicating the use of sign-based encoding. Lists of phonetically similar words, however, were not recalled less accurately by deaf signers than were lists of unrelated words, an outcome suggesting that speech-based encoding was not being used by the subjects.

The studies just summarized indicate that a sign-based code can be used as a basis for representing linguistic material in short-term memory, but they are unanalytic with respect to the question of whether there are special properties of a speech-based or a sign-based code that might make a particular encoding strategy most effective on a given task. The present study provides such an examination as it relates to one hypothesized function of a speech-based code: retention of order information (Baddeley, 1978; Crowder, 1978; Healy, 1975). This study investigates speech-based and sign-based encoding of printed words by deaf native signers of ASL. Two experiments are reported here. The first is an ordered recall paradigm, requiring recall of items and the order in which they are presented; the second is a free-recall paradigm, requiring recall of items regardless of order. If temporal order information is most effectively retained by a speech-based code, then persons not using this code should be hindered in the ordered recall task of Experiment 1. If retention of item information, however, does not require the use of a speech-based code, then recall accuracy should not be related to the use of a speech-based code in the free-recall task of Experiment 2.

Experiment 1

In Experiment 1, the encoding of printed words by deaf native signers of ASL was investigated by using a modified version of the ordered recall paradigm developed by Baddeley (1966). The paradigm involves presentation of sets of words chosen to be similar along one dimension. Each similar set is matched with a control set of words that bear no similarity to each other. With spoken word presentations, Baddeley found that for hearing persons there is a decrement in performance when to-be-recalled spoken words are phonetically similar. Using this paradigm with ASL sign presentations, Poizner et al. (1981) found that for deaf signers there is a decrement in performance when to-be-recalled signs are formationally similar.

Method

Stimulus Sets

Three experimental sets of eight monosyllablic words each were constructed: (a) formationally (sign) similar, (b) phonetically similar, and (c) graphemically similar. For each of these three experimental sets, a control set of words was constructed. Each control set was matched with its corresponding experimental set for part of speech and for frequency of occurrence in written English (Thorndike & Lorge, 1944). As a result, performance on an experimental set is interpretable only in relation to performance on its matched control. A practice set, consisting of words unrelated to each other, was also constructed. Deaf signers (not participating in the experiment) acted as ASL informants regarding the corresponding signs for each English word.

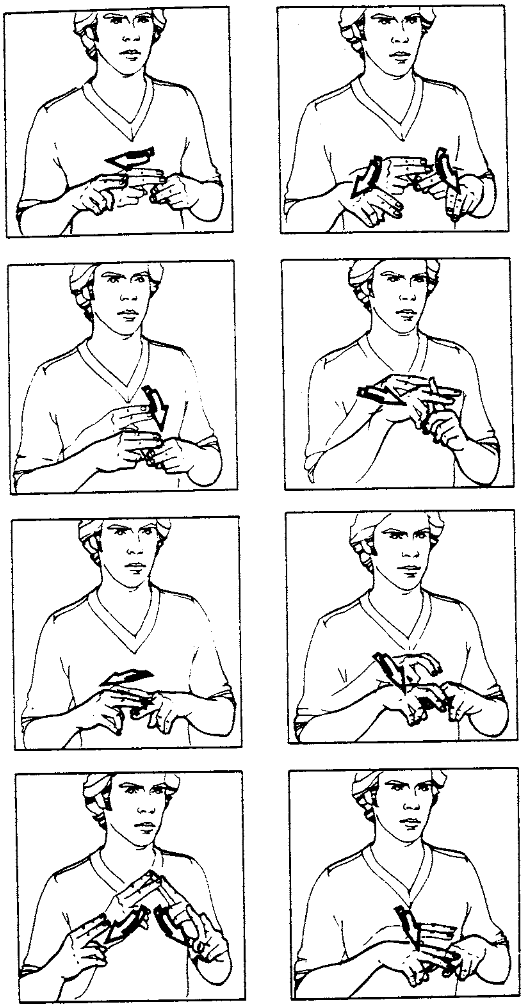

Figure 1. Formationally similar signs from Experiment 1. (Shown left to right from the top are KNIFE, EGG, NAME, PLUG, TRAIN, CHAIR, TENT, SALT.)

The words in the formationally similar set were phonetically and graphemically dissimilar. The criteria for formational similarity were that the signs for each of the words were signed with similar handshapes and with the two hands contacting in neutral space in front of the body. The following eight words were, as a result, selected: KNIFE, EGG, NAME, PLUG, TRAIN, CHAIR, TENT, SALT. Illustrations of signs for these words appear in Figure 1.

The words of the phonetically similar set rhymed and were formationally dissimilar and as graphemically dissimilar as possible. The eight words of the phonetically similar set were the following: TWO, BLUE, WHO, CHEW, SHOE, THROUGH, JEW, YOU. Since some graphemic similarity was unavoidable for this set, an experimental set of graphemically similar words was constructed to tease apart possible confounding effects due to this similarity. The following words were used for this latter set: BEAR, MEAT, HEAD, YEAR, LEARN, PEACE, BREAK, DREAM.

Appendix A lists all the words for the experimental and control sets.

Design

A group of hearing subjects and a group of deaf subjects were tested with the printed words. In order to ensure that the stimuli were appropriate for detecting sign encoding, an additional condition was run. As previous work has shown that sign presentation elicits sign-based encoding of the stimuli (Bellugi et al., 1975; Poizner et al., 1981), a second group of deaf subjects was tested with signed presentation of the stimulus items.

Procedure

The paradigm of Baddeley (1966) was modified here to be a probed recall task. In this task, a series of five words (or signs) was presented, followed by a probe (one of the first four of the just-presented, items). Subjects responded by indicating the word (or sign) following that probe in the series.

Printed word presentation. A microcomputer was used for stimulus display and data collection. Trials were blocked by stimulus set. The order of experimental set presentation was randomized, with the restriction that an experimental set and its control were always presented consecutively. Prior to testing with each set, the eight words of the set were displayed on a card. The words were each assigned a number (1–8), and the words and their numbers were typed on a 3 × 5 in. index card. This card was continuously displayed during the 16 trials of testing with a set.

On each trial, subjects were presented a warning signal, a +, followed by five words consecutively displayed in the center of the cathode-ray-tube (CRT) screen. The words were printed in uppercase letters and were shown at a rate of 1 sec per word. Word order was random with the constraint that each word appeared twice in each serial position during a block. Each of the eight words of a set was used twice as a probe word and twice as an answer.

The probe word was presented 3 sec after the last stimulus word. Subjects responded with the word that followed the probe on that trial, pressing the key on the computer terminal to indicate the number of the word that was their answer. This response procedure was chosen for two reasons. First, it was necessary to provide a response that could be used equally well by deaf and hearing subjects. Second, pilot testing had indicated that writing the words tended to encourage many deaf subjects to fingerspell as they were writing. Fingerspelling is a system based on English in which there is a manual configuration for each letter of the alphabet and words are spelled by the sequential production of each letter. Due to the similarity of spellings for the words in the graphemically similar list, it was desirable not to use a response procedure that would specifically encourage such a strategy.

Instructions were written. In addition, a summary of the instructions was signed for deaf subjects and spoken for hearing subjects.

Table 1
Percentage of Correct Trials for Each Stimulus Set in Experiment 1

Group	Formational	Phonetic	Graphemic	*M*
Signed (deaf)				
Similar	41.3	60.0	63.6	
Control	59.0	71.6	69.9	66.8
% decrement	17.7*	11.6*	6.3	
Deaf				
Similar	51.4	47.6	47.6	
Control	52.9	65.4	52.2	56.8
% decrement	1.5	17.8*	4.6	
Hearing				
Similar	87.4	70.2	86.7	
Control	84.2	96.9	89.9	90.3
% decrement	−3.2	26.7*	3.2	

* $p < .05$.

Sign presentation. The signed stimuli were recorded on videotape by a native singer of ASL at the same rate of presentation as that used with the printed words. The signer maintained a neutral expression throughout the signing of the stimuli (i.e., no mouth movement or facial expressions accompanied the signs). Instructions, signed in ASL, were recorded on the beginning of the test videotape.

Constraints imposed by the use of videotaped rather than computer-displayed stimuli necessitated a few procedural differences from the printed word condition. Rather than having the card with the English words presented during a block, subjects were given a paper on which the signs for that block were drawn as in Figure 1. Subjects responded by signing the item that followed the probe. A videotape was made of each subject in this sign presentation condition, and the videotaped answers of each subject were later transcribed. Stimulus sets were presented to subjects in the following fixed order: practice set, formational control set, formationally similar set, phonetically similar set, phonetic control set, graphemically similar set, and graphemic control set.

Subjects

Three groups of subjects were tested. They were paid for their participation in the experiment which lasted approximately 1 hour.

Sign presentation. Seven prelingually deaf volunteers were recruited through the Salk Institute and through California State University, Northridge. Five had a hearing loss of 90 dB or greater in the better ear. The remaining two subjects had a loss of 70 dB in the better ear. All were native signers of ASL.

Printed word presentation. Hearing subjects were eight college-age persons who responded to an advertisement in a local newspaper requesting subjects for a psychology experiment.

Deaf subjects were eight volunteers recruited through the Salk Institute, California State University, Northridge, and Gallaudet College. All were native signers of ASL. Two were recent college graduates, and the other six were presently enrolled in college. With only one exception, deaf subjects had a hearing loss of 90 dB or greater in the better ear. That one subject had a loss of 80 dB in the better ear.

Results and Discussion

Encoding

Sign presentation. Data from the sign presentation condition were examined to determine whether the stimulus materials were suitable for detecting sign encoding. A deaf native signer of ASL assisted in the transcription of the signed responses. Subjects were found to be significantly less accurate on the formationally similar set than on the formational control set, $t(6) = 4.19$, $p < .01$. This significant decrement for the formationally similar set is in agreement with other work indicating sign-based encoding when ASL signs are presented (Bellugi et al., 1975; Poizner et al., 1981). For purposes of the present study, it demonstrates that the formationally similar set was appropriate for detecting sign encoding. Results are given in Table 1.

Compared with its matched control, the graphemically similar set did not produce a significant decrement in performance, $t(6) = .75$, $p > .20$. An effect of phonetic similarity was found, however, with subjects being less accurate on the phonetically similar set than on its matched control set, $t(6) = 3.15$, $p < .05$. This result is consistent with observation of subjects' rehearsal strategies on the recorded videotapes: Rehearsal often involved the simultaneous signing and mouthing of the English word for each of the presented signs. This speech-based rehearsal occurred despite the neutral facial expression maintained by the signer during presentation of the signed stimuli.

Printed word presentation. For the printed words, an analysis of variance was performed on subject group (deaf vs. hearing) by dimension (formational vs. phonetic vs. graphemic) by set (experimental set vs. control set). The analysis revealed an interaction of dimension by set, $F(2, 28) = 8.04$, $MS_e = 146.96$, $p < .005$, a result indicating a significant decrement in performance only for some of the experimental sets. This effect did not significantly interact with group, $F(2, 28) = .68$, $MS_e = 146.96$, $p > .20$, and suggests a similar pattern of results for both deaf and hearing subjects. The percentage of correct trials for the two groups on each set is given in Table 1.

Post hoc analyses on the simple effects revealed that subjects did not exhibit a significant performance decrement for the formationally similar set, $F(1, 28) = .04$, $p > .20$. The subjects did, however, show a performance decrement for the phonetically similar set compared with its control set, $F(1, 28) = 26.80$, $p < .001$. There was no significant effect of graphemic similarity, $F(1, 28) = .82$, $p > .20$, which indicates that the decrement for the phonetically similar set was not due to graphemic similarity.

Since the sign presentation condition obtained evidence for sign-based encoding, it does not seem that the failure to find such evidence with printed words can be attributed to inappropriate stimulus materials or design. As the sign correspondence for each word in the formationally similar set is quite straightforward, it does not seem that failure to find evidence of sign-based encoding is attributable to variability in the word-to-sign translations. Rather, it appears that stimulus input had an effect on encoding strategy by deaf subjects: Presentation of ASL signs encouraged the use of sign-based encoding.

The present experiment suggests the use of speech-based encoding in short-term ordered recall by deaf adults. Both with sign and printed word presentation, subjects evidenced speech-based encoding. The reason for this cannot definitely be determined here, but it may be that speech-based rehearsal was in use because of the experimental situation. Given the requirement or order recall in the present experiment, subjects may have been influenced to use speech-based encoding.

Accuracy

The measure of overall accuracy in this experiment was the accuracy on the three control sets. With printed word presentation, the hearing subjects responded correctly significantly more often than did deaf subjects, $t(14) = 4.53$, $p < .001$. This finding that deaf subjects had difficulty with ordered recall is consistent with those of other studies (Conrad, 1970; MacDougall, 1979; Pintner & Paterson, 1917; Wallace & Corballis, 1973) that found poorer performance of deaf than hearing subjects on short-term memory tasks.

The difficulties of deaf populations on memory tasks have been often attributed to difficulties with English (Belmont & Karchmer, 1978; Furth, 1971). But work by Conrad (1979) suggests another interpretation. He found that memory span was related to use of phonetic coding. Those deaf subjects who used a speech-based code recalled more items in an ordered recall task than did those deaf subjects not using this code. It appeared, as a result, that recall accuracy in ordered recall was a function of speech encoding. Indeed, there is a similar suggestion from the present experiment. For the eight deaf subjects tested on recall of printed words, the number of correct responses on the three control sets correlated with the performance decrement on the phonetically similar set ($r = .63$). That is to say, the larger the decrement due to phonetic similarity, and thus the greater the evidence for use of a speech-based code, the greater the recall accuracy for the subject. This suggests that recall accuracy in this ordered recall task may be a function of the use of a speech-based code.

Experiment 2

Experiment 2 was designed to address whether difficulties of deaf subjects in short-term recall are limited to ordered recall. The hypothesis that a speech-based code is particularly suitable for temporal order recall (Baddeley, 1978; Crowder, 1978; Healy, 1975) leads to the prediction that ordered recall should be difficult for persons not having normal access to speech input. Experiment 2 employed a free-recall paradigm. If order recall, more than item recall, is dependent on the use of a speech-based code, then deaf subjects may not show short-term memory difficulties when only item recall is required.

Two conditions were included in Experiment 2: formational similarity and phonetic similarity. With hearing adults, Watkins, Watkins, and Crowder (1974) found that for free recall, phonetic similarity of words in a list improved recall accuracy when compared with unrelated words in a list. Thus, when memory for order was not required, the phonetic similarity of words proved to be of benefit to subjects using a speech-based code. The phonetic similarity condition of the present experiment was similar to that of Watkins et al. Lists of phonetically similar words were constructed such that, in relation to lists of unrelated words, subjects using speech-based encoding should benefit from the phonetic similarity. In the formationally similar condition, lists of words were constructed such that the corresponding signs were formationally similar. In comparison with performance on unrelated lists of words, formational similarity should improve performance if subjects are using sign-based encoding.

Method

Stimulus Sets

The formational similarity condition and the phonetic similarity condition each employed five sets of words. Each set contained an experimental list of formationally or phonetically similar words and a control list of unrelated words. There were 12 words per list. As in Experiment 1, words were chosen so that each English word had a corresponding sign.

For the formational similarity condition, each word in an experimental list had a corresponding sign that was formationally similar to the signs of the other words in the list. The signs for all words in the experimental lists were produced with both hands having the same handshape and with the place of articulation being neutral space in front of the body. For each of the five formationally similar lists, a different handshape was used. Each formationally similar list was matched with a control list for number of syllables and frequency of occurrence in written English (Thorndike & Lorge, 1944); this, as in Experiment 1, made performance on an experimental list interpretable only in relation to performance on the matched control. The signs for words in each of the control lists were formationally dissimilar.

For the phonetic similarity condition, five lists of phonetically similar words were constructed. Each phonetically similar list was composed of monosyllabic words related in the vowel sound of the word. As much as possible, words in the phonetically similar lists were graphemically dissimilar. Control lists, matched as described above, were constructed for each of the phonetically similar lists.

Appendix B lists the sets of words.

Design

Four experimental groups of subjects participated in the free-recall task: There was a group of deaf subjects and a group of hearing subjects in each of the two conditions. In order to test whether the lists of words having formationally similar signs were suitable for obtaining evidence of sign encoding, an additional group of deaf subjects was tested. This group was instructed to think of the signs for each word presented in the formationally similar condition.

Procedure

A videotaped CRT display presented the 12 words of a list at the rate of one word every 2 sec. All words were displayed in the center of the screen. The list presentation was followed by the instruction WRITE ALL THE WORDS YOU REMEMBER. Subjects were given as much time as necessary to write their answers. Presentation of the next list then began. Each list presentation was preceded by the word READY displayed for 2 sec.

A practice list was first presented, followed by a random presentation of the 10 test lists. Two different random list orders were used, and half of the subjects were tested with each list order.

Instructions, signed in ASL, were also recorded on videotape. The instructions informed subjects that they would see several groups of 12 words. They were told that when they were given the recall cue, they were to write all the words they could remember in any order they wanted. In the instructed condition, subjects were also told to think of the signs for the words presented and use the signs to help them recall the words. They were not, however, informed about the nature of the list construction.

Subjects

Subjects were tested in groups of one to three. They were paid for their participation in this 30-minute experiment.

Hearing subjects. Each group of hearing subjects was composed of eight staff members of the Salk Institute.

Deaf subjects. Deaf subjects were native signers of ASL recruited through the Salk Institute, California State University, Northridge, and Gallaudet College. All had a hearing loss of 90 dB or greater in the better ear. All were currently enrolled in college or were recent college graduates. There were eight deaf subjects in each of the three groups.

Table 2
Percentage of Words Recalled in Experiment 2

Group	Sets 1 and 2	All sets		
	Formational	Formational	Phonetic	M
Instructed (deaf)				
Similar	66.1	60.0	—	
Control	47.4	54.4	—	
% benefit	18.7*	5.6	—	
Deaf				
Similar	51.0	54.2	50.2	
Control	46.4	49.8	47.1	48.4
% benefit	4.6	4.4	3.1	
Hearing				
Similar	55.7	55.8	53.5	
Control	56.3	56.5	42.5	49.5
% benefit	−.4	−.7	11.0*	

* $p < .05$.

Results and Discussion

Encoding

In order to examine whether the formationally similar sets were suitable for obtaining evidence of sign encoding, the responses of the group instructed to use signs were analyzed in an analysis of variance for list type (experimental vs. control) by stimulus set (Sets 1–5). The results indicated no significant overall benefit due to formational similarity, $F(1, 7) = 1.90$, $MS_e = 334.25$, $p > .20$, but there was a significant interaction of list type by set, $F(4, 28) = 4.52$, $MS_e = 140.67$, $p < .01$. This indicated that benefit due to formational similarity was obtained only for some of the stimulus sets. Analysis of the simple effects revealed that only two of the five formationally similar lists showed a reliable improvement in performance, compared with their matched control: Set 1, $F(1, 28) = 16.34$, $p < .001$; Set 2, $F(1, 28) = 5.19$, $p < .05$. For the other three sets, subjects actually recalled somewhat fewer words on the experimental list than on the control, although the differences were not significant: Set 3, $F(1, 28) = .27$; Set 4, $F(1, 28) = .03$; Set 5, $F(1, 28) = .75$; all $ps > .20$. While it is puzzling that the benefit due to formational similarity was not more generally obtained, an outcome suggesting that the sign analog of phonetic similarity was not completely captured in the present design of experimental stimuli, there were at least two sets of stimuli that were suitable for testing whether sign-based encoding is used in the task. Results shown in Table 2 indicate the benefit in performance due to formational similarity both for these two sets and for all sets.

Analyses for the formational similarity condition were based only on those two sets of the formational similarity condition that appeared appropriate for obtaining evidence of sign-based encoding. An analysis of variance (ANOVA) was performed on percentage correct for subject group (instructed [deaf] vs. deaf vs. hearing) by list type by stimulus set (Sets 1 and 2). The analysis revealed an overall benefit due to formational similarity, $F(1, 21) = 4.82$, $MS_e = 290.94$, $p < .05$, that tended to interact with subject group, $F(2, 21) = 2.72$, $MS_e = 290.94$, $p < .10$. Analysis of the simple effects revealed that there was a significant benefit due to formational similarity for deaf subjects in the instructed condition, $F(1, 21) = 9.66$, $p < .01$, but that the deaf subjects in the experimental group did not show a significant benefit due to formational similarity, $F(1, 21) = .60$, $p > .20$. Hearing subjects, as expected, showed no benefit due to formational similarity, $F(1, 21) = .01$, $p > .20$. This suggests that the deaf subjects, unless specifically instructed to do so, were not encoding the written word in terms of a sign-based code, and this is in accord with the results of Experiment 1 in which sign-based encoding of printed words was not indicated.

So few intrusion errors were made on Sets 1 and 2 that analysis of the types of intrusions made was not feasible. In the instructed condition, deaf subjects made a total of 13 intrusions, 5 of which were in the formationally similar lists. Deaf subjects in the experimental group made 17 intrusion errors, 7 of which were made on recall of the formationally similar lists. Hearing subjects made 13 intrusion errors, 6 of which occurred on recall of the formationally similar lists.

The percentage correct for deaf and hearing subjects in the phonetic similarity condition was analyzed for group (deaf vs. hearing) by list type by set. Results indicated that there was a main effect of similarity, $F(1, 14) = 21.09$, $MS_e = 95.08$, $p < .001$, and this suggests a benefit due to phonetic similarity. This effect interacted with group, however, $F(1, 14) = 6.59$, $MS_e = 95.08$, $p < .05$. Analysis of the simple effects indicated a significant benefit due to phonetic similarity for hearing subjects, $F(1, 14) = 25.63$, $p < .001$, but not for the deaf subjects, $F(1, 14) = 2.05$, $p > .10$. The benefit of phonetic similarity for the hearing subjects did not interact with set, $F(4, 28) = .94$, $MS_e = 99.23$, $p > .20$, a result reflecting benefit for all five stimulus sets.

Further results were consistent with this finding: Examination of the intrusion errors on the five sets revealed that hearing subjects, more often than deaf subjects, made intrusion errors consistent with those for the phonetically similar lists. Hearing subjects made a total of 33 intrusions. Of the 16 on the phonetically similar lists, 12 errors (75%) were phonetically similar to the other words. Deaf subjects made 36 intrusions, and of the 15 intrusions on the phonetically similar lists, only 2 errors (13%) were phonetically similar to the other words.

This experiment, then, was suitable for obtaining evidence of speech-based encoding, as the results of the hearing subjects indicate. However, evidence for the use of speech-based encoding by deaf subjects was not indicated. This seems inconsistent with the results of Experiment 1 in which speech-based encoding was indicated. But rather than considering these results as inconsistent, two qualifying factors must be taken into account. The first is the task requirements. The task varied in the two experiments, and this may have influenced encoding strategies.

The second factor to consider is that failure to find evidence of speech-based encoding by deaf subjects must be viewed with caution in studies relying on phonetic similarity for such detection. In these studies, no evidence of speech-based encoding will be obtained if subjects are using pronunciations different from those anticipated by the experimenter. As deaf adults at times differ from hearing adults in their judgments about whether pairs of printed words rhyme (Hanson, 1980), word lists constructed by the experimenter to be phonetically similar may not always be phonetically similar as pronounced by deaf subjects.

This caution applies to the interpretation of the present nonsignificant results for deaf subjects in the phonetic similarity condition. In this regard, it is worth examining the performance of deaf subjects on Set 1 in the phonetic similarity condition of Experiment 2. The experimental list of Set 1 contained words from the phonetically similar set of Experiment 1. In Experiment 1, these words did provide evidence of speech-based encoding, an outcome implying that subjects were using the expected pronunciations of words. It is interesting to note that for Set 1, deaf subjects in Experiment 2 did recall more words from the experimental list than from its control, $t(7) = 2.88$, $p < .05$. While it would be inappropriate to draw strong conclusions from this analysis, it is interesting to note that the finding is consistent with the hypothesis that failure to find evidence of speech-based encoding may result, at least in part, from deaf subjects' not using the expected pronunciations of words.

Accuracy

Of concern in the present study is overall accuracy in the free-recall task of Experiment 2. In order to address this issue, the percentage correct for all control lists was analyzed. The ANOVA on data from the four experimental groups indicated that there was no significant difference in recall accuracy for deaf and hearing subjects, $F(1, 28) = .07$, $MS_e = 583.12$, $p > .20$. This finding is of major interest because memory studies typically show performance levels of deaf subjects to be lower than performance levels of hearing subjects (Conrad, 1970; MacDougall, 1979; Wallace & Corballis, 1973). The comparable recall accuracy of deaf and hearing subjects in this free-recall task was also in marked contrast to the results of the ordered recall task used in Experiment 1.

In a search of the literature, only one previous study was found that was concerned with free-recall accuracy of words by deaf subjects. In that research, by Koh, Vernon, and Bailey (1971), deaf subjects recalled about one item fewer than hearing subjects did. However, a methodological confounding noted by the investigators makes it uncertain whether their study actually tested memory for words. In the method employed, pictures of the words were presented simultaneously with the written words, a procedure that perhaps influenced subjects toward use of memory strategies different from those employed in recall of purely linguistic material.

In the present task, then, which required only item recall, deaf subjects were not found to have short-term memory deficits, compared with hearing subjects. This finding raises the question of how the item information was retained, as evidence was obtained for use of neither a speech-based nor a sign-based code by deaf subjects. With hearing subjects, Healy (1977) found evidence indicating a non-speech code involved in retention of item information. It is not unreasonable to expect that deaf subjects might make extensive use of this (perhaps visual) code in recall of item information. However, the above caution regarding failure to find evidence of speech-based coding by deaf subjects must be borne in mind before concluding that deaf subjects were not employing such a code in Experiment 2.

General Discussion

In understanding the nature of the internal representation of English words for deaf persons, it may be necessary to discuss encoding as it relates to specific subjects in a specific task, rather than to try to determine *the* encoding strategy employed by deaf persons. The present research is consistent with earlier research in finding that adult signers are able to use a sign-based code for short-term retention of linguistic material (Bellugi et al., 1975; Conlin & Paivio, 1975; Poizner et al., 1981; Shand, 1982), although the present findings further suggest that factors such as stimulus input (signs or printed English words) and task requirements are likely to influence encoding strategy. Although not examined in the present research, individual subject characteristics, such as degree of hearing loss, linguistic background, access to a speech-based code (Conrad, 1979), age, and educational achievement, are also factors that may influence choice of encoding strategy. The present results should be interpreted bearing in mind that the subjects were well-educated, profoundly deaf adult native signers of ASL.

The experiments reported here provide converging evidence that the distinction between item recall and order recall is an important one for short-term memory (Bjork & Healy, 1974; Lee & Estes, 1981; Murdock, 1976), and they provide support for the hypothesis that temporal order recall may be facilitated by the use of a speech-based code (Crowder, 1978; Healy, 1975, 1977). In ordered recall tests for English letters and words (MacDougall, 1979; Pintner & Paterson, 1917; Wallace & Corballis, 1973), for fingerspelled letters (Liben & Drury, 1977), and for ASL signs (Bellugi et al., 1975), deaf persons recall fewer items than hearing persons. The present findings are in agreement with these results. Deaf subjects in Experiment 1 responded less accurately in probed recall for order of printed English words than did hearing subjects. Furthermore, the extent to which a speech-based code *was* used correlated with the accuracy of ordered recall. However, in the free-recall task of Experiment 2, deaf subjects did not differ significantly in recall accuracy from hearing subjects. Thus, deaf subjects seem to differ from hearing subjects in recall accuracy when recall of item and order information is required but not when recall of only item information is required. Consistent with this hypothesis, that deaf subjects may have specific difficulties with retention of temporal order information, is the finding by O'Connor and Hermelin (1972, 1973) that, given the choice of spatial or temporal order recall, deaf subjects used spatial strategies; in contrast, hearing subjects used temporal order recall strategies. Also, Lake (1980) reported that deaf children do not attend to word order when learning English.

As English is a language in which word order plays a critical syntactic role, this suggestion that deaf persons may have special trouble with recall of order information is of major interest. It is known that, on the average, deaf persons have difficulty with reading (Karchmer, Milone, & Wolk, 1979), and closer analysis shows that there are certain syntactic constructions that are particularly difficult for deaf persons to comprehend (Quigley & King, 1980). Work such as the present study on the underlying cognitive processes of deaf persons may help in understanding these reading and language problems.

References

Baddeley, A. D. Short-term memory for word sequences as a function of acoustic, semantic, and formal similarity. *Quarterly Journal of Experimental Psychology*, 1966, *18*, 362–365.

Baddeley, A. D. The trouble with levels: A reexamination of Craik and Lockhart's framework or memory research. *Psychological Review*, 1978, *85*, 139–152.

Bellugi, U., Klima, E. S., & Siple, P. Remembering in signs. *Cognition*, 1975, *3*, 93–125.

Belmont, J. M., & Karchmer, M. A. Deaf people's memory: There are problems testing special populations. In M. Gruneberg, P. Morris, & R. Sykes (Eds.), *Practical aspects of memory*. London: Academic Press, 1978.

Bjork, E. L., & Healy, A. F. Short-term order and item retention. *Journal of Verbal Learning and Verbal Behavior*, 1974, *13*, 80–97.

Conlin, D., & Paivio, A. The associative learning of the deaf: The effects of word imagery and signability. *Memory & Cognition*, 1975, *3*, 335–340.

Conrad, R. An association between memory errors and errors due to acoustic masking of speech. *Nature*, 1962, *193*, 1314–1315.

Conrad, R. Acoustic confusions in immediate memory. *British Journal of Psychology*, 1964, *55*, 75–84.

Conrad, R. Short-term memory processes in the deaf. *British Journal of Psychology*, 1970, *61*, 179–195.

Conrad, R. *The deaf school child*. London: Harper & Row, 1979.

Crowder, R. G. Language and memory. In J. F. Kavanagh & W. Strange (Eds.), *Speech and language in the laboratory, school, and clinic*. Cambridge, Mass.: MIT Press, 1978.

Frumkin, B., & Anisfeld, M. Semantic and surface codes in the memory of deaf children. *Cognitive Psychology*, 1977, *9*, 475–493.

Furth, H. G. Linguistic deficiency and thinking: Research with deaf subjects 1964–1969. *Psychological Bulletin*, 1971, *76*, 58–72.

Hanson, V. L. Implications of research on sign languages for theories of reading. In B. Frøkjaer-Jensen (Ed.), *The sciences of deaf signing*. Copenhagen: Audiologopedic Research Group, 1980.

Healy, A. F. Coding of temporal-spatial patterns in short-term memory. *Journal of Verbal Learning and Verbal Behavior*, 1975, *14*, 481–495.

Healy, A. F. Pattern coding of spatial order information in short-term memory. *Journal of Verbal Learning and Verbal Behavior*, 1977, *16*, 419–437.

Hintzman, D. L. Articulatory coding in short-term memory. *Journal of Verbal Learning and Verbal Behavior*, 1967, *6*, 312–316.

Karchmer, M. A., Milone, M. N., Jr., & Wolk, S. Educational significance of hearing loss at three levels of severity. *American Annals of the Deaf*, 1979, *124*, 97–109.

Kintsch, W., & Buschke, H. Homophones and synonyms in short-term memory. *Journal of Experimental Psychology*, 1969, *80*, 403–407.

Klima, E., & Bellugi, U. *The signs of language*. Cambridge, Mass.: Harvard University Press, 1979.

Koh, S. D., Vernon, M., & Bailey, W. Free-recall learning of word lists by prelingual deaf subjects. *Journal of Verbal Learning and Verbal Behavior*, 1971, *10*, 542–547.

Lake, D. Syntax and sequential memory in hearing impaired children. In H. N. Reynolds & C. M. Williams (Eds.), *Proceedings of the Gallaudet conference on reading in relation to deafness*. Washington, D.C.: Division of Research, Gallaudet College, 1980.

Lee, C. L., & Estes, W. K. Item and order information in short-term memory: Evidence for multilevel perturbation processes. *Journal of Experimental Psychology: Human Learning and Memory*, 1981, *7*, 149–169.

Liben, L. S., & Drury, A. M. Short-term memory in deaf and hearing children in relation to stimulus characteristics. *Journal of Experimental Child Psychology*, 1977, *24*, 60–73.

MacDougall, J. C. The development of visual processing and short-term memory in deaf and hearing children. *American Annals of the Deaf*, 1979, *124*, 16–22.

Moulton, R. D., & Beasley, D. S. Verbal coding strategies used by hearing-impaired individuals. *Journal of Speech and Hearing Research*, 1975, *18*, 559–570.

Murdock, B. B., Jr. Item and order information in short-term serial memory. *Journal of Experimental Psychology: General*, 1976, *105*, 191–216.

O'Connor, N., & Hermelin, B. Seeing and hearing and space and time. *Perception & Psychophysics*, 1972, *11*, 46–48.

O'Connor, N., & Hermelin, B. The spatial or temporal organization of short-term memory. *Quarterly Journal of Experimental Psychology*, 1973, *25*, 335–343.

Odom, P. B., Blanton, R. L., & McIntyre, C. K. Coding medium and word recall by deaf and hearing subjects. *Journal of Speech and Hearing Research*, 1970, *13*, 54–58.

Pintner, R., & Paterson, D. G. A comparison of deaf and hearing children in visual memory for digits. *Journal of Experimental Psychology*, 1917, *2*, 76–88.

Poizner, H., Bellugi, U., & Tweney, R. D. Processing of formational, semantic, and iconic information in American Sign Language. *Journal of Experimental Psychology: Human Perception and Performance*, 1981, *7*, 1146–1159.

Posner, M. I., Boies, S. J., Eichelman, W. H., & Taylor. R. L. Retention of visual and name codes of single letters. *Journal of Experimental Psychology Monograph*, 1969, *79*(1, Pt. 2).

Quigley, S. P., & King, C. M. Syntactic performance of hearing impaired and normal hearing individuals. *Applied Psycholinguistics*, 1980, *1*, 329–356.

Shand, M. A. Sign-based short-term coding of American Sign Language signs and printed English words by congenitally deaf signers. *Cognitive Psychology*, 1982, *14*, 1–12.

Stokoe, W. C., Jr., Casterline, D. C., & Croneberg, C. G. *A dictionary of American Sign Language*. Washington, D.C.: Gallaudet College Press. 1965.

Thorndike, E. L., & Lorge, I. *The teacher's word book of 30,000 words*. New York: Columbia University, Teachers College, 1944.

Wallace, G., & Corballis, M. C. Short-term memory and coding strategies in the deaf. *Journal of Experimental Psychology*, 1973, *99*, 334–348.

Watkins, M. J., Watkins, O. C., & Crowder, R. G. The modality effect in free and serial recall as a function of phonological similarity. *Journal of Verbal Learning and Verbal Behavior*, 1974, *13*, 430–447.

Wickelgren, W. A. Distinctive features and errors in short-term memory for English vowels. *Journal of the Acoustical Society of America*, 1965, *38*, 583–588.

Wickelgren, W. A. Distinctive features and errors in short-term memory for English consonants. *Journal of the Acoustical Society of America*, 1966, *39*, 388–398.

Appendix A

Stimulus Sets for Experiment 1

Phonetically similar set:	TWO, BLUE, WHO, CHEW, SHOE, THROUGH, JEW, YOU.
Phonetic control set:	SOME, KING, THAT, CRY, FARM, WITH, TAX, CHURCH.
Formationally similar set:	KNIFE, NAME, PLUG, TENT, TRAIN, EGG, SALT, CHAIR.
Formational control set:	RING, COKE, RULE, MONTH, COW, HOUSE, NOON, KISS.
Graphemically similar set:	BEAR, MEAT, HEAD, YEAR, LEARN, PEACE, BREAK, DREAM.
Graphemic control set:	TREE, NORTH, GIRL, WORLD, KNOW, DRINK, WAIT, MOVE.

Appendix B

Stimulus Lists for Experiment 2

Formational similarity condition

Set 1

Experimental list: MONTH, DURING, HAPPEN, SAME, MEET, CAN'T, DEPEND, TEMPERATURE, REGULAR, STARS, PAIN, SOCKS.

Control list: BLUE, VISIT, GROUP, READ, ACCIDENT, LAW, COMFORTABLE, WAIT, SECRET, NIECE, SOMETIMES, NEXT.

Set 2

Experimental list: NAME, RAILROAD, CHAIR, SALT, TENT, EGG, HURRY, SHORT, WEIGHT, UNIVERSE, INCREASE, VERY.

Control list: EYE, THING, GOLD, FLOWER, MARRY, UMBRELLA, BUILD, NIGHT, KEY, ABLE, HEAVEN, MEAT.

Set 3

Experimental list: STOP, TOWN, CLEAN, BECOME, PROVE, WOOD, PAPER, WINDOW, OPEN, COOK, SCHOOL, PIE.

Control list: APPLE, COW, THROUGH, PROBLEM, WARM, FAMOUS, HANDS, KING, CLEAR, TREE, ISLAND, GREEN.

Set 4

Experimental list: TEACH, NUMBER, INSIDE, BANQUET, PUT, GIVE, SMOOTH, NONE, SELL, MORE, PACK, SOIL.

Control list: DAY, SMART, BIRD, DEVIL, SUNSET, GAME, BREAD, REFUSE, COUNT, LAUGH, HOUSE, RULE.

Set 5
Experimental list: SCIENCE, COFFEE, BICYCLE, POSSIBLE, WHICH, SHOES, ADVERTISE, BREAK, HABIT, TOGETHER, MAKE, FOLLOW.
Control list: MILK, PEOPLE, TELEPHONE, RESPECT, AFTERNOON, TEASE, WATER, FIRST, SCISSORS, PRESIDENT, BEAUTIFUL, HOME.

Phonetic similarity condition

Set 1
Experimental list: BLUE, CHEW, TOO, THROUGH, NEW, SHOE, WHO, TRUE, FEW, TWO, YOU, KNEW.
Control list: SICK, PACK, ALL, BREATHE, RED, TIME, COP, MORE, HOT, OUT, BOY, PLAY.

Set 2
Experimental list: WEIGH, GREAT, PRAY, SKATE, EIGHT, THEY, LATE, DAY, STRAIGHT, ATE, WAIT, GRAY.
Control list: SMELL, RIGHT, HUNT, SNAKE, LARGE, THAT, RICH, ICE, STRENGTH, AID, PLAY, BALD.

Set 3
Experimental list: FREEZE, PIECE, PLEASE, THESE, PEAS, EAST, TEASE, CHEESE, GREECE, PEACE, NIECE, PRIEST.
Control list: PREACH, PLANT, PRAISE, THEIR, LUCK, HERE, SPELL, THRILL, PURSE, TRAIN, CLOWN, THIEF.

Set 4
Experimental list: CALM, DAWN, FROM, BOMB, ONE, SOME, GONE, FUN, DONE, COME, MOM, THUMB.
Control list: NEED, LIST, ELSE, PLUS, JOY, REAL, BORN, CAT, FINE, POOR, ART, MOUSE.

Set 5
Experimental list: TRY, LIE, EYE, FLY, PIE, WHY, DIE, GUY, MY, HIGH, BYE, DRY.
Control list: CRY, END, LAW, GET, PEN, MAD, EAT, OWL, WE, LONG, JOG, OLD.

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