Remembering without Words: Manual Memory

4 We all have a vivid impression of the immediate present, but if we are asked to recall in detail the moment just passed, we can reproduce only a limited part of its contents. If we are remembering sights, a partial image is available to us for a brief time. And it is common experience for hearing people to remember sounds, such as the last few words of a sentence, even when they have not been paying attention to the sounds as they were occurring. Such "echoes" are the mode in which we experience the present and briefly retain its details after it is no longer physically available. We can partially hold onto and seemingly even reinvigorate visual and auditory experiences just passed in the time stream.

Our capacity for immediate memory plays a special role in language processing. When we hear spoken language, we must process and store a stream of ongoing speech until we have taken in enough to understand structure and meaning—we must remember, for instance, from the beginning to the end of a sentence or proposition in order to grasp a communication. The form in which linguistic signals are stored in immediate memory has been of much interest to psychologists and linguists and has been the focus for a large number of experiments (reviewed, for example, by Norman 1976). The form in which words are encoded has turned out to provide evidence of the psychological reality of some levels of language structure—in particular, of sublexical structure.

To determine the form in which words are stored in short-term memory, researchers have presented subjects lists of items to be remem-

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bered and then have examined the attempted reproductions of the lists. When we hear a list of unrelated words and then try to remember what we have heard, not only is there a maximum list length beyond which items cannot be recalled, but some of the items may get transposed and some of those we think we remember are not even among those originally presented—there are errors as well as omissions. The comparison of the errors with the items originally presented shows which characteristics of the items are retained and which are distorted. The nature of the characteristics retained and distorted in the errors suggests the basis of encoding for temporary storage.

Results of studies producing such errors, called intrusion errors, have led toward an agreement that for hearing people, short-term memory for words has a phonological basis (perhaps acoustic, perhaps articulatory (kinesthetic), perhaps a combination of the two). Conrad (1962) was the first to show that for hearing subjects, intrusion errors in short-term memory for visually presented printed letters correlated with errors in perception of spoken letters under noise. For instance, when the printed letter *c* is given as a stimulus, it is not misremembered as the visually similar *o* but rather as the phonologically similar voiced *z;* the auditory rather than the visual aspect of the material predominates. In later experiments Conrad (1972) has shown that hearing children tend to code pictures pictorially up to the age of five; from then on word-based phonological coding predominates. There is now abundant experimental evidence that most people code linguistic information in short-term memory on the basis of the sound-form of words or letters. This is consistent with our everyday experience of memory for language as a memory of sounds: a hearing person is accustomed to the "inner voice" he uses when he rehearses a phrase, recalls a sentence, or remembers a list or a line.

But in what form might a deaf person encode the language of signs? Hearing people find it difficult to imagine an inner world without sound; how might deaf people remember without an "inner voice"?

Deaf parents tell us that their children sign to themselves in their sleep; we have observed deaf toddlers signing to themselves and their toy animals before bedtime when they thought they were alone. We have seen hands "muttering" to themselves; we have seen deaf people rehearsing *a mano* before a videotape session, repeating a grocery list in sign, and signing to make clear to themselves something read in English. Deaf people tell us they dream in signs, plan conversation in signs, imagine the perfect retort in signs. Is this inner "voice" in the hands related to the way deaf people initially process the linguistic symbols of their own language?

One way to investigate this question is to look at the coding of signs in short-term memory. As hearing people with only a beginning knowledge of sign language, we ourselves have tried remembering lists of signs and have found that we say to ourselves the English word translation-equivalents of the signs as they are presented. Thus errors that we make in recall tend to be based on the sounds of the words we assigned to the ASL signs. Many of the deaf people we work with have command of several different linguistic codes—American Sign Language, written English, and even spoken English; consequently, before conducting the present experiments we had no idea what kinds of codes they might use for remembering signs.

Conrad (1970) suggests that for deaf people "we have to be able to conceive of a *verbal* memory store (for language-symbolic material) which may be full of pictures of words as written, or as they might appear on fingerspelling hands, on 'signing' hands, on speaking lips, not to mention the kinaesthetic/tactual analogues of these" (p. 192). He concludes that "the deaf do use 'symbols' in memorizing, and that the nature of them is open to empirical inquiry . . . That the deaf, with little overt speech, learn and think is self-evident. What they do it in remains a challenge with far-ranging implications" (p. 194).

In the study cited, Conrad was exploring the possibility that some deaf people might code visually presented English symbols in terms of the visual shapes of printed English letters or words along with, or instead of, articulatory phonological characteristics. He found that deaf children proficient in articulating English speech coded visually presented symbols in terms of articulatory phonological characteristics but that children less proficient in articulation employed neither visual nor articulatory properties in coding. He did not explore the possibility that his subjects relied on other types of coding. His subjects were deaf children whose education was exclusively oral; he did not explicitly specify what further linguistic background they had had or whether any of them had any knowledge of a sign language.

The question of our own memory studies is not how the overall deaf population remembers and processes symbols of written English but rather how a particular sample of deaf people—primarily those who have learned from deaf parents, as their first language, a purely visual-gestural language—remember and process the visual-gestural symbols of that sign language.

Memory for Random Lists of Signs: Experiment 1

To investigate the question of how deaf signers code the signs of their native language in short-term memory, experiment 1 compares deaf signers' ordered recall of random lists of visually presented signs with hearing speakers' recall of matched lists of spoken words.

The subjects were two groups of eight college students, one deaf group and one hearing group. The eight deaf subjects, students at Gallaudet College in Washington, D.C., were all deaf children of deaf parents; they all grew up in homes where the primary form of communication was American Sign Language.[1] The eight hearing subjects were students at the University of California at San Diego, none of whom had any knowledge of a sign language.

Design of Experiment

ASL is a language very different from English; but just as any two languages used by people in more or less similar cultures will have some pairs of lexical items that are near equivalents semantically, so pairs of ASL signs and English words form fairly good matches, like the ASL sign glossed as GIRL and the English word *girl*. For experimental studies of sign language we use the DASL and the intuitions of deaf native signers to create lists composed, as far as possible, of signs with fairly direct translation-equivalents in English. In experiment 1 we used some 135 common signs that can function as nominals in ASL.

There is, of course, no word-frequency index in ASL, so we selected particular signs according to one or more of the following criteria: (1) they occurred in the vocabulary of the young deaf children in our language acquisition study (ages 18 months to 5 years)[2]—GIRL, MILK, COOKIE, TREE, CANDY, for example; (2) they were judged by several deaf signers to be commonly known—WEST, LAW, VOTE, GROUP, DIAMOND; (3) they were easily translated by deaf signers into single English words (thus excluding signs requiring more than one English word in translation, signs such as SIGHT-SEEING and ASSEMBLY-LINE); and (4) they allowed a standard rate of presentation of a close-up view of the signer on videotape (thus excluding compound signs in ASL and signs that exceed the usual signing space, like DOG, SKUNK, and LION).

We constructed 124 randomly ordered lists of three, four, five, six, and seven signs each, using a sign only once in the set of lists of each length. Approximately 100 signs appeared in each of the five sets of lists; other signs were selected from the remaining pool to make up an even number of lists for each length. We then divided these lists into two 62-list sets, assigning half the lists of each length to each of these two sets. Ten extra three-item lists were prepared as warm-up lists.

ASL signs made by a native signer were presented on videotape; they were framed for maximum visibility, including an area from forehead to just above the waist. The signs were made with neutral facial expression[3] and were presented at the rate of one sign per second with what may be considered the equivalent of a list intonation.[4] Two tapes were made: the first, for a Naming task (hereafter Naming tape), consisted of each of the 135 signs presented slowly and clearly in random order with 7 seconds between signs; the second, the test tape for the Memory task (hereafter Memory tape) consisted of the two 62-list sets. Approximately 12 seconds elapsed between lists.

Test materials for hearing subjects were prepared in an analogous manner. Words (the English translation-equivalents of the signs) were spoken by a native speaker of American English and were presented on an audiotape recorder at the same rate (one word per second) and in the same order as the equivalent signs presented on videotape. Two audiotapes were made: a Naming tape and a Memory tape.

Test procedures were analogous for hearing and deaf subjects, with two exceptions: (1) in addition to the written instructions presented to both groups, instructions were also presented to the deaf subjects in ASL on videotape, and (2) the deaf subjects responded by translating ASL signs into corresponding English words, whereas the hearing subjects responded without the extra step of translation.

Before beginning the memory experiment, deaf subjects were asked to watch each sign on the Naming videotape and to identify it by writing down an English word translation for that sign. These English translations of ASL signs gave us some objective basis for scoring correct and incorrect responses for each individual subject. As is expected in translating between two languages, subjects sometimes differed in the word chosen as a translation-equivalent for a sign; we cataloged for each subject the instances in which the name he gave differed from the word we had chosen as a gloss. The opportunity to identify and name each sign without the particular pressures of rapid identification and remembering also reduced the possibility that intrusion errors would result from misperception of the sign rather than from some loss in memory.[5] Analogously, hearing subjects began by simply identifying 135 spoken words from the Naming audiotape.

The experiment was divided into two sessions. In the first session the Naming task was followed by the warm-up lists of three signs and then by one set of Memory lists. Two weeks later the subjects were given the second set of Memory lists. In each session all lists of three items were presented first, followed by lists of four items, then five, six, and seven items. Each list was recalled immediately after its presentation. Subjects were permitted to write down the items in any order, as long as they ended with a correctly ordered sequence.

Although ordered recall was required by the instructions, we scored the results in two ways. In position scoring, an item was scored as correct if it was recalled correctly in the correct position. In item scoring, an item was considered correct if it had appeared anywhere in the presented list.

For the deaf subjects, a response was considered correct if it matched the English translation given by the subject himself in the Naming task, was a translation provided by the DASL, or, occasionally, was a translation judged correct by our deaf informants. Thus, if a subject wrote *city* for the sign we glossed as TOWN, *city* was considered correct for him. For 108 of the 135 signs used, at least seven of the eight deaf subjects responded with the English word they had given on the Naming task as their translation-equivalent for that sign. When greater variation occurred, the alternate translations for the most part were (a) synonyms of the name chosen on the Naming task (*cop* and *policeman*), (b) the verb rather than the noun form for the name chosen (*eat* and *food*), or (c) homonyms in ASL (*gold* and *California*). In the Memory test itself, subjects consistently used the names they had given on the Naming task as translation-equivalents for the correctly remembered sign. For this experiment, we distinguish the written word responses to signs or words—*cat*—from the spoken word stimuli presented to hearing subjects: /cat/. (The slashes in this chapter do not represent phonemic notation.)

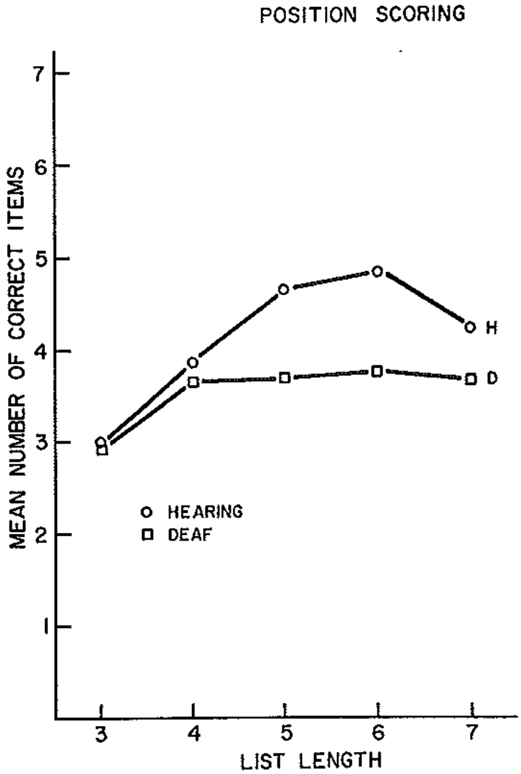
For hearing subjects, a word was considered a correct response if it was the same as or a homophone of the word listed by that subject on the Naming task. Variations between subjects in Naming were for the most part homophones: *bare* and *bear; knight* and *night; tea* and *tee.*

Recall

Figure 4.1 presents the mean number of items correctly recalled in the correct position for each list length for the two experimental groups. We also computed memory span, defined as the threshold (or list length) at which exactly half the lists were recalled correctly (Woodworth 1938, p. 202). For the deaf, memory span in signs is 4.9 items, approximately one item shorter than memory span in words for the hearing subjects (5.9 items). This difference is significant ($F(1,14) = 15.53, p < .01$). An analysis of variance performed on the data for the deaf and hearing groups (position scoring, mean number correct) yielded results that were consistent with the difference in memory span: the hearing subjects recalled more items overall ($F(1,14) = 12.16, p < .01$). We also found an interaction between experimental groups and list lengths ($F(4,56) = 5.30, p < .01$), since the deaf reached asymptotic performance before the hearing subjects did. Item scoring yielded the same pattern of results.

Some explanation for the difference in performance of deaf and hear-

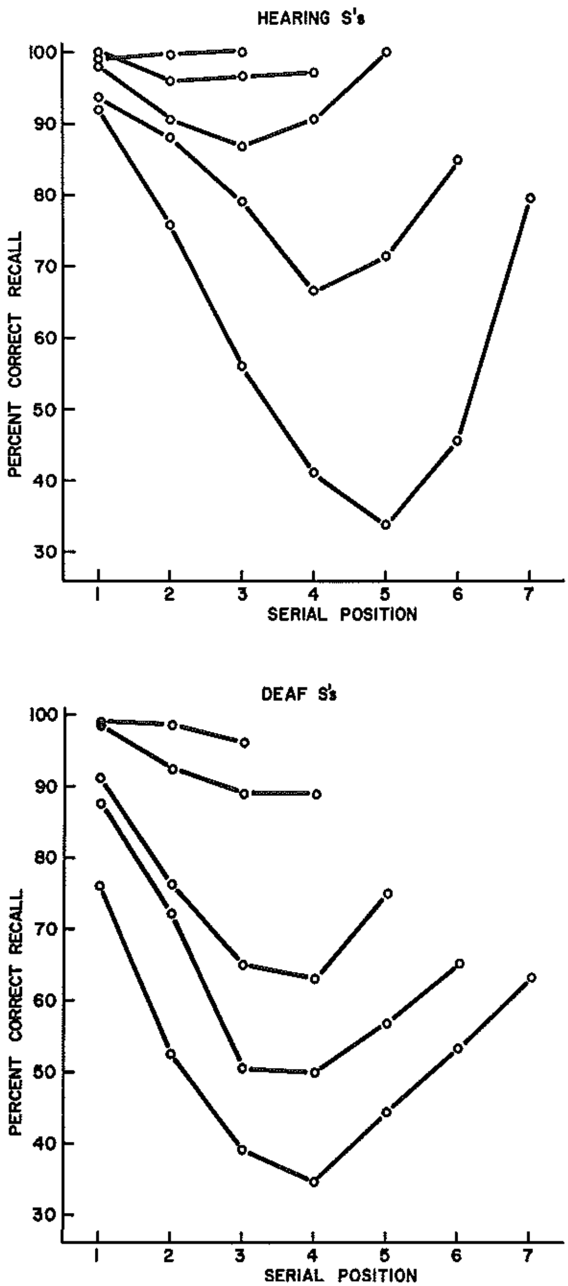
Figure 4.1 Mean number of items correctly recalled in ordered recall for hearing and deaf subjects.



ing subjects may be found by considering serial position curves for both groups (figure 4.2). Both produced bowed curves with large primacy and recency effects: both recalled items at the beginnings and ends of lists better than items in the middle of a list. This similarity is evidence for similar processing mechanisms.

The primacy effect is considered to be a product of the rehearsal mechanism, which keeps items available until they can be transferred into a more permanent memory system (Atkinson and Shiffrin 1968). Items at the beginning of a list get more rehearsal and thus have a greater probability of being remembered. If we allow ourselves to consider rehearsal to be the same as implicit speech for hearing subjects (for the deaf, the same as implicit signing), then we can measure rehearsal rate, which should be proportional to the rate at which the items are produced. Landauer (1962) has shown that the rate of implicit speech is not different from that of overt speech; similarly, we

Figure 4.2 Serial position curves for hearing and deaf subjects.



have found that the rate of overt signing does not differ from the rate of implicit signing.[6] But in a comparison of the rate of articulation of signs and of speech, it was found that on the average signs take longer to produce than words—nearly twice as long in narrative signing (see chapter 8). Therefore, although the rate of presentation in the Memory task was one item per second for both words and signs, about twice as much of that one-second interval was taken up in signing than in speaking. If the deaf are rehearsing in signs, they would have less opportunity for rehearsal and thus would be expected to show a smaller primacy effect than the hearing. And they do. That the memory span for deaf subjects is about one item less than that for hearing subjects might well be due to differences in rehearsal for the two groups.[7]

Recency effects for hearing subjects consistently cover the last two items in five- to seven-item lists, a common result at this rate of presentation; for deaf subjects, recency effects are still clearly evident, though somewhat less consistent at comparable list lengths. Thus short-term memory mechanisms such as those producing primacy and recency effects seem to be parallel in hearing and deaf subjects despite the different perceptual modalities.

For hearing subjects, the recency portion of the curve is usually attributed to a precategorical acoustic store (sometimes called an echo box) for spoken words (see, for example, Crowder and Morton 1969). Although this store is short-lived, a few recent items can be retrieved by immediate recall. A similar precategorical store of shorter duration is thought to exist for visually presented words, though some authors (Sperling and Speelman 1970, for example) argue that incoming words, whether presented auditorily or visually, are immediately encoded into a phonemic representation and that an auditory store is responsible for the entire recency effect.

Our data clearly show strong recency effects for deaf as well as hearing subjects. Unless our deaf subjects were encoding the signs as spoken words in order to store them (an assumption our intrusion error results will show to be false), we must conclude that there is more than one kind of precategorical store—that the "echo" can be in some other modality. But an echo of what? Of a written or printed word? Of an image or picture? Of signing hands?

Intrusion Errors

The critical question in this experiment is the nature of the errors that were made by hearing subjects and deaf subjects. Both groups responded in written English words, so correct responses for hearing and deaf subjects would be identical. But hearing subjects had spoken words as input and deaf subjects had ASL signs as input; thus the nature of the intrusion errors in each group should be revealing of the form in which the items are stored in short-term memory.[8]

Whenever possible in our studies, we endeavor to minimize the effect of blind guesses: from among the pooled errors we single out for special attention and analysis the errors that occur more than once in response to an item. In the current study there were 26 such multiple errors made by deaf subjects; table 4.1 presents these errors together

Table 4.1 Intrusion errors made by hearing and deaf subjects.[a]

Hearing errors		Deaf errors	
Items presented: Spoken words	Errors (written responses)	Items presented: Signs	Errors (written responses)
/vote/	*boat	GIRL	aunt
/tea/	*tree	KNIFE	peas
/coke/	*coat	CANDY	apple
/father/	*bother	CAKE	cup
/seat/	eat	VOTE	tea
/soap/	hope	CANDY	gum
/wood/	word	BEER	brown
/peas/	knees	LEAK	grease
/bath/	bat	CAT	Indian
/work/	*word	CANDY	jealous
/coffee/	copy	SALT	sit
/word/	work	BOY	man
/horse/	house	TOWN	house
/gravy/	baby	HOUSE	town
/train/	tree	NOON	tree
/water/	mother	CAKE	glass
/bath/	*fat	NAME	egg
/turtle/	cattle	SUN	owl
/book/	body	KEY	tea
/friend/	fish	LETTER	penny
/yesterday/	*day	SALT	shoe
/tea/	day	TEA	town
/car/	fat	MEAT	milk
/shoe/	*coat	TURTLE	gum
/movie/	day	SOAP	color
/dress/	town	ANIMAL	cow

a. Deaf errors are all multiple errors. Starred hearing errors are multiple errors; remaining hearing errors were selected randomly from the full list of hearing errors.

with the 8 multiple errors made by hearing subjects combined with 18 randomly-selected errors made by hearing subjects.

An examination of the item-and-error pairs for hearing subjects reveals the basis for many of the errors (hereafter called hearing errors). Some errors differ from the presented spoken word in initial segments only: /vote/, for instance, was misrecalled as *boat,* /peas/ as *knees,* /soap/ as *hope.* Some errors differ from the presented word in medial segments only: /wood/ was misrecalled as *word,* /horse/ as *house.* Some errors differ from the word presented in final segments only: /coke/ misrecalled as *coat,* /bath/ as *bat,* /work/ as *word.* A few errors are not phonologically similar to the word presented: for instance, /car/ was misrecalled as *fat.* Some other item-and-error pairs can be said to share semantic category membership at some level, like /shoe/ (item) and *coat* (error). The predominant impression overall, however, is that a significant number of the hearing errors are sound based.

From this experiment one can infer that the hearing subjects were coding and remembering auditorily presented words predominantly in terms of phonological properties.[9] We would expect this result from hearing subjects regardless of the mode of presentation of the material; previous experimental results indicate that had we presented words as visual stimuli (in their printed form), intrusion errors still would have been found to be based on the sound-form of words (see Sperling 1963; Wickelgren 1965a; Baddeley 1966; and Hintzman 1967). But what of deaf people?

Deaf subjects recalling visually presented ASL signs made errors of an entirely different sort. The items presented to hearing and deaf subjects were equivalent: for example, the English word and the ASL sign for 'cat.' Yet there was no overlap whatsoever in the intrusion errors made by the two groups of subjects, even though the correct (written) response was the same for both groups. The errors made by hearing and deaf subjects are completely distinct. Whereas hearing subjects encode linguistic material in short-term memory in phonological form, our analysis of intrusion errors in short-term memory for visually presented ASL signs indicates that deaf native signers encode their language in a quite different way.

Table 4.2 illustrates the differences between selected hearing and deaf intrusion errors to presented items. For instance, for a word that hearing subjects heard as /vote/, a common (multiple) intrusion error is the written response *boat.* For the ASL sign, which deaf subjects named VOTE, a common (multiple) intrusion error is, surprisingly, the written response *tea.*

As both table 4.1 and table 4.2 show, the deaf errors are clearly not sound based. How, then, can they be explained? (We want to stress that

Table 4.2 Selected intrusion errors made by hearing and deaf subjects to equivalent presented items.[a]

	Presented items		
Hearing errors	Spoken words	Signs	Deaf errors
world	/girl/	GIRL	aunt*
*boat	/vote/	VOTE	tea*
hurt	/cat/	CAT	Indian*
noun	/noon/	NOON	tree*
keys	/cheese/	CHEESE	new
fraud	/frog/	FROG	gum
house	/horse/	HORSE	uncle
mother	/month/	MONTH	temperature
knees	/peas/	PEAS	then
sauce	/socks/	SOCKS	star
tree	/tea/	TEA	vote
work	/week/	WEEK	nice

a. Starred items are multiple errors.

though the responses are written English words, for deaf as well as for hearing subjects, the deaf subjects' responses are English translations of presented ASL signs.)

One might have expected that the errors made by deaf subjects could have been based, in some broad sense, on the form of English words. Since the deaf subjects all knew how to read and write English and perhaps in some cases could lipread English as well as articulate some English words, it is conceivable that they would convert the signs immediately into some representation of the form of the corresponding English words. Thus the errors could have reflected the printed or written form of English words (for instance, *oat* for CAT). If this were the nature of the errors of deaf subjects, there would be some support for the notion that signs are merely symbols for words—that in terms of its lexical items American Sign Language is not an independent language. But in fact the repeated intrusion errors made by the deaf can not be attributed to resemblance to either phonological or orthographic forms of the corresponding English words even though deaf subjects responded to ASL signs by writing down the corresponding English words.

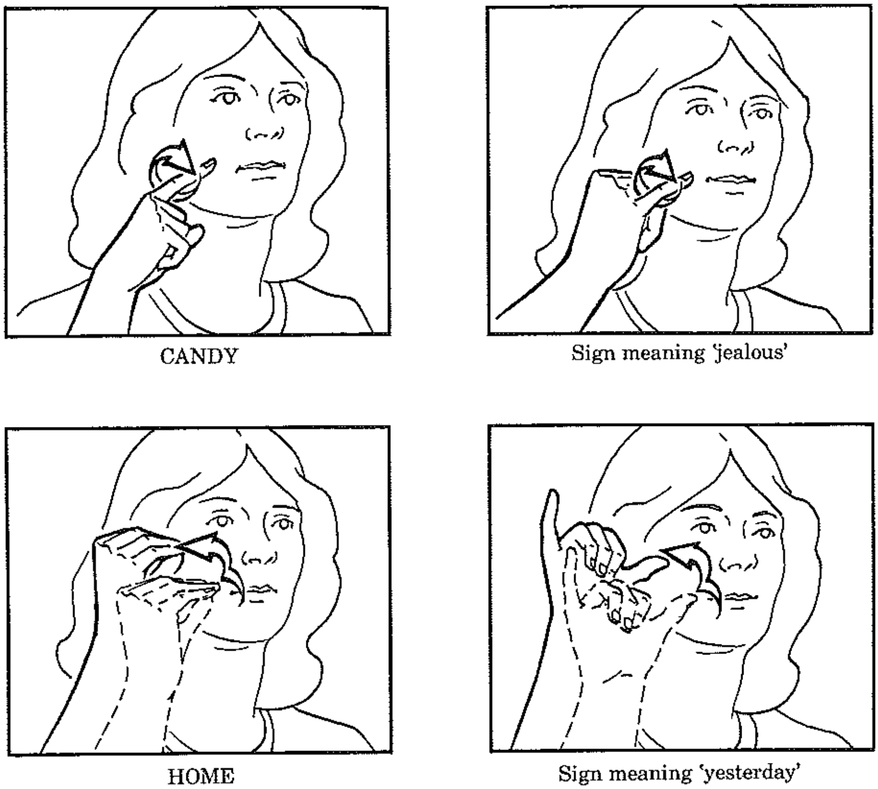
Another possibility is that the errors made by deaf subjects are based on some special properties of ASL signs that have no direct analogue in spoken language. Many common ASL signs in this experiment appear to be representational (or iconic) in the sense that characteristics of their denotation are represented by aspects of their form, a kind of manual image. The sign CAT can be thought to represent a cat's whiskers, for example, or the sign BIRD to represent the opening and closing of a bird's beak. Thus it is conceivable that errors in the recall of such signs would tend to be based on some image or icon supposedly represented by the sign. If deaf people were coding in pictures or images, CAT might have been misremembered as 'whiskers,' or even 'paws,' 'fur,' or 'claws'; BIRD might have been misremembered as 'beak,' 'peck,' or 'wing.' But the errors are not of this nature at all, and seem instead quite arbitrary. For example, for CAT several subjects wrote the word, *Indian,* and for BIRD a number wrote *newspaper.*

Previous experiments with hearing subjects suggest that though in short-term memory for verbal stimuli, errors in recall tend to be sound based, in long-term memory, errors are more likely to be semantic (Shulman 1971). Therefore, it is conceivable that for deaf subjects, who receive no auditory input, the basis of intrusion errors might be predominantly semantic in nature. If signs were encoded semantically, errors such as *dog* for CAT, or *elect* for VOTE might predominate. Again, however, such was not the case; although a few pairs such as the word *aunt* for the sign GIRL occurred, these pairs are similar in other ways as well, as we shall show.

What then is the dominant common characteristic of the intrusion errors made by deaf subjects in response to signs? It might have been the case that the errors represented a grab bag of blind guesses, each one made on a different basis. We found that even this was not the case.

What we did find was that one special type of error occurred frequently: If we retranslate the written responses back into ASL signs, in a striking number of cases the ASL sign for the error is *visually* highly similar to the *sign* presented—that is, to the sign for the correct response. Just as there is similarity in phonological form between the pair of words *vote* and *boat,* so there is an equally close relation in visual form between the pair of signs VOTE and TEA. Just as there is similarity in the sound forms of the words *noon* and *noun,* there is an equally close similarity in the visual forms of the signs NOON and TREE. (The similarity may be both visual and kinaesthetic for deaf signers; we will generally use the term *visual* similarity here, to mean similarity in form.) And the same kind of similarity holds for the other examples shown in table 4.2. Moreover, not only are the sign equivalents of the written errors visually similar to the presented signs, they are similar in form in specific and regularly classifiable ways. For one thing, the error signs tend to preserve the number of hands of the origi-

Figure 4.3 Sign-and-error pairs differing only in Hand Configuration.

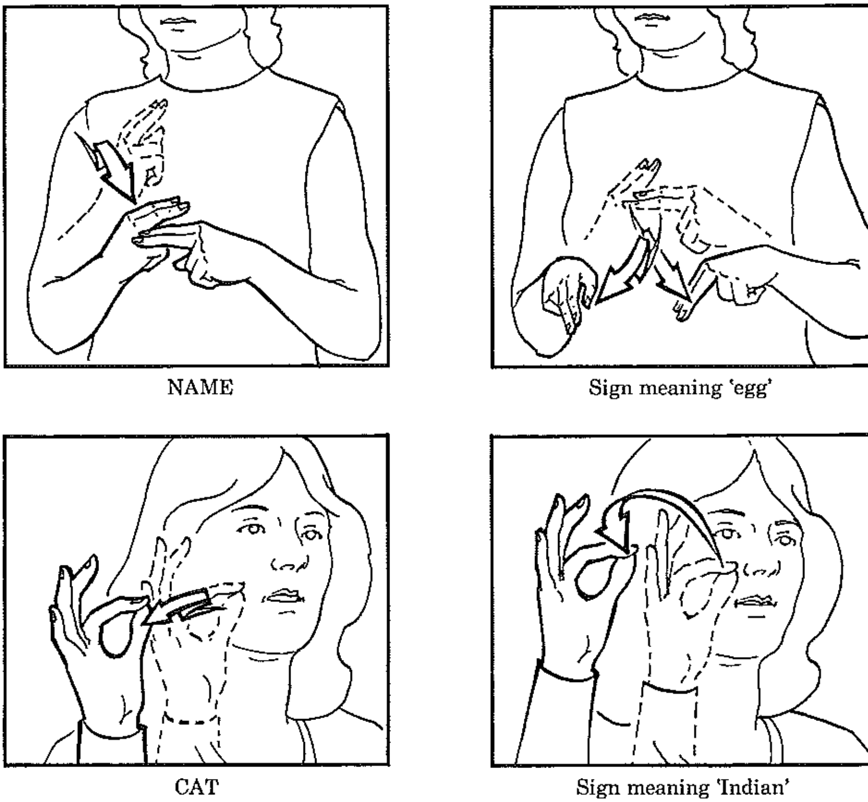


nal sign presented. But even more significantly, the majority of the multiple errors preserve all but one of the values of the major formational parameters of the original sign. Thus they differ from the sign presented in only one prime of one parameter: the errors tend to be minimally differing in form from the original items presented.

Some of the sign item-and-error pairs differ only in hand configuration. That is, the ASL sign corresponding to the written intrusion error preserves the place of articulation and the movement of the original sign: the sign for the error differs from the sign presented only in the particular configuration in which the hand is held. For instance, for the sign WEEK, an intrusion error was the written response *nice,* for ROLL it was *who,* for CANDY it was *jealous,* and for HOME it was *yesterday* (see figure 4.3).

A number of sign-and-error pairs differ only in movement; that is, the ASL sign corresponding to the written intrusion error preserves

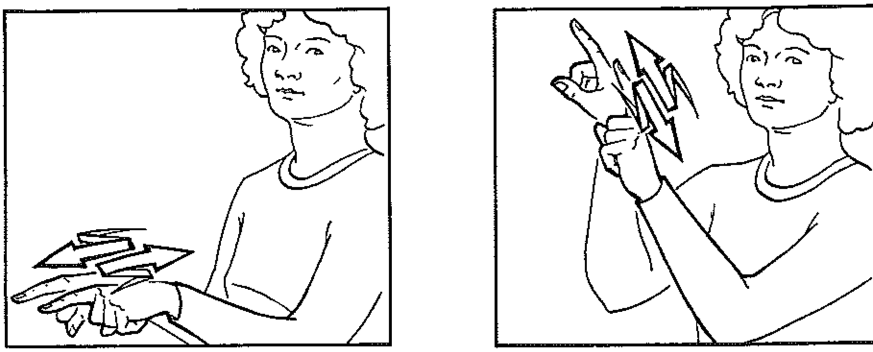
Figure 4.4 Sign-and-error pairs differing only in Movement.



the HC and PA of the original sign and differs from the sign presented only in MOV. There were many examples of such sign-and-error pairs. For example, an intrusion error for BEER was the written response *brown,* for NOON it was *tree,* for GIRL it was *aunt,* for KNIFE it was *peas,* for VOTE it was *tea,* for MONTH it was *temperature,* for PENNY it was *for,* for NAME it was *egg,* and for CAT it was *Indian* (see figure 4.4).

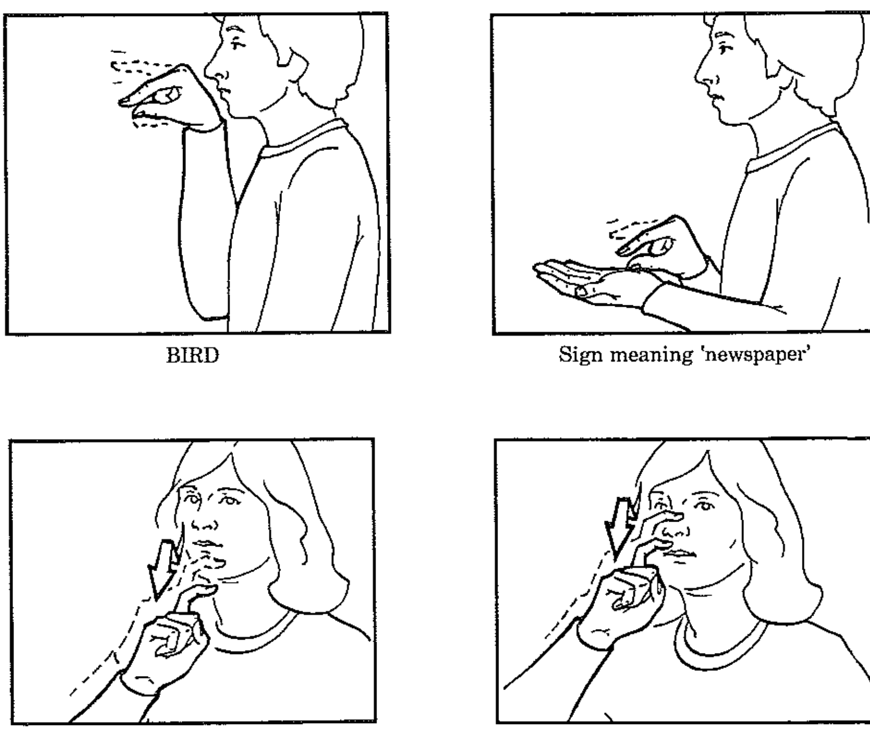
Other pairs differ only in orientation of the hands, as when the response to SOCKS was *star* (figure 4.5). No multiple sign-and-error pairs in this experiment differ only in place of articulation, though with a larger sample of subjects we assume more errors of this type would have occurred, as they have in other memory experiments we have completed. In the current experiment a response to the sign ONION was *apple,* to BIRD was *newspaper,* and to RUBBER was *doll* (figure 4.6). In addition, as with the errors from hearing subjects, scat-

Figure 4.5 Sign-and-error pair differing only in orientation.



SOCKS | Sign meaning 'star'

Figure 4.6 Sign-and-error pairs differing only in Place of Articulation.



BIRD | Sign meaning 'newspaper'

RUBBER | Sign meaning 'doll'

tered instances of sign-and-error pairs have no discernible relation and a few instances can be said to share semantic category membership.

Thus, when we think of the erroneous responses as representing ASL signs, it is obvious that a large proportion of the errors made by deaf subjects are formationally—that is, visually-manually—based.

In this study, although signs were presented, recall was in written English translations of the signs. How would errors made under conditions of translation compare with errors made if recall were directly in signs? In a preliminary memory study using some of the same sign lists used in the current study (Bellugi and Siple 1974, hereafter called the 1974 study), we compared deaf subjects' immediate ordered recall on identical lists of ASL signs when the responses were in written form (English words) and in signed form (ASL signs). Subjects viewed the videotaped lists of signs and, depending on prior instruction, responded either by writing their English gloss or by actually signing the ASL sign remembered. Signed responses were videotaped; at the end of the experiment subjects transcribed (using English glosses) their own signed responses.

We anticipated that these two procedures might give us entirely different results—that coding for recall in signs might be an entirely different process from coding for recall in written English translations of signs. But of the multiple intrusion errors to a single stimulus in the 1974 study, in over half of the instances the *same* error was made by deaf subjects when the response was signed and when the response was written down as an English gloss. This suggested to us that the deaf subjects were using essentially the same strategies for remembering, whether the response required was in ASL signs or in a different language and a different mode. The types of intrusion errors made in signed responses—ASL-based not English-based errors—were carried over into the written English responses. (This was very convenient for the current experiment because it allowed us the advantage of group presentation, which would not have been possible if each subject had to be videotaped while responding in signs.)

In the 1974 study, as in the current experiment, the intrusion errors made by deaf subjects did not overlap those made by hearing subjects to the same presented items, an indication that deaf subjects and hearing subjects are using different strategies for encoding.

Similarity Ratings of Item-and-Error Pairs

To what degree are the errors made by deaf subjects visually based (based on the form of the signs)? And how does that compare with the degree to which errors made by hearing subjects are sound based

Table 4.3 Similarity ratings of hearing subjects' intrusion errors.[a]

		Mean similarity ratings		
Items presented: Spoken words	Hearing errors	Auditory similarity of words	Visual similarity of signs	Semantic similarity of pairs
/vote/	*boat	1.0	4.0	4.9
/tea/	*tree	1.0	4.5	4.3
/coke/	*coat	1.1	4.8	4.8
/father/	*bother	1.1	4.6	3.9
/seat/	eat	1.2	4.7	3.7
/soap/	hope	1.3	4.2	4.8
/wood/	word	1.6	4.2	5.0
/peas/	knees	1.6	3.9	4.9
/bath/	bat	1.6	4.4	5.0
/work/	*word	1.7	3.7	4.4
/coffee/	copy	1.8	3.9	4.9
/word/	work	1.8	3.6	4.4
/horse/	house	2.1	4.8	4.4
/gravy/	baby	2.2	4.4	4.6
/train/	tree	2.8	4.4	4.3
/water/	mother	3.0	2.6	4.9
/bath/	*fat	3.0	4.7	4.8
/turtle/	cattle	3.1	4.8	2.8
/book/	body	3.4	4.4	4.8
/friend/	fish	3.5	3.9	4.5
/yesterday/	*day	3.5	4.5	1.6
/tea/	day	4.4	4.5	4.8
/car/	fat	4.7	4.1	4.8
/shoe/	*coat	4.8	3.0	2.9
/movie/	day	4.9	4.6	4.7
/dress/	town	4.9	3.7	3.7
Mean Rating		2.58	4.19	4.33

a. The starred errors are multiple errors; the others were selected randomly from the full list of hearing errors.

(based on the form of the words)? To what degree are both semantically based (based on meaning rather than form)? To examine and compare the special properties of the pairs generated by deaf and hearing subjects, we pooled the item-and-error pairs listed in table 4.1 into a single 52-item randomized list (the I–E Pool). The I–E Pool was subjected to three different ratings (results are presented in tables 4.3 and 4.4):

(1) Presented on videotape as ASL signs, the pairs were rated for visual similarity.
(2) Presented on audiotape as spoken English words, the pairs were rated for auditory similarity.
(3) Presented as printed English words, the pairs were rated for semantic similarity.

Table 4.4 Similarity ratings of deaf subjects' multiple intrusion errors.[a]

		Mean similarity ratings		
Items presented: Signs	Deaf errors	Visual similarity of signs	Auditory similarity of words	Semantic similarity of pairs
GIRL	aunt	1.3	4.9	2.3
KNIFE	peas	1.4	4.7	4.2
CANDY	apple	1.5	4.9	2.3
CAKE	cup	1.5	3.0	3.7
VOTE	tea	1.8	4.8	4.9
CANDY	gum	1.8	5.0	1.9
BEER	brown	1.9	3.1	4.2
LEAK	grease	1.9	3.2	3.6
CAT	Indian	1.9	5.0	4.1
CANDY	jealous	1.9	4.9	4.8
SALT	sit	2.1	2.4	4.9
BOY	man	2.1	4.9	1.3
TOWN	house	2.2	4.4	2.6
HOUSE	town	2.2	4.5	2.7
NOON	tree	2.3	4.9	4.7
CAKE	glass	2.4	4.7	4.5
NAME	egg	2.6	4.7	4.7
SUN	owl	2.7	4.9	4.1
KEY	tea	3.4	1.1	4.9
LETTER	penny	3.7	4.4	4.8
SALT	shoe	3.8	3.6	4.9
TEA	town	4.1	3.3	4.8
MEAT	milk	4.2	3.3	2.0
TURTLE	gum	4.3	5.0	4.8
SOAP	color	4.7	4.4	4.5
ANIMAL	cow	4.8	5.0	1.7
	Mean Rating	2.63	4.20	3.77

a. The pairs were rated as signs for visual similarity, as spoken words for auditory similarity, and as printed words for semantic similarity.

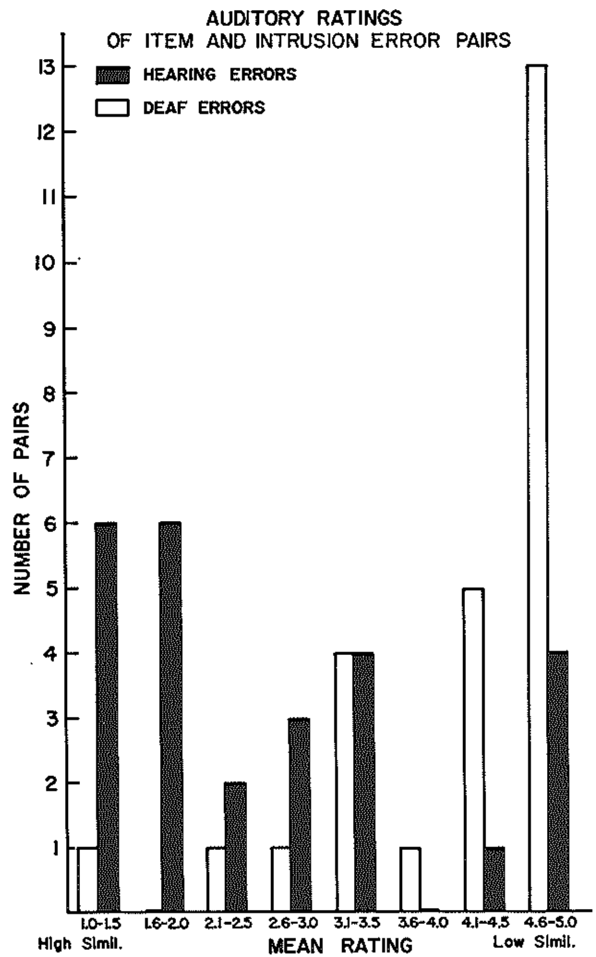
Hearing raters: The I–E Pool pairs presented as signs were rated for visual similarity by ten hearing people with no knowledge of sign language. Raters were not told the source of the pairs or the meaning of the signs. The I–E Pool pairs presented as spoken words were rated for acoustic similarity by ten other hearing raters. A scale of 1 to 5 was used, with 1 for most similar and 5 for most different. In each case, we gave examples (pairs not on the list) that could be considered most similar or most different. The results in figure 4.7 show a clear separation between the errors made by deaf and hearing subjects. The deaf I–E pairs had a mean visual similarity rating of 2.63 (as signs) and a mean auditory similarity rating of 4.20 (as spoken words). The hearing I–E pairs had a mean visual similarity rating of 4.19 (as signs) and a mean auditory similarity rating of 2.58 (as words). According to these ratings, the deaf errors (as signs) are visually similar to the presented item to the same degree that the hearing errors (as words) are auditorily similar to the presented item. Not only was there no overlap in actual intrusion errors made by the deaf and hearing, but the very nature of the errors is demonstrably different in the two cases.

Deaf raters: It could be argued that hearing people with no knowledge of sign language would rate pairs of signs for visual similarity on the basis of global, holistic impressions. To determine whether knowledge of sign language makes a difference in visual similarity ratings assigned to pairs of signs, we also asked experienced deaf signers to make ratings. Again the results show a clear separation between hearing and deaf errors; yet, overall, visual-similarity ratings by deaf raters show much greater agreement than do those made by hearing raters. The mean of the standard deviations of the ratings for deaf raters was 0.41; for hearing raters it was 0.84. The difference between matched pairs of standard deviations of deaf and hearing raters was found to be significant by the Wilcoxon test ($z \leq 0.01$). The difference is particularly striking with respect to I–E pairs generated by hearing subjects: for these pairs, the mean standard deviation for deaf raters was only 0.19, whereas for hearing raters it was 0.84. For the deaf raters, the mean visual similarity rating of hearing I–E pairs (as signs) was 4.88, almost the maximally dissimilar rating of 5.

A comparison of ratings and comments on one I–E pair will put this difference into focus. In experiment 1 a subject misrecalled the word /dress/ as *town;* when the pair was presented as signs on videotape (see figure 4.8) to hearing raters for visual similarity rating, three rated the pair 2, one rated it 3, two rated it 4, and four rated it 5. By contrast, all ten deaf raters assigned the pair a most-different rating of 5.

Afterward, when asked to describe the similarity between the two signs, a hearing subject noted that each sign uses two hands, that in

Figure 4.7 Comparison of hearing and deaf item-and-error pairs rated for auditory and visual similarity.



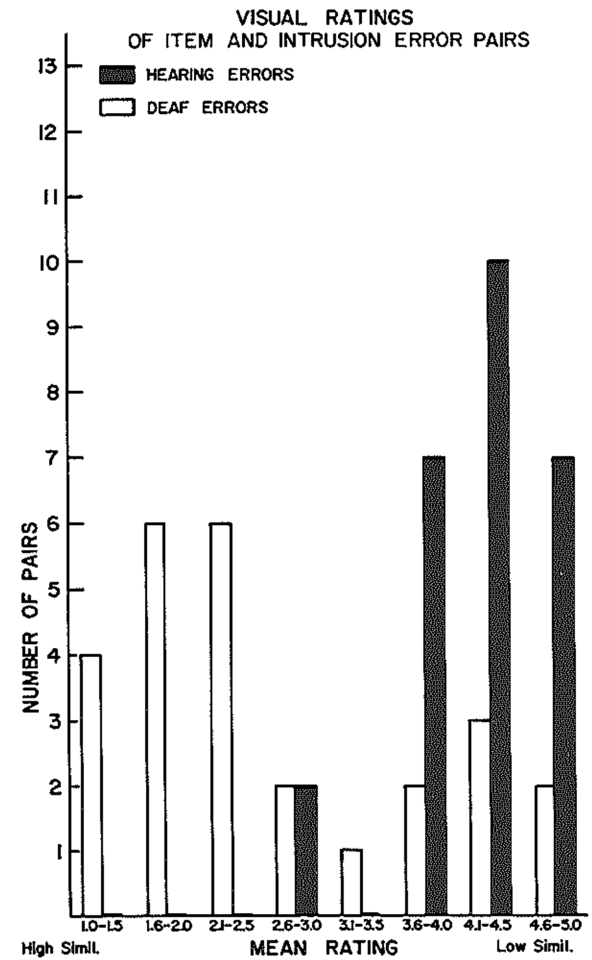
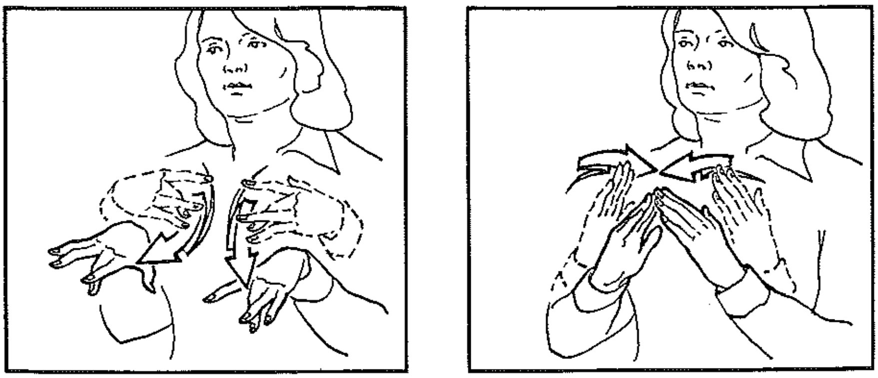


Figure 4.8 An item-and-error pair presented for visual similarity rating as signs.



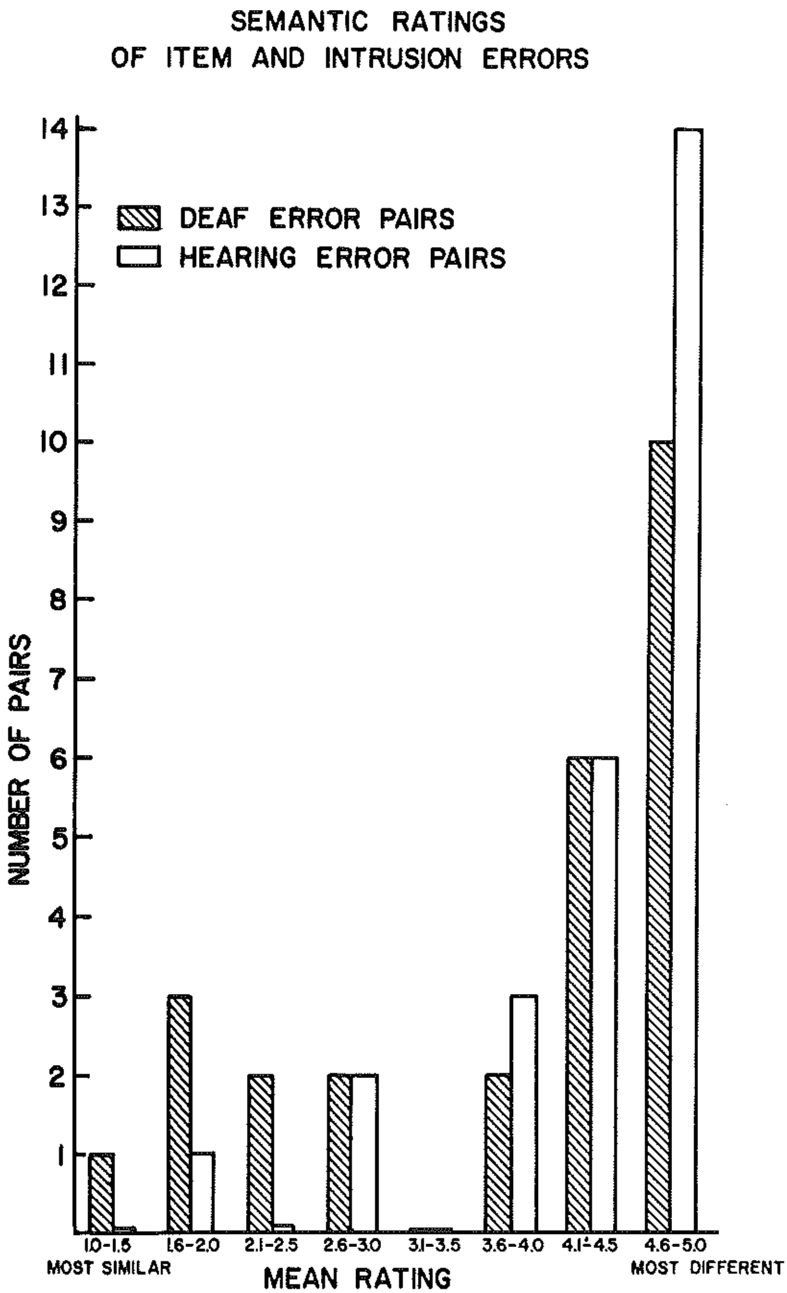
Sign meaning 'dress' Sign meaning 'town'

each sign the hands come together and perform the same action, that both signs are in the same area in front of the chest, and that both signs use the whole hand. Thus the hearing person rated the signs as similar. When a deaf subject discussed the signs, he noted that the motions of the two signs differ (a contact in TOWN and a downward brushing in DRESS), that the hands in the two signs are different (TOWN uses an open flat nonspread hand and DRESS uses an open spread hand with the middle finger bent), and that the signs are made in different places (TOWN in the space in front of the signer, and DRESS touching the chest). The deaf subject had accordingly rated the pair as maximally dissimilar. In the deaf rater's sublexical analysis, then, none of the primes of the major parameters (movement, hand configuration, place of articulation) are the same for this item-and-error pair, and the general vague similarities noted by the hearing subject do not count.

Semantic similarity ratings: The evidence presented so far indicates that deaf subjects code and rehearse in visual-manual properties of signs to the same extent that the hearing subjects code in acoustic-articulatory properties of words. To what degree might coding for either group be also semantically based? A third group of ten hearing raters rated the I–E Pool (presented as printed pairs of words) for similarity of meaning, again on the 5-point scale. The I–E pairs generated by both the hearing and the deaf were rated toward the dissimilar end of the scale: rated for semantic similarity, the mean of the deaf I–E pairs was 3.77 and the mean of the hearing I–E pairs was 4.33 (see figure 4.9 and tables 4.3 and 4.4).

Most of the intrusion errors made by deaf subjects have no semantic

Figure 4.9 Comparison of hearing and deaf item-and-error pairs rated for semantic similarity.



relation to the item presented: VOTE and *tea,* NAME and *egg,* NOON and *tree,* for example. A few pairs, however, are both semantically similar and visually similar. The signs GIRL and AUNT share HC and PA; the signs CANDY and APPLE share MOV and PA. Thus occasional error pairs may well reflect the combination of semantic and formational properties. Despite these occurrences of item-and-error pairs related in both form and meaning, it is clear from our results that the major source of intrusion errors is from signs that are similar only in form to the original sign presented on the test.

Coding by Formational Parameters

We have argued that for one group of deaf subjects—deaf people whose native primary language is the visual-gestural system called American Sign Language—intrusion errors in short-term memory may indicate significant properties of the nature of the coding of a special restricted set of visual symbols, ASL signs. For these subjects, even when their responses are in written English words, multiple intrusion errors do not at all reflect, as they do for hearing subjects, the phonological structure of the words; nor, rather surprisingly, do they reflect the visual form of those words in terms of the letters, their shape or number. Nor do the errors seem to reflect, as might be expected, the iconic (or representational) character of some signs. Nor do the errors reflect an essentially semantic organization in the processing and remembering of signs in the short-term memory paradigm. Rather, the multiple sign-and-error pairs reflect special organizational principles of the signs of American Sign Language, as they are described in terms of a specific, limited set of simultaneously occurring formational parameters that combine to constitute individual ASL signs.

When the multiple intrusion errors from experiment 1 are combined and classified with those from the 1974 study, the consistency of results is clear: over 80 percent of the multiple intrusion errors (translated into ASL signs) share at least one major parameter value with the original sign presented, and—most significantly—in 70 percent of the cases, the signs for the intrusion errors are identical in all but one major parameter value to the original sign presented; that is, the presented and error signs are minimally differing pairs. The proportion of errors of this type has remained roughly the same throughout our experiments under varying conditions of response mode: in the 1974 study it was 75 percent; in experiment 1, 70 percent. The encoding and rehearsing processes for deaf native signers evidently are in terms of the visual-manual properties of the signs themselves.

Memory for Multiparameter Similarity: Experiment 2

The intrusion error results of experiment 1 indicate that signs of ASL are encoded by native signers in terms of formational properties such as HC, PA, and MOV. Despite the fact that signs are far more representational than are words of a spoken language, their representational character seems to be irrelevant to this stage of immediate-memory processing. That errors were not based on the properties of the English words used in written recall suggests that translation into English was a late step in the process and that storage and rehearsal were in terms of properties of the signs themselves.

Some sign-and-error pairs in experiment 1, however, reflect both semantic and formational similarity; that is, the presented sign and the error sign share meaning as well as form. Since semantic families of signs do occur in ASL,[10] we wanted to examine the effect of formational similarity of signs apart from semantic similarity, to investigate the effect of formational similarity alone on short-term memory encoding. Investigators of the processing of spoken languages in short-term memory (Conrad 1963; Sperling 1963; and others) have suggested that lists of acoustically similar items are less well recalled than lists of acoustically different items. We examined an analogous phenomenon in sign processing: memory for lists of formationally similar (but semantically dissimilar) signs compared with memory for lists of dissimilar signs.

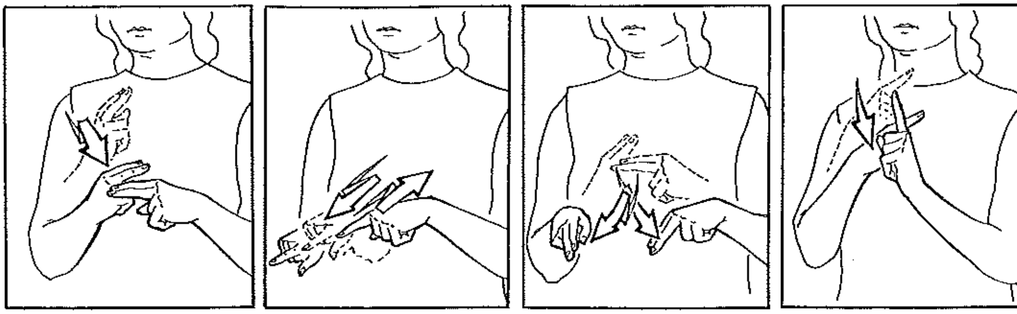
In experiment 2 we use a paradigm developed by Baddeley (1966) to examine the effects of formational similarity without other confounding factors. We constructed sets of eight formationally similar, semantically dissimilar signs, with matched sets of eight unrelated (random) items. From the eight signs within a set, we constructed sixteen four-sign lists. Ordered recall of the lists was required.

Our subjects were thirteen deaf college students from California State University at Northridge, all chosen for their expertise in signing ASL; most of them came from deaf families and had learned ASL as a native language.

Design of Experiment

As in experiment 1, lists were drawn from a pool of signs selected according to the following criteria: they were commonly known signs with a common English translation; they could function as nominal signs; they could be made in a relatively small space and at a fairly rapid rate. In addition, signs selected for this experiment have occurred in other memory experiments, giving us information on ease of recall.

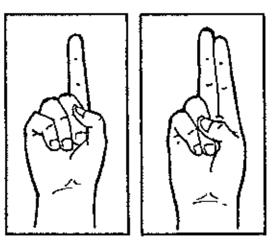
Figure 4.10 Experiment 2: Signs in a list exhibiting multiparameter similarity.



NAME SOCKS EGG MONTH

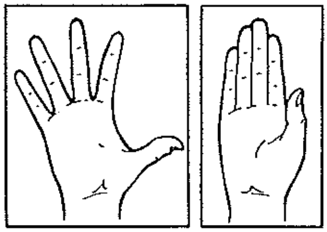
We selected three sets of formationally similar, semantically dissimilar signs, eight signs in each set. Our choice was limited not only by the requirement that signs within each set be similar in form but also by the control requirement to match them with random signs of equal difficulty; thus a few of the items overlap sets. We used the intuitions of our deaf researchers to help choose these maximally similar sets. Within each set, signs are similar in HC (differing only minimally), PA (identical), and in number of hands used. Signs within a set differ primarily in the major parameter MOV; minor parameters may also vary. The four signs from Set 1 shown in figure 4.10 illustrate the degree of formational similarity within a set.

Set 1. SOCKS, KNIFE, MONTH, TEMPERATURE,
TAPE, CHAIR, NAME, EGG



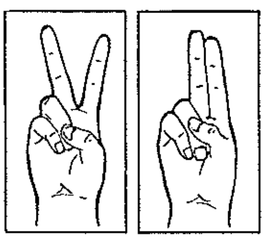
The signs in Set 1 are identical in PA (the neutral space in front of the torso) and are all made with two hands in contact. Only two HCs are used, and the two are highly similar, differing only in the number of fingers extended. The signs SOCKS, KNIFE, MONTH, and TEMPERATURE are made with one finger extended; in TAPE, CHAIR, NAME, and EGG, two fingers are extended. The contacting region for these signs is along some portion of the extended fingers.

Set 2. AMERICA, MACHINE, FORT,
CHEESE, MOVIE, PAPER, SOAP, SCHOOL



The signs in Set 2 are identical in PA (the neutral space in front of the torso) and are all made with two hands in contact. The HCs are all flat open-palm hands. In AMERICA, MACHINE, and FORT the fingers are spread and interlaced; in CHEESE, MOVIE, PAPER, SOAP, and SCHOOL the fingers are not spread and the contacting region is the palm or base of the palm.

Set 3. PRISON, PLUG, TENT, SALT,
NAME, EGG, TRAIN, CHAIR



The signs in Set 3 are identical in PA (the neutral space in front of the torso) and are all made with two hands in contact. The HCs have two fingers extended from a closed fist. In PRISON, PLUG, TENT, and SALT the fingers are spread; in NAME, EGG, TRAIN, and CHAIR the two fingers are together. The contacting region is along some portion of the extended fingers.

To choose signs for the three control random sets we used results from another memory experiment. Each sign on a list of dissimilar signs was matched for difficulty of recall and serial position with a sign on the corresponding similar-form list. From each of the eight-sign sets, we composed 16 four-sign memory lists. In these lists, each of the eight possible signs appeared twice in each of the four serial positions, once in the first half of the tests and once in the second half. (Eight warm-up lists of random signs were chosen from another group.)

The signs, made by a deaf signer, were presented on videotape in the same manner and at the same rate as in experiment 1. Each of the 16 four-sign lists drawn from a single set of eight signs was presented as a group; similar-form sets alternated with matched random sets.

Before the presentation of each group of test lists, the eight signs from which the lists were drawn were shown individually on the videotape. A sign was presented with its printed English word translation on the videotape so that the subjects would become familiar with the signs used in each set and with an English gloss for those signs. Slides with two different arrangements of the English glosses for a set were prepared to be displayed continuously on a screen throughout that portion of the experiment.

Subjects were tested in a group session. Instructions were presented in printed English and signed in ASL on the videotape. After a warm-up session subjects were asked to pay attention to the presentation of the eight signs and their English glosses which would be used in the memory task. Then they were instructed to watch each list of four signs chosen from the eight-sign set and to write down, in the correct order, the translations for the signs, using prepared response sheets. Each list was recalled immediately after presentation. Subjects were permitted to refer to the slide containing the list of eight words; periodically the slide was changed so that the same eight words appeared in a different arrangement.

Several subjects preferred the English translation *trap* for the sign we called PRISON and used their translation consistently throughout the test; either response was considered correct. Lists were counted as correct only when the correct signs were reported in the correct order. We also scored for the percentage of items correct overall.

Interference Effects of Similarities

For each set of stimuli, the percentage of lists correct for the random condition was considerably higher than the percentage of lists correct for the matched formationally similar condition.

	Correct lists		
Condition	Set 1	Set 2	Set 3
Random	60.6%	69.7%	77.4%
Formationally similar	45.7%	53.3%	57.2%

An analysis of variance showed no significant differences between sets (although there was some slight improvement across the test); this information could therefore be pooled ($F(2,24) = 2.15$, not significant). The number of lists correct for the random-form condition is significantly greater than the number of lists correct for the formationally similar condition ($F(1,12) = 9.34$, $p < 0.01$). This effect is consistent across sets as attested by the negligible interaction between Set by List Type, ($F(2,24) = 0.08$, not significant). It is not just incorrect order of items that shows a decrement in recall; overall, the percentage of items recalled in formationally similar sets of signs was less than that in random-form sets (78.0 percent as compared with 85.6 percent correct recall). Across subjects this difference is significant at the .01 level according to the Wilcoxon sign-pairs test. (There were no extralist intrusion errors in this paradigm.)

Thus it is significantly more difficult to recall the order of signs in formationally similar lists than to recall the order of signs in random lists. That formational similarity has a detrimental effect on recall suggests that despite the simultaneous organization of signs, and despite the iconicity present in signs, it is abstract formational properties that are used as a basis for coding at this stage of processing.

Memory for Single Parameter Similarity: Experiment 3

Given that the formational parameters of ASL signs are generally salient in short-term memory, do the major parameters have differential effects? If so, what is the relative effect of each parameter? Is there some kind of hierarchical ordering in memory among the major parameters? To begin to investigate these questions, we compared recall of signs identical on only one major parameter with recall of dissimilar signs. Because the parameters occur simultaneously rather than sequentially, we cannot isolate single parameters while presenting signs. We can, however, hold each of the parameters constant in a list of signs while varying the other two and compare memory for signs in formationally similar lists with memory for the same signs in formationally dissimilar lists.

Twenty-four deaf college students, all prelingually deaf, served as subjects; eleven were students at California State University at Northridge, thirteen were students at Gallaudet College in Washington, D.C. Seventeen of the subjects had deaf parents and had learned sign language as a native language; the others were chosen because they were highly fluent signers and were experienced in ASL. The experiment was run in two groups, one at each college.

Design of Experiment

Ninety signs were selected for the memory lists. As in previous experiments, all the signs were judged to be commonly known, had fairly direct translations into single English words, could function as nouns in ASL, and were neither inordinately large or long nor compound signs. Specific classifications of signs into lists were made on the basis of the intuitions of our deaf researchers with the help of the DASL.

We constructed eighteen lists of five signs, six lists each shared a particular HC prime, six a particular PA prime, and six a particular MOV component (see table 4.5). For example, of lists holding a HC prime constant, in one list all signs had the thumb extending from a closed fist /A/, in another all signs had the index and middle fingers extending and spread from a closed fist /V/. Of lists holding PA constant, in one list all signs were made on the back of the hand, in another all signs were made on the cheek. Of lists holding MOV constant, in one list all signs involved a circular motion, in another all signs involved flicking open the fingers. Within each list, while we held one prime of a major parameter constant, we varied the values of the other two major parameters as much as possible, allowing minor parameters to vary freely.

Figure 4.11a illustrates some signs chosen for a list controlling for HC (two-finger extension); note that the signs vary in MOV and in PA. Figure 4.11b illustrates signs in a list holding PA constant (the palm of the hand) and varying HC and MOV. Figure 4.11c illustrates signs controlling MOV (circular movement); the signs vary in HC and in PA. Note that these are not minimally differing sets of signs, but sets in which the prime value of one parameter is held constant while the other parameters vary.

The same 90 items chosen for the similar-form lists were used to make up 18 random lists of items in which all three parameters varied (see figure 4.11d). Items retained the same serial position in both types of lists, appearing once in the first half and once in the second half of the test. For example, the sign SHEEP appeared in the third serial position of a formationally-structured list in which a HC prime was held constant in the first 18 lists. The sign SHEEP occurred again in the third serial position of a random list in the second 18 lists.

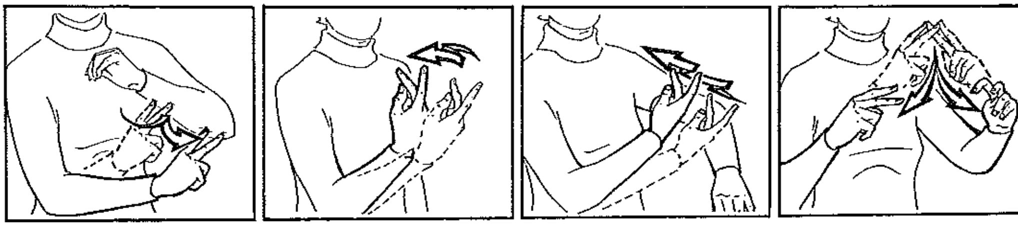
Instructions were given on videotape in ASL by a deaf signer and were also presented in printed English. Signs made by a native signer were presented on videotape in the same manner and at the same rate as in experiments 1 and 2. Because recall was in written English glosses for the 90 signs on the test, the Memory test was preceded by a Naming task like that in experiment 1. This procedure allowed the subjects to become familiar with the signs used on the test, to identify them, and to give them English glosses.

After a warm-up set of 16 five-item lists, signs were presented for the Memory test, in the five-item test lists. Structured and random lists alternated, and the structured lists were arranged so that two HC lists, for example, did not appear close to one another. Following the presentation of each five-item list, subjects immediately recalled the signs and wrote them in the test booklet, indicating the order in which they had occurred. Subjects were permitted to write down the items in any

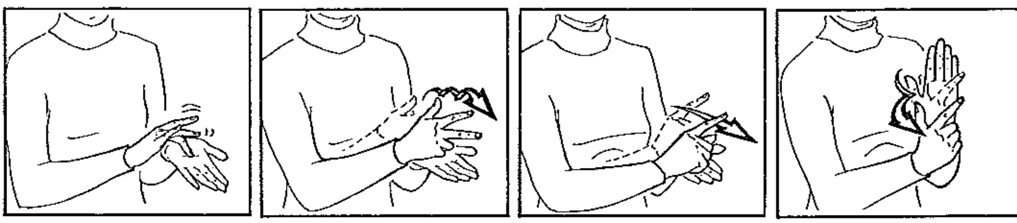
Table 4.5 Sign lists exhibiting single-parameter identity (experiment 3).

Same Hand Configuration (different Place of Articulation and Movement)					
BRIDGE	WE-TWO	SHEEP	VINEGAR	TENT	two-finger extension
SIGN	CANDY	EYES	DAY	PENNY	pointing hand
SCHOOL	SONG	WOOD	BODY	NOON	flat nonspread
FRIDAY	INDIAN	VOTE	SENTENCE	CAT	pinching hand
CHEMISTRY	GIRL	LETTER	YOURSELF	OPERATION	fist, thumb extended
PAPER	TREE	TRAFFIC	AMERICA	GRANDFATHER	flat spread hand
Same Movement (different Hand Configuration and Place of Articulation)					
SWEETHEART	BEAR	COLOR	TEST	DEVIL	fingers wiggling
QUEEN	HOME	PICTURE	PENCIL	BUTTON	two contact points
SURPRISE	MARBLE	BLOSSOM	SHOWER	FROG	fingers flicking open
WHO	REASON	YEAR	TEA	SNAKE	rotating
CANADA	TICKET	WEDDING	MEAT	EAR	grasping
BOY	MILK	NEWSPAPER	GRAVY	DUCK	fingers closing
Same Place of Articulation (different Hand Configuration and Movement)					
FOUNDATION	CHOCOLATE	MELON	EARTH	STONE	back of hand
BEE	YESTERDAY	GUM	APPLE	BED	cheek
FOX	DOLL	INSECT	GREEK	ODOR	nose
RUBBER	SUGAR	CHICKEN	LIAR	MOTHER	chin
MEDICINE	SHIP	WEEK	LAW	PIE	palm of hand
SUMMER	FATHER	LINCOLN	HORSE	IDEA	forehead

Figure 4.11 Experiment 3: Signs in structured lists exhibiting single parameter similarity (a,b,c) and signs in a nonstructured list (d).

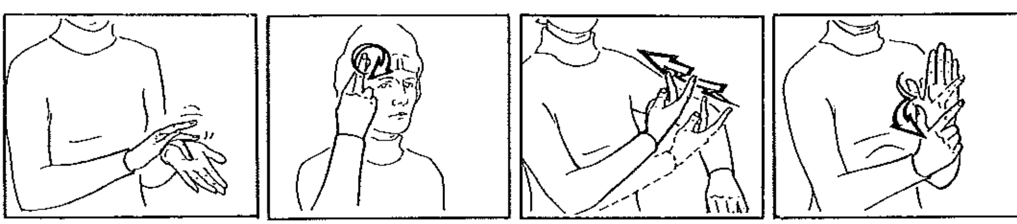


(a) Signs in a list holding Hand Configuration constant



(b) Signs in a list holding Place of Articulation constant

(c) Signs in a list holding Movement constant



(d) Signs in a random (nonstructured) list

order, so long as they ended with a correctly ordered sequence. The task was presented separately to the groups of students at the two colleges. One group started with list 1 on the test, the other with list 18.

All the words given as translation-equivalents in the DASL as well as a few additional translations given by native signers were considered to be correct responses. As in previous experiments these responses plus the translation-equivalents given by a subject on the Naming task were used to score that subject's recall. An item was scored as correct only if it was recalled correctly in the correct position. We also scored intrusion errors, items in a particular serial position that were neither from the presented list nor from the immediately preceding list. In nearly all cases subjects consistently used the names they had given on the Naming task as translations for correctly remembered signs.

Differential Effects of Parameters

As in experiment 1, there is a bowed serial position curve with a large primacy and recency effect, as shown in figure 4.12. This bowed effect occurs equally for similar-form lists and for random lists.

The mean number of items correctly recalled per list was used to compare the effects of the three types of similarity. To control for possible frequency and serial position effects, we compared recall of items appearing in lists with one parameter in common (HC, for instance) with recall of those same items when they occurred in random lists. The mean number of items correctly recalled in random lists has been subtracted from the mean recall for those items as they occurred in lists with a parameter held fixed. The average increase or decrease

Figure 4.12 Serial position curve, experiment 3: percent correct recall.

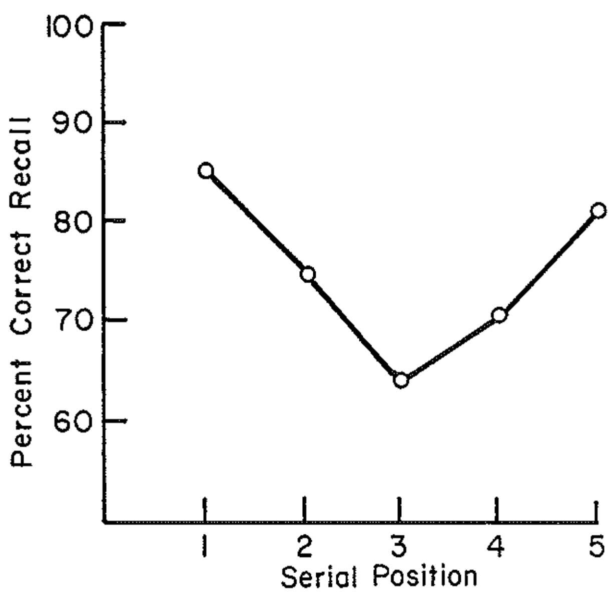
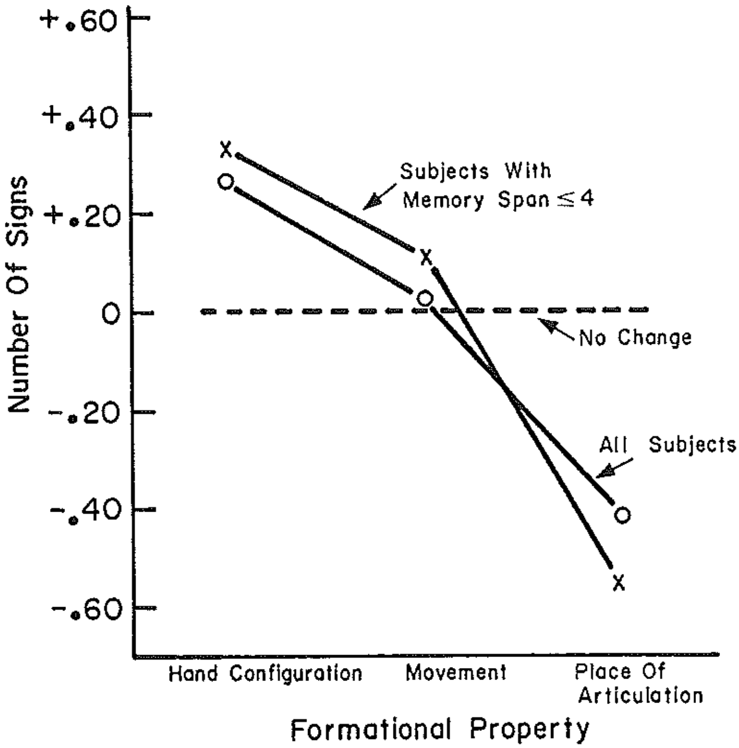


Figure 4.13 Average increase or decrease in mean recall due to formational similarity of Hand Configuration, Movement, and Place of Articulation (experiment 3).



in recall per list due to single-parameter similarity is shown in figure 4.13. The figure indicates that of the three major parameters, only similarity in PA produces a decrement in recall. Similarity of MOV seems not to affect recall in a consistent way; similarity of HC enhances recall. Six subjects had a memory span greater than four items and thus recalled nearly every list perfectly; with the data from these subjects removed, we get a better estimate of the actual increase or decrease in recall: a similar HC throughout a list increases recall by approximately one-third an item (9 percent); a similar PA throughout a list decreases recall by over half an item (14 percent).

An analysis of variance was performed on the data from those eighteen subjects who did not show a large ceiling effect. When the signs are divided into categories according to the parameter held common in a list (HC, MOV, or PA), the recall of these signs in random lists differs very little. However, when the signs appear in the lists with a common parameter, we find the trend shown in figure 4.13. This difference produces a significant interaction between parameter set and whether or not the items occurred in lists of similar items, and a main effect for the parameter set.

The comparisons between presentation in a random list and presentation in a list of similar items for each parameter set indicate that similar HC increased recall ($F(1,32) = 4.60, p < 0.05$), similar PA decreased recall ($F(1,32) = 14.08, p < 0.01$), and similar MOV did not affect recall ($F(1,32) = 0.65$, not significant). When the same comparisons were based on data from all twenty-four subjects, the same results were obtained.

Within each parameter, such as HC, we had selected six different primes. Figure 4.14 illustrates the contribution of each list to the total within a parameter set. All but one of the lists similar in HC showed some increase in mean recall. All but one of the lists similar in PA showed some decrease in mean recall. For lists similar in MOV there was a wide spread of results: one list showed a large decrement in mean recall, one list showed no change at all, and the other four lists showed some increase. For the most part, then, the individual lists (each holding a different prime constant) contributed to the differential finding of an increase in mean recall with HC held constant and a decrease with PA held constant.

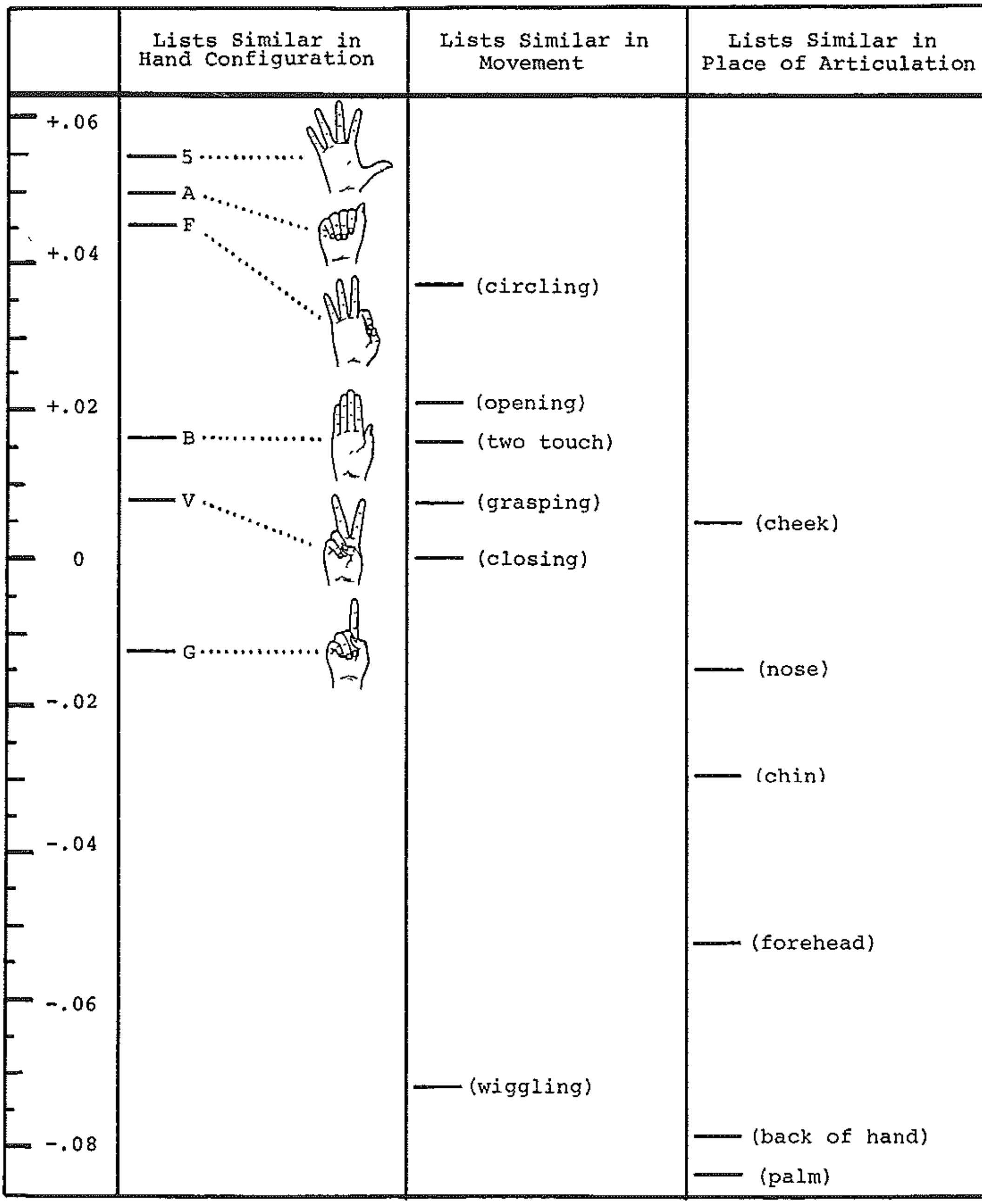
Similarity Ratings

Reasoning that the difference in recall could be related to differences in the general salience of the similarity of the signs selected for each of the parameter sets, we asked eight hearing people who did not know ASL to rate the similar-form lists. They were told that in each list some property was common to all the signs on that list. After observing the lists once to familiarize themselves with the array they would be rating, subjects viewed the lists a second time and rated each list for the degree of shared similarity among signs, with 1 for most similar and 5 for most different. The mean rankings for lists similar in HC and for lists similar in PA were 2.60 and 2.33 respectively. The mean ranking for lists similar in MOV was 3.52. It appears that for these lists similarity in MOV is less salient than similarity in HC or in PA.

Holding MOV constant while varying other parameters seems to have no predictable effect on recall. The similarity ratings made by hearing nonsigners suggest that the lists of signs holding MOV constant were less similar than lists with either of the other two parameters held constant; perhaps the similarity is just less salient and therefore has less effect.

When HC is held constant and other parameters are varied, recall is enhanced. It could be that in this experiment HC was stored as a prop-

Figure 4.14 Average increase or decrease in mean recall per list in formationally similar lists as compared with random lists (experiment 3).



erty of the entire list, which could then be used at recall to make better use of the sensory information remaining in short-term storage. Perhaps HC functions in these lists to provide a strategy for choosing alternatives at the time of recall.

Whatever produces the interference in short-term memory for similar lists in spoken language—the association net suggested by Wickelgren (1965b) or temporal decay of sequentially and independently encoded features (Sperling and Speelman 1970)—our data indicate that in sign language it is similarity in the PA of signs that produces a decrement in short-term memory for sign lists. This suggests that PA may well be the key information associated with the serial position of remembered items.

Summary

Several memory experiments yielded consistent results with respect to the coding of signs in short-term memory by deaf people whose native primary language is American Sign Language: coding is clearly in terms of the special organizational principles of the signs themselves—perhaps visual, perhaps kinesthetic, perhaps some combination of the two. One deaf person, when asked to introspect on how she remembered the lists of signs in our experiment, signed that she watched each sign on videotape and then formed a mental image of her own hands making the signs. For this signer, inner rehearsal of signs seemed as natural and obvious as inner rehearsal of words does to a hearing person. The intrusion errors from our experiments indicate that she is indeed, as she claims, coding and rehearsing in signs. Further, these results indicate that despite the global iconicity of certain signs, and despite the simultaneous organization of the formational components of signs, so different from the organization of the sound segments of words, the formational elements of signs are independently encoded in short-term memory processes.

As Conrad (1972) observed, there is abundant evidence that short-term memory "thrives on a speech like input." Our studies show that, in a broadened context, it is advisable to amend this to a *language-like input,* so that the characterization is not limited to the speech mode.