WHEN A WORD IS NOT THE SUM OF ITS LETTERS:
FINGERSPELLING AND SPELLING*

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Abstract. In an experiment examining reading of fingerspelling, deaf signers of American Sign Language were asked to view fingerspelled words and nonwords. They then wrote the letters of the item just presented and made a judgment as to whether the item was a word or nonword. There was a large difference in ability to report the letters of words and nonwords. The letters of words tended to be accurately reported, while the letters of nonwords were much less accurately reported. Results indicated that these deaf subjects did not read fingerspelled words as individual letters. Rather, subjects made use of the underlying structure of words. Misspellings of words in this task and from free writing of deaf adults demonstrated a productive knowledge of English word structure, with striking similarities in error pattern being found from these two sources.

INTRODUCTION

Fingerspelling is a manual communication system in which there is a manual sign for each letter of the alphabet. Words are spelled out in this system. Fingerspelling is an important part of American Sign Language (ASL) as well as an integral part of manual systems based on English. As such, it is important to understand how fingerspelled words are processed by skilled users of the system. For this reason, an experiment was designed to examine the following questions: How are fingerspelled words read? Is reading words a letter-by-letter process of recognition? That is, is it necessary to

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identify each letter of the word? Or, rather, when reading words is there recognition of letter groupings? And what kinds of errors are made when reading fingerspelling?

METHOD

Sixty fingerspelled items were presented, one at a time. Thirty were real words ranging in length from five to thirteen letters. Mean length was 8.3 letters per word. The following words were used: ADVERTISEMENT, AWKWARD-LY, BANKRUPTCY, BAPTIZE, CADILLAC, CAREFUL, CHIMNEY, COMMUNICATE, ELABORATE, FUNERAL, GRADUATE, HELICOPTER, HEMISPHERE, INTERRUPT, MOUNTAIN, PANTOMIME, PHILADELPHIA, PHYSICS, PREGNANT, PSYCHOLOGICAL, PUMPKIN, RHYTHM, SUBMARINE, SURGERY, THIRD, TOMATO, UMBRELLA, VEHICLE, VIDEO, VINEGAR. These thirty words were matched for average length with 30 nonwords. Twenty of these matched nonwords were pseudowords. Pseudowords were pronounceable, but they do not happen to be English words. The following pseudowords were used: BRANDIGAN, CADERMELTON, CHIGGETH, COSMERTRAN, EAGLUMATE, FREZNIK, FRUMHENSER, HANNERBAD, INVENCHIP, MUNGRATS, PHALTERNOPE, PILTERN, PINCKMOR, PRECKUM, RAPAS, SNERGLIN, STILCHUNING, SWITZEL, VALETOR, VISTARMS. The other ten nonwords were not possible English words. These orthographically impossible words were not pronounceable. The impossible words were as follows: CONKZMER, ENGKSTERN, FTERNAPS, HSPERACH, PGANTERLH, PIGTLANING, PKANT, RANGKPES, RICGH, VETMFTERN.

Stimulus words were recorded on videotape by a native ASL signer. Items were fingerspelled at a natural ASL rate of 354 letters per minute (see Bornstein, 1965). While words were fingerspelled at a slightly faster rate than nonwords, this difference in rate between words (mean rate of 369 letters per minute) and nonwords (mean rate of 339 letters per minute) was not statistically significant, $t_{(58)}=1.87$, $p > .05$. Real words, pseudowords, and impossible words were mixed throughout the list with each item followed by a 10 second blank interval to be used as a response period. Subjects were instructed that they would see many fingerspelled items and that for every item they were to do two things: First, write the letters they had just seen, and second, make a judgment as to whether that item was a word or nonword. The instructions, signed in ASL by the same person who fingerspelled the stimuli, were recorded on videotape.

Subjects were 17 congenitally deaf adults recruited through New York University and California State University, Northridge. Fifteen were native signers of ASL. The other two had learned ASL at age five and were considered by native signers to be fluent in ASL. There were eight men and nine women ranging in age from 17-53 years, mean age 31 years.

RESULTS AND DISCUSSION

Responses were analyzed for accuracy of letter report and correctness of word judgments. Shown in the first line of Table 1 are percentages of subjects' correct responses in the three conditions. These were trials on which both the letter report and word judgment decisions were correct. As can readily be seen, there were large performance differences for words, pseudo-words, and impossible words.

Table 1

Mean percentage of items correct in the three conditions.

	Words	Pseudowords	Impossible words
Total correct responses	61.0%	25.0%	11.2%
Correct word judgments	92.9%	83.5%	82.9%
Correct spelling following correct word judgment	62.9%	28.1%	12.9%

Response Accuracy

There are two possible sources of error in this experiment: recognition and letter report. It is possible that subjects recognized all the letters of an item correctly but later were unable to report the letters. Bearing on this issue, it is important to take note of the fact that subjects were accurate at making decisions as to whether a fingerspelled item was a word or nonword. As shown in Table 1, when words were presented, subjects correctly indicated that item was a word on more than 90% of the trials. The analysis of accuracy across conditions indicated, however, that accuracy was not constant across all stimulus types, $F(2,32)=3.84$, $p<.05$. Although word judgments were made more accurately for words than for nonwords (Newman-Keuls, $p<.05$), most likely indicating an expectancy for words, there was no difference in ability to respond that pseudowords were nonwords and ability to respond that impossible words were nonwords. If subjects were making decisions based simply on whether the fingerspelled nonwords were consistent with English orthography, there should have been more of a tendency to respond that pseudowords were English words than to respond that impossible words were English words. This was clearly not the case. It is reasonable to assume, therefore, that subjects generally recognized the words correctly when they responded that an item was a word, and to assume that they responded that an item was not a word when there was no recognition of an English word.

But while subjects were accurate at this word judgment task, they were not as accurate at letter report. If a word was correctly recognized as an English word, what was the probability that the word would be correctly spelled? As shown in the bottom line of Table 1, subjects correctly spelled 62.9% of the words following a correct word judgment. The fact that there were errors in letter report indicates that it is possible to recognize a word from its letters but not be able to use this knowledge productively to spell the words. Several times the experimenter noticed that when a fingerspelled word was presented, a subject produced the sign for the word, indicating that he or she recognized the word, but then was unable to spell the word. 147

In contrast to the accuracy in letter report for words following a correct word judgment, if pseudowords or impossible words were correctly identified as nonwords, accuracy of letter report was poor: 28.1% for pseudowords and 12.9% for impossible words. This difference in ability to report the letters of words, pseudowords, and impossible words is significant, $F(2,32)=82.59$, $p<.001$, with post hoc analysis revealing that letter report for words was significantly more accurate than letter report for nonwords (Newman-Keuls, $p<.01$). There was thus a word familiarity effect in this fingerspelling task. In addition, signers were more accurate at letter report for pseudowords than at letter report for impossible words (Newman-Keuls, $p<.01$). This greater accuracy for pseudowords than impossible words, consistent with effects in recognition of printed pseudowords and impossible words reported by Gibson, Shurcliff, and Yonas (1970) indicates that signers were able to make use of orthographic structure to read and remember letters of a new fingerspelled item.

The difference in ability to receive and report the different types of items suggests that much different processes are involved in reporting the different items. It suggests that subjects use orthographic structure to read and remember letters of words and pseudowords, while impossible words might have to be read on a letter-by-letter basis. Whether or not fingerspelled items are processed simply on a letter-by-letter basis can be ascertained by determining whether there is independence of letter report. To do this, words are scored for letter accuracy regardless of position. The probability of correctly reporting all of the letters in a word or nonword is compared with the probability of correctly reporting individual letters of the items. Independence of letter processing is indicated if the following equation holds:

$$p(\text{all letters of an item}) = p(\text{individual letters})^n$$

where n=number of letters in the word. Tests of letter independence were performed separately on words, pseudowords, and impossible words.

Analyzing probability (all letters vs. individual letters) by item length, it was found that for words and pseudowords the probability of correctly reporting all the letters of a word was greater than the probability of reporting the letters independently: for words, $F(1,16)=67.74$, $p<.001$; for pseudowords, $F(1,16)=27.82$, $p<.001$. This nonindependence of letter processing for these items indicates that words and pseudowords were not processed as individual letters. Rather, processing of a given letter was influenced by other letters of the item. This result is consistent with the idea that orthographic structure influenced recognition for words and pseudowords.

For impossible words, however, the probability of correctly reporting all the letters of an item was not greater than the probability of independently reporting each letter, $F(1,16)=1.82$, $p>.05$. Thus, for impossible words the letters were processed independently. These impossible words were not processed as groups of letters, but rather as letter strings. The reduced accuracy of letter report for impossible words in comparison to words and pseudowords indicates that subjects were not good at remembering fingerspelled items as unrelated letter strings.

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The analyses above, therefore, indicate that subjects were more accurate at reporting words than pseudowords and were more accurate at reporting pseudowords than impossible words. This was due to differences in processing. While impossible words were processed as individual letters, letters of words and pseudowords were not processed independently. This nonindependence of letter processing suggests that the processings of these items are sensitive to orthographic structure. The word familiarity effect indicates additional processing benefits for actual English words.

Error Analysis

Incorrect responses were next subjected to an analysis of error type. Several determinations were made for each of the incorrectly reported words. First, were the written responses consistent with English orthography? Second, did the misspelling of a word preserve the pronunciation of the word presented, thus resulting in a phonetically accurate spelling? And third, what types of spelling errors were made?[1]

Orthography. It is clear that subjects were aware of the orthographic structure of English words. As shown in Table 2, for more than 70% of the words and pseudowords the incorrect responses were consistent with English orthography. For impossible words, 60% of the incorrect responses were thus consistent, resulting in pronounceable letter strings. In fact, the most frequent incorrect responses for impossible words were changes of this type. For example: FTERNAPS>ferntaps, PKANT>plant, VETMFTERN>vetfern, RICGH>rich, and RANGKPES>rangkes. These incorrect responses indicate a productive knowledge of English word structure.

Table 2

Classification of errors for the incorrect responses.

	Words	Pseudowords	Impossible words
Errors consistent with English orthography	76.8%	71.9%	60.4%
Phonetic misspellings	16.5%	(3.4%)	-----

Phonetic misspellings. Did the misspellings of the English words preserve the pronunciation of the words presented? The majority did not. Errors that are pronunciation preserving may be called phonetic misspellings. Examples of common phonetic misspellings for hearing people are analisis (for analysis), bankrupcy (for bankruptcy), catagory (for category), and vidio (for video) (Masters, 1927; Sears, 1969). As shown in Table 2, only about 16% of the incorrect spellings for the English words in this experiment were

Table 3

Examples of incorrect responses in fingerspelling experiment. Word judgments were correct for all incorrect responses listed. Numbers in parentheses indicate duplicate responses.

Stimulus word	Deletions	Transpositions	Substitutions	Additions
ADVERTISEMENT	adverisement	adveristement		
BANKRUPTCY			bankrupacy	bankruptucy (2)
BAPTIZE		bapitze (3)		
CHIMNEY			chimmey	
FUNERAL		funreal	fuderal	
GRADUATE				grauduate
HEMISPHERE		hemipshere		
INTERRUPT	interupt			
PHILADELPHIA	Philadephia		Philalelphia	
SURGERY	.	surgrey (2)	surgury	
THIRD			thyrd	
UMBRELLA	umbella	umberlla		
VEHICLE	vehile	vechile (4)		
VIDEO	vido	viedo		
VINEGAR	vingar (3)	vineagr	vinigar	vineagar
BRANDIGAN		brandagin	brandigin	
CHIGGETH	chigeth (3)		chiggets	
COSMERTRAN		comsertran		
FREZNIK		frezink (3)		
HANNERBAD				hannerband (2)
MUNGRATS			mungrate (2)	
PILTERN				pilltern
RAPAS	raps (2)			
SWITZEL	swizel (2)	swiztel		
VALETOR				valentor
ENGKSTERN	engstern (4)			
FTERNAPS		ferntaps (2)		afternaps
RANGKPES	rangkes (2)	rangkeps		
RICGH	righ (3)			
VETMFTERN	vetfern (2)			

phonetic. Thus, while the misspellings were consistent with English orthography, for any given word the misspelling was not consistent with the pronunciation of that word.

Since by definition impossible words were not pronounceable, it was not possible to have pronunciation-preserving misspellings of the impossible words. Phonetic misspellings of the pseudowords are theoretically possible, but inspection of Table 2 reveals that pronunciation-preservings misspellings of these words were rare.

Types of errors. The types of errors in the incorrect responses were analyzed. The following categories were used for error classification: Letter deletions, additions, substitutions, and transpositions. Letter transpositions were incorrect orderings of the letters of an item. An error was counted as a substitution when an incorrect letter was written. Letter deletions and additions are self-explanatory. Examples of each of these error types are shown in Table 3.

In decreasing order of occurrence, the following kinds of errors were found in the present misspellings: letter deletions, transpositions, substitutions and additions. Percentages of occurrence for each kind of error are shown in Table 4. Notice that the occurrence for the different types of errors is similar for words and nonwords.

It is interesting to take notice of the error analysis for pseudowords. Since these items are possible English words, their analysis suggests the kind of errors people may make when learning a new word from fingerspelling. So, the kinds of errors to be expected in learning new words from fingerspelling would be predominantly letter deletions with letter transpositions and substitutions also fairly common.

Table 4

Percentage of each type of error for the incorrect responses examined in the analysis of error type.

	Words	Pseudowords	Impossible Words
Deletions	36.6%	34.7%	38.0%
Transpositions	31.4%	29.0%	23.9%
Substitutions	20.9%	24.5%	29.2%
Additions	10.9%	11.6%	8.8%

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For each of the substitutions, a determination was made as to whether this was a substitution of a letter of similar handshape. This determination was based on the visual confusions of handshapes reported by Lane, Boyes-Braem, and Bellugi (1976). Since not all letters of the manual alphabet were included in that study of handshapes, it was necessary to extrapolate from their results for the present analysis. For example, in their study with moving signs the compact handshapes A, E, and O were found to be confusing. For purposes of the present analysis, the handshapes M, N, S, and T were included as compact handshapes that could be possible substitutions based on fingerspelling. Another fingerspelling substitution based on their study was the pair I and Y. The pair K and P were also counted as possible substitutions based on misreading of fingerspelling.

Using this system, it was found that many of the letter substitutions for words and pseudowords could be accounted for as misreading of fingerspelling based on handshape. The following are the percentages of substitution errors that may have been based on misreading of fingerspelling: 80.9% for words, 72.4% for pseudowords, 15.8% for impossible words. There is no apparent reason, however, why misreading of fingerspelled letters should be more common for words than for, say, impossible words. This pattern of substitution error therefore suggests a second alternative as to the basis for the substitutions. It is possible that substitutions were based on English word constraints. Inspection of the letters involved in the above analysis reveals that the analysis is confounded with vowel/vowel confusions and consonant/consonant confusions. In fact, analysis of the substitution errors revealed that subjects tended to substitute a vowel for a vowel or substitute a consonant for a consonant. This was true for 87.5% of the substitutions for words, for 69.0% of the substitutions for pseudowords, and for 68.4% of the substitutions for impossible words. Due to the confounding inherent in the letters examined here, it is not possible to state with certainty the basis for the substitution errors, although the error pattern is suggestive of the idea that letter substitutions were based on substitutions of a phonologically possible letter.

Error position. The position of the first error in each of the misspellings was also calculated. To make error position independent of word length, position was calculated as a proportion of the total word length. Mean position of first errors was as follows: words=.598, pseudowords=.602, impossible words=.538. Thus, the majority of incorrect responses did not occur until the second half of the word. Subjects were good at knowing the letters in the first half of the words with problems generally developing in the middle of the word. This finding is consistent with work showing that initial and final letters of fingerspelled words are identified better than medial letters (see Caccamise, Hatfield, & Brewer, 1978) and may be related to the fact that initial and final letters are held longer than medial letters (Reich, 1974).

Summary. In summary, analysis of the incorrect responses indicates that there were similar errors for words and nonwords. The majority of incorrect responses were found to be consistent with English orthography. The incorrect responses did not tend to preserve the pronunciation of the intended words. The errors tended to be letter deletions, transpositions, and substitutions occurring in the second half of the word.

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Spelling

Spelling requires the ability to make productive use of English orthography. Hearing people tend to spell according to the pronunciation of words as evidenced in the frequency of phonetic misspellings they produce (Fischer, 1980; Masters, 1927; Simon & Simon, 1973). But reliance on pronunciation alone can lead to errors in spelling for a language with a complex orthography such as English. Simon and Simon (1973) have estimated that strict reliance on pronunciation will generate correct spellings for only about 50% of the words in English.

Deaf persons may not rely primarily, if at all, on word pronunciations when spelling. Hoemann, Andrews, Florian, Hoemann, and Jansema (1976) tested deaf children in a recognition test for spelling of common objects and found that no more than 19% of the errors for any age group were phonetic misspellings. In contrast, up to 83% of the misspellings made by hearing children in the same task were phonetic (Mendenhall, 1930). These results suggest that deaf children are not primarily relying on word pronunciations when spelling.[2]

To generate hypotheses as to the spelling processes used by deaf persons whose primary language is ASL, misspellings from the writing of deaf adults were collected. These misspellings, shown in Table 5, bear a striking resemblance to the spelling errors in the fingerspelling experiment. As in that experiment, the vast majority of misspellings are consistent with English orthography.

As in the results of Hoemann et al. (1976), the majority of errors did not preserve the pronunciation of the intended word. For these deaf persons, then, there does not seem to be reliance on word pronunciation when spelling. What process could be used? Inspection of error type may be of help in answering this question. Hoemann et al. found the most common type of spelling error to be letter deletions (42%), a finding that is consistent with the errors collected here from adults. Notice that this is also the most frequent type of misspelling in the fingerspelling experiment.

The pattern of errors for hearing and deaf persons is clearly different. For hearing persons, phonetic substitutions dominate the errors made (Fischer, 1980; Mendenhall, 1930). For deaf adults, the misspellings found in writing and the errors in the fingerspelling experiment were predominantly non-phonetic letter deletions. Also striking is that often in the misspellings of deaf persons all the correct letters for a word were found to be present, but the order of the letters was in error. As shown in Table 5, these transpositions occur not only within a syllable, but also across syllable boundaries, rendering misspellings that definitely are not phonetic. Again, this is consistent with the results of the fingerspelling experiment where transpositions were more common than even letter substitutions.

It would be too strong a statement to conclude from these observations that reliance on fingerspelling led to these misspellings found in free writing. These results, however, provide a basis for interesting speculation and further study.

Table 5

Examples of misspellings found in writing.

	Word spelled	Word intended
Letter deletions	bapist	baptist
	elborate	elaborate
	pinic	picnic
	psylogical	psychological
	stiring	stirring
Letter transpostions		
Within a syllable	thristy	thirsty
	umberlla	umbrella
Across syllable boundaries	bankcrupty	bankruptcy
	contuine	continue
Letter substitutions	chocalate	chocolate
	butch	dutch
	licinse	license
	mosquoto	mosquito
Letter additions	cancell	cancel
	frence	fence
	grazed	gazed
	preferre	prefer

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FOOTNOTES

[1]Not all incorrect responses could be classified in this way. Subjects' responses were often just a word judgment followed by a dash or the first letter or two of the stimulus item. If subjects failed to write at least 50% of the word, the word was not scored in the analysis of error type. In addition, there were responses that were so different from the target word that the origin of the error could not be determined. Combining these two sources, the following percentages of errors could not be counted in the analysis of error type: 16.0% for words, 45.4% for pseudowords, and 48.6% for impossible words.

[2]Cromer (1980) analyzed misspellings in the free writing of six orally educated deaf children in England (median age 10.5). By his analysis 67.5% of the misspellings could be described as phonetic. But it should be remembered that the strong oral tradition in England may have led to the phonetic misspellings he found.