

Determinants of spelling ability in deaf and hearing adults: Access to linguistic structure*

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Abstract

The extent to which ability to access linguistic regularities of the orthography is dependent on spoken language was investigated in a two-part spelling test administered to both hearing and profoundly deaf college students. The spelling test examined ability to spell words varying in the degree to which their correct orthographic representation could be derived from the linguistic structure of English. Both groups of subjects were found to be sensitive to the underlying regularities of the orthography as indicated by greater accuracy on linguistically-derivable words than on irregular words. Comparison of accuracy on a production task and on a multiple-choice recognition task showed that the performance of both deaf and hearing subjects benefited from the recognition format, but especially so in the spelling of irregular words. Differences in the underlying spelling process for deaf and hearing spellers were

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revealed in an analysis of their misspellings: Deaf subjects produced fewer phonetically accurate misspellings than did the hearing subjects. Nonetheless, the deaf spellers tended to observe the formational constraints of English phonology and morphology in their misspellings. Together, these results suggest that deaf subjects are able to develop an appreciation for the structural properties of the orthography, but that their spelling may be guided by an accurate representation of the phonetic structure of words to a lesser degree than it is for hearing spellers.

Those who do research on the psychology of language have not, until recently, displayed much interest in spelling. As long as it is regarded as a low-level, isolated ability that feeds chiefly on rote learning and visual memory, spelling seems remote from a concern with language. Only now is it becoming generally recognized that to understand how people learn to spell is an interesting and challenging problem both linguistically and cognitively (Fritth, 1980). There appears to be a growing tendency to progress beyond the notion that the orthography of English is a highly inconsistent system. Rather, it is a multileveled system containing regularities that penetrate deeply into the morphophonemic and lexical aspects of language (Chomsky, 1970; Klima, 1972; Venezky, 1970). For the speller who lacks sensitivity to these regularities of the orthography, the spellings of many words must appear arbitrary and opaque.

How the consciences that the orthography captures actually affect the speller of English is, of course, an empirical question. For present purposes, it will be assumed that there exists a linguistic speller in the same sense that it has been assumed that there exists a linguistic reader (Martingly, 1972; 1979). The ideally proficient reader-writer is sensitive to various kinds of linguistic information that are contained in the orthographic representation of words in the lexicon. Accordingly, the linguistic reader-writer can unpack this information in the act of reading, and can fully and correctly package it in the act of spelling.

The question raised in the research presented here is to what extent the acquisition of linguistic principles of the orthography is dependent on the spoken language. To examine this question, the pattern of spelling errors for profoundly and profoundly deaf college students is compared to that of hearing college students.

To put this issue in perspective, the research literature that pertains to interpretation of spelling errors both for hearing and deaf persons will first be briefly examined. In general it may be said that hearing spellers appreciate

that the orthography maps the phonetic structure of words,¹ but that they sometimes fail to appreciate the other regularities that the orthography captures. Thus, there is much evidence that the predominant form of spelling error for hearing children and adults consists of misspellings consistent with the words's phonetic representation, i.e., their misspellings can be read as phonetically equivalent to the target word (Alper, 1942; Fischer, 1980; Masters, 1927; Sears, 1969). These phonetic misspellings appear to stem from a failure to appreciate fully the phonological and derivational facts that English spelling preserves.

Evidence that some structural principles of the orthography are acquired and used in spelling was found in a study by Fischer (1980). Fischer constructed a spelling test designed to assess spellers' sensitivity to the underlying linguistic structure of words. Hearing college students had little difficulty with words in which the spelling was straightforwardly related to the phonetic structure (e.g., *zebra*), but had difficulty on words for which the correct spelling could not be fully derived from morphophonemic information (e.g., *sergeant*). Good spellers, more than poor spellers, were found to be able to make use of linguistic regularities to spell words.

Some investigators have suggested that rote memory and/or visual retentiveness may be a major factor in skilled spelling with spellers relying, at least in part, on stored word images (Baron *et al.*, 1980; Barron, 1980; Ehri, 1980; Sloboda, 1980). If success in spelling is highly related to retention of visual patterns, then good spellers would be expected to make more efficient use of such a strategy than poor spellers. It is not the case, however, that good spellers exceed poor spellers in visual retentiveness of every kind of material; Fischer (1980) found no difference between hearing good and poor spellers on a test of memory for nonword abstract patterns, the Recurring Figures Test of Kimura (1963). There is some evidence, however, that spellers can benefit from the presence of visual forms of the word. When the test offers choices among printed alternative spellings of a word, performance has been found in some cases to improve (Simon and Simon, 1973; Tenney, 1980). Whether it does so or not seems to depend on the type of word being tested. Fischer (1980) found that multiple-choice recognition performance is more accurate than spelling to dictation for both good and poor spellers, but that

¹The levels of structure described here as 'phonetic' denote a level considerably more abstract than sound. Unfortunately, linguistic disciplines offer no terms that have won general acceptance to capture differences in level of abstractness. It must be noted at the outset, however, that alphabets do not map sound as such, and could not, if they are to function as intended: i.e., no writing system in general usage captures details of the speech sound pattern associated with dialect and idiolect, or those associated with coarticulation and environment [see Klima (1972) and Liberman (in press) for discussions of these points].

the advantage of the recognition format is limited primarily to words whose spellings are not linguistically derivable (e.g., *sergeant*). It is possible that the importance of rote memorization and/or visualization for spelling ability may be greater for deaf spellers than for hearing spellers. The absence of normal experience with the sounds of the spoken language may make acquisition of linguistic regularities difficult. Indeed, early work implicated visual retention as a factor important to spelling success for deaf children (Gates and Chase, 1926), but no comparison between production and multiple-choice recognition with deaf subjects has been carried out to date.

A few studies have examined the ability of deaf subjects to make use of phonetic structure of words during spelling. One such study was carried out by Dodd (1980) on orally-trained deaf children in England. The children (mean age 14.5 years) were required to lipread pseudowords. Analysis of their spoken and written productions indicated that if a consonant was correctly represented in the spoken response, it was generally also correctly represented in the written response. The implication is that these deaf children had acquired the ability to use the alphabet analytically.

Nonetheless, there is evidence that deaf spellers' misspellings are often quite unlike those of hearing persons. In contrast to the misspellings of hearing persons, fewer of the misspellings produced by deaf children and adults can be considered phonetically equivalent to the target word (Dodd, 1980; Hanson, 1982; Hoemann et al., 1976). The unanimity of the studies is especially striking in that the studies have tested deaf subjects with backgrounds that are quite heterogeneous with regard to many factors—degree of hearing loss, age, and type of schooling, to name a few. The implication from this finding is that the spelling process for deaf persons may be fundamentally different than the spelling process for hearing persons.

Although a study by Cromer (1980) would seem somewhat at odds with this interpretation since he found that the majority of misspellings by deaf children were 'phono-graphical' errors, it must be noted that Cromer's phono-graphical errors are not the same as phonetic misspellings. According to Cromer, a phono-graphical error occurs when the 'mis-spelled word resembles in some respect the sound of the target word when pronounced' (p. 412). Errors such as *basking* for *basket* and *amanals* for *animals* were, as a result, scored as phono-graphical errors. Clearly, as these examples indicate, this classification system does not distinguish between those responses that are phonetically consistent with the target and those responses that are not. Thus, no direct comparisons between Cromer's study and the other spelling studies with deaf subjects is possible.

For the present study, subjects were chosen who have been profoundly

In order to examine deaf and hearing subjects' access to linguistic structure, the tasks of Fischer (1980) were adapted for the present study. These tasks allow for a determination of spelling ability as a function of phonological and orthographic structure. If subjects rely on linguistic sensitivity, then the more orthographically transparent the word spelling, the greater ease subjects should have in spelling the word. Thus, if deaf persons have acquired knowledge of the structure of words and they use this knowledge in spelling, then their spelling accuracy should vary as a function of level of orthographic transparency. As such, words whose spellings are derivable from linguistic principles should be more accurately spelled than irregular words whose spellings are not thus derivable. If deaf persons rely primarily on rote memorization or visual memory in spelling, then, other things being equal, words with linguistically-derivable spellings should be spelled no more accurately than irregular words.

Studies of spelling with hearing subjects most commonly rely on dictated word lists. For deaf subjects, results from this method of presentation would necessarily be ambiguous since errors of spelling would be inextricably confounded with errors of lipreading. To avert this confounding, the spelling test used in the present study provided written cues to elicit the subjects' responses. The performance of the deaf subjects was compared with that of a group of hearing subjects.

Method

Subjects

A group of deaf subjects and a group of hearing subjects were tested in a one hour experiment. Neither group was pre-selected on the basis of spelling ability.

The deaf subjects were 27 profoundly deaf college students from Gallaudet College and from California State University, Northridge. All were prelingually deaf and had a hearing loss of greater than 85 dB in the better ear. They had no other handicapping conditions. The educational background of the subjects varied as to particular instructional method. All were proficient in the use of sign language (American Sign Language and signed English) and fingerspelling. Fourteen had deaf parents.

The hearing subjects were 37 college students from the University of Connecticut and from Central Connecticut State University.

Procedure

A reading comprehension test and a two-part spelling test (consisting of a production task and a recognition task) were administered to all subjects. The reading test was always given first, followed by the spelling production task and finally by the spelling recognition task.

Reading test

The reading achievement of each subject was tested on the comprehension subset of the Gates-MacGinitie Reading Test (1969, Survey F, Form 2). Survey F of the test is designed for grades 10 through 12. This testing level was chosen as previous work had indicated that deaf college students could be expected to read at the ninth or tenth grade level (Reynolds, 1975). For each of the subjects, a standard score on the reading comprehension test was obtained for grade level 10.1. A standard score of 50 on the test represents the mean performance for grade 10.1. Each 10 points on the standard score represents one standard deviation.

Spelling test

The spelling test required the spelling of 45 English words. Three different classes of words were defined according to criteria framed by Fischer (1980). The classes ranged from level I, in which the spellings were most transparent and related very straightforwardly to phonetic structure, to level III, in which the spellings were opaque. In order to ensure that the words were not ones having highly overlearned spellings, all stimulus words were selected to be low in frequency of occurrence in written English. There were 15 words per level.

For level I words, the correct spelling fairly straightforwardly reflected the phonetic structure; success with these words requires that the users know the basic conventions of orthographic mapping including, for example, conventions for representing long and short vowels. In addition, the spelling patterns had a high frequency of occurrence in written English. The level I words were as follows: *explode, hardware, harpoon, migrate, plastic, refund, regret, replicate, rodeo, splash, splinter, stamper, tadpole, torpedo, transplant*. Mean frequency was 6.33 occurrences per 1,014,232 words of natural language text (Kučera and Francis, 1967).

For level II words, the correct spelling was not completely reflected in the phonetic structure, but could be obtained by reliance on linguistic principles. In eight of the fifteen level II words, the phonetic structure reflected the morphophonemic structure, but knowledge of how to form suffixes was required for correct spelling. The words fitting this pattern were the following:

In the other seven of the level II words, the underlying morphophonemic relation was ambiguously represented in the phonetic structure. For these words, segment(s) were unstressed and thus ambiguous in the phonetic representation of the word and could be disambiguated by reference to a related word that stressed the segment (e.g., *grammar-grammatical* and *digestible-digestion*). The following stimuli fit this pattern: *condemn, digestible, grammar, imaginary, janitor, permissible, repetition*. For the level II words, mean frequency of occurrence in written English was 8.60 (Kučera and Francis, 1967). For level III words, the correct spelling could only be partially derived by use of phonetic and morphophonemic structure. These included some borrowed words that contained spelling patterns infrequent in English. The following words were in the level III category: *ache, cantaloupe, champagne, chauffeur, Fahrinheit, morning, moustache (mustache), neighbor, plagiarism, plumber, receipt, sergeant, vacuum, vinegar, yacht*. Mean frequency of occurrence was 8.67 (Kučera and Francis, 1967).

In the *production task*, subjects were asked to spell the 45 words using a Cloze procedure, in which a written sentence context was provided for the target word and the first letter of the target word was presented. This procedure had two advantages over spelling from dictation tasks. First, it was advantageous with deaf subjects in that it did not require that stimuli be lipread. Second, for both subject groups it assured that all misspellings were misspellings of words in the subjects' vocabularies. The following is an example of a test sentence:

(1) Temperature is measured in degrees F ——— .

Since this experiment was concerned only with spelling processes, not with additional cues if they were unable to figure out the target word from the sentence context. The following written instructions were given to subjects:

This experiment is concerned with spelling. For each sentence below, complete the spelling of the word that fits in the blank (the first letter of the omitted word is always given). If you are not sure what word fits in the sentence, ask the experimenter. PLEASE PRINT!

If subjects had questions about a word to be spelled, the experimenter provided an alternative definition of the word. The word was not spoken for hearing subjects. If a sign existed for the target word, that sign was produced for deaf subjects. The same 45 words were also used in the *recognition task*. Words were tested in the same order as in the production task. On each trial there were

three alternative spellings of the target word plus the choice 'None of these'. The written instructions were as follows:

Circle the correct spelling for each of the following words. If the correct spelling is not listed, circle 'None of these'. (These are the same words you just spelled).

The alternative choices were generally phonetically consistent with the target. Also, since deaf adults sometimes make ordering errors when spelling (Hanson, 1982), an attempt was made to include misspellings that deaf subjects might choose (e.g., *roedo* for *rodeo*).

Scoring

A disadvantage of the Cloze procedure is that sometimes the sentence cue fails to elicit the desired word, or it may fail to elicit any word at all. Since it is inappropriate to score such responses as spelling errors, they were scored as omissions. The following criteria were adopted for classification of a response as an omission:

- (a) No response.
- (b) A response that was a correctly spelled word, but was not the target word (e.g., *silver* for *splinter*).
- (c) A response that did not contain at least half of the letters of the target word (e.g., *phorger* for *plagiarism*).
- (d) A morphologically incorrect form of the target in which the target word was not completely represented in the response (e.g., *hero* for *heroes* and *digestive* for *digestible*). (This was done so as not to confound grammatical abilities with the current test of spelling proficiency.) A morphologically incorrect form in which the target was completely represented in the response was not scored as an omission (e.g., *splinters* for *splinter*).

Analysis of the production task was based on only those trials that were not scored as omissions. Since the purpose of the recognition task was to examine whether subjects would benefit in spelling accuracy from having visually presented alternatives available, analyses in the recognition task were based on only those trials that had been analyzed in the production task.

Results

Spelling production task

Nearly all subjects failed to respond with the correct word on at least one occasion. Because data based on too few responses in each portion of the

test are unstable, it was decided to exclude from further analysis the data of those subjects who had as many as 15 responses scored as omissions (i.e., one third of the total number of items). This criterion excluded 11 deaf subjects and no hearing subjects. Those excluded tended to be the poorest readers, but not necessarily the poorest spellers. Indeed, it is the case that the excluded deaf subjects scored significantly worse on the reading comprehension test than did the included deaf subjects, $t(25) = 4.41, p < 0.001$, two-tailed, but did not differ significantly in spelling proficiency from those included, $t(25) = 1.82, p < 0.05$, two-tailed.

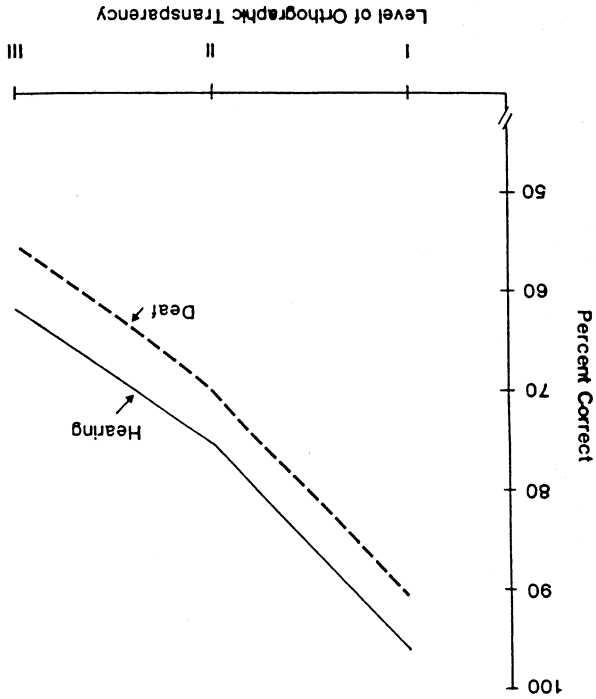
One hearing subject was excluded for failure to complete the recognition task. The analysis of spelling proficiency in relation to orthographic transparency was based on the remaining 36 hearing college students, and 16 deaf college students.

Results of the spelling production task for these subjects are shown in Figure 1. An analysis of variance was performed on the percentage correct responses for the two subject groups at the three levels of orthographic transparency. Of major concern to the present study was the finding that there was a significant main effect of level of orthographic transparency, $F(2, 100) = 107.82, p < 0.001, MSE = 126.36$, that did not interact with subject population, $F > 1$. Post hoc analyses demonstrated significant differences between each level of orthographic transparency (Newman-Keuls, $p < 0.01$). These results indicate that words of different orthographic types differed greatly in difficulty of spelling; in this the present findings are in complete agreement with Fischer (1980). Words of high orthographic transparency are consistently more often spelled correctly than words of low transparency or exception words. What is newly demonstrated is that, by and large, parallel differences in effect of orthographic transparency are shown by deaf and hearing subjects.

Comparison of production and recognition tasks

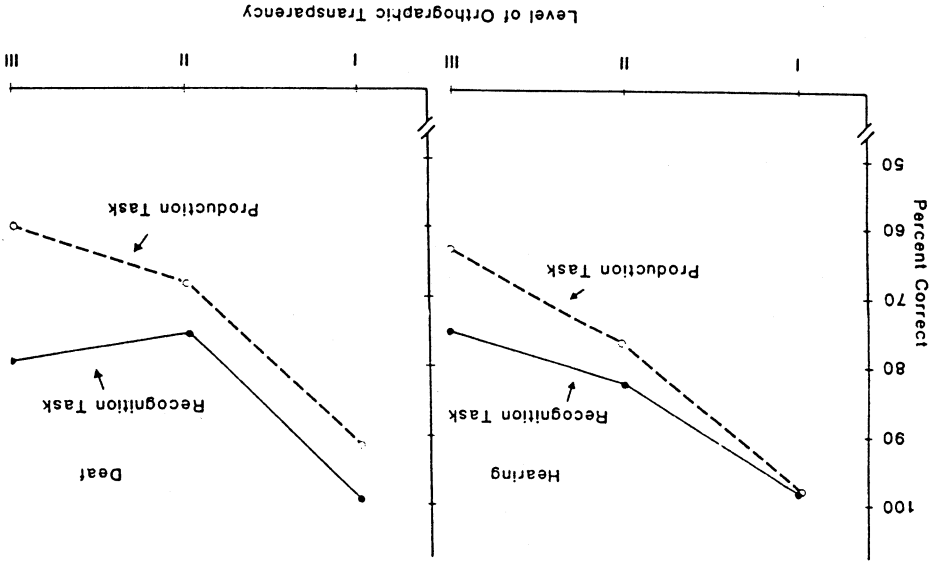
Results comparing performance on the production task and the recognition task are shown in Figure 2. An analysis of variance was performed on the percent correct scores with the between subjects factor of subject population and the within subjects factors of orthographic transparency and task (production task *versus* recognition task). A significant main effect of task, $F(1, 50) = 62.63, p < 0.001, MSE = 90.82$, indicated that spelling performance was more accurate on the recognition task than on the production task. In addition, subject population interacted with task, $F(1, 50) = 5.28, p < 0.05, MSE = 90.82$. This interaction reflected a greater improvement in performance on the recognition task for deaf subjects than for the hearing subjects,

Figure 1. Mean percentage correct responses in the spelling production task as a function of level of orthographic transparency.



although a *post hoc* analysis revealed that there was a significant improvement in the recognition task for each group individually [for hearing subjects, $F(1, 50) = 25.62, p < 0.001$; for deaf subjects, $F(1, 50) = 37.66, p < 0.001$]. There was also a significant interaction of task by orthographic transparency, $F(2, 100) = 17.88, p < 0.001, MSe = 43.15$. Since performance on the level I words was so accurate, even for the production task, this interaction probably reflects to some extent a ceiling effect. The high level of performance on level I words dramatically illustrates a major point of the present study—that spellers are influenced by orthographic transparency. Orthographically transparent words are not often misspelled by either hearing or deaf spellers. To determine whether there was an interaction of task by orthographic transparency for level II and III words, neither of which are at ceiling, an additional analysis of variance was performed on these two levels of orthographic transparency alone. Again a significant interaction was obtained, $F(1, 50) = 14.99, p < 0.001, MSe = 57.62$. The source of this interac-

Figure 2. Mean percentage correct responses in the spelling production and recognition tasks as a function of level of orthographic transparency.



tion, as shown in Figure 2, is that there is more improvement with the recognition task for level III words than for level II words. A significant three-way interaction with population, $F(1, 50) = 7.17, p = 0.01, MSE = 57.62$, indicated that deaf subjects improved more on level III words than did hearing subjects. To summarize, the comparison of performance on the production and recognition tasks revealed that spelling performance was more accurate on the recognition task than on the production task, but the advantage of having the printed alternatives available was limited primarily to level III words. Although both hearing and deaf spellers benefited from the recognition format, deaf spellers appeared to benefit somewhat more.

Error types

Examination of misspellings can be used to gain insight into the spelling process. With groups of deaf and hearing subjects matched for overall proficiency in spelling, this allows us to ask, given a particular level of competence in spelling, whether it builds on the same underlying cognitive ability for deaf and hearing spellers. This analysis was therefore based on subsets of the two subject populations matched in overall spelling ability on the production task.

These matched groups consisted of nine subjects each, with the subjects drawn from the deaf and hearing subjects included in the preceding analyses. The spelling proficiency and reading achievement of the resulting subgroups are shown in Table 1. These matched groups did not differ significantly in spelling accuracy on this task, $t(16) = 1.10$, $d < 0.05$, two-tailed, but did differ significantly in reading achievement, $t(16) = 4.06$, $d > 0.001$, two-tailed. These results indicate that the deaf subjects were poorer readers than the hearing subjects of comparable spelling proficiency.

Each misspelling was scored in terms of whether or not the misspelled segment(s) of the word constituted a substitution (e.g., janiter for janitor), omission (e.g., chamagne for champagne), or insertion (e.g., torpedo for torpede). If multiple errors occurred within a given word each error was scored separately. For example, two errors were scored when *vinegar* was spelled as *viniger* and when *digestible* was spelled as *disgestable*. By this analysis, only two misspellings were unclassifiable (the response *tad pole* for *tadpole* by a hearing subject and the response *puglarism* for *plagiarism* by a deaf subject).

Each segment substitution error was further scored in two respects. First, it was asked whether or not the substitution was a 'phonetic' substitution (e.g., *vineger* for *vinegar*) or a 'nonphonetic' substitution (e.g., *redeo* for *torpedo*). Determination as to whether or not a substitution was phonetic was based on Hanna *et al.*'s (1966) listing of alternative patterns for the spelling of English phonemes. Using this analysis, spellings were scored in terms of spelling patterns rather than individual letters. Thus, if *condom* was spelled as *condem*, it was scored as a phonetic substitution since *mn* and *m* are both legitimate spelling patterns for /m/ in final position. Other examples of phonetic substitutions include *grammar* for *vacuum*, and *champagne* for *torpedo* and *champagne* for *champagne*. Examples of nonphonetic substitutions include *torpado* for *torpedo* and *champagne* for *champagne*. Second, it was asked whether the substitution was a vowel segment substitution (e.g., *digestible* for *digestible*) or a consonant segment substitution (e.g., *plummer* for *plumber* and *chaufeur* for *chauffeur*).

This analysis indicated that the groups of deaf and hearing subjects matched for spelling proficiency differed considerably in the types of errors they produced. As can be seen from Table 2, segment substitutions predominated for both deaf and hearing spellers, with only a small percentage of misspellings for either group resulting from segment insertions. However, deaf subjects made more errors that were not substitutions than did the hearing subjects. For the hearing subjects, only about 9 percent of the errors were omissions and insertions, while for the deaf subjects 29 percent of the errors were omissions and insertions. This difference in the percentage of

nonsubstitution errors for the two groups was statistically significant, $t(16) = 4.45, p < 0.001$, two-tailed. Since substitution errors represent an awareness of the number of phonemic segments of words, this finding suggests that the number of segments in words was not apprehended as accurately by the deaf subjects. Moreover, for those substitution errors that did occur, the deaf subjects had less of a tendency to produce errors that were phonetically acceptable renderings of the target segments. More than 80 percent of the errors by hearing subjects were phonetically acceptable substitutions, as compared to fewer than 50 percent of the errors of deaf subjects. This difference between the two groups was statistically significant, $t(16) = 7.90, p < 0.001$, two-tailed.

Both deaf and hearing subjects were found to make more substitutions on vowel segments than on consonant segments: hearing subjects made 70.0 percent of the substitutions on vowels, deaf subjects made 70.6 percent of their substitutions on vowels. Thus, these hearing and deaf subjects did not

Table 1. Characteristics of the subject groups matched for spelling proficiency. Shown is the mean accuracy on the spelling production task and the mean standard scores on the Gates-MacGinitie reading comprehension test

	Hearing (N = 9)	Deaf (N = 9)
Spelling	70.5%	69.1%
S.D.	2.5	3.0
Reading	61.3	49.3
S.D.	6.0	6.5

Table 2. Mean percentage of each error type for the matched subject groups. Standard deviations are given in parentheses

	Hearing		Deaf	
	Phonetic	Nonphonetic	Phonetic	Nonphonetic
Substitutions	81.6% (9.1)	9.0% (7.6)	46.3% (9.8)	24.7% (13.9)
Omissions		6.4% (5.6)		20.1% (7.8)
Insertions		3.0% (3.6)		8.9% (5.2)
Total	81.6%	18.4%	46.3%	53.7%

differ significantly in their tendency to make vowel substitutions, $t(16) = -0.11, p < 0.05$, two-tailed. The greater difficulty on spelling vowel segments here and elsewhere with hearing subjects (Fischer, 1980; Masters, 1927; Seymour and Forpodas, 1980) underscores the greater complexity of vowel representation than consonant representation in English orthography.² Consistent with previous findings (Hanson, 1982) several of the misspellings of the deaf subjects contained an error in ordering of one or more letters of the word, resulting in misspellings that did not preserve the phonetic representation of the target word. Thus, for example, a misspelling of *vinegar* was *vingear*, a misspelling of *janitor* was *janitor*, a misspelling of *repitile* was *retipile*, and a misspelling of *cantaloupe* was *cantapole*. Of the words misspelled by deaf subjects, 13.0 percent contained such an ordering error. Of the misspellings by hearing subjects, only 0.9 percent contained this type of error.

The misspellings were further scored to examine whether or not they were orthographically regular. Only those responses that were pronounceable and had legal letter sequences were considered to be orthographically admissible. Two judges independently scored the responses. Of the 208 misspellings considered in this analysis, the judges agreed on the classification for 94.2 percent. On those responses for which they originally disagreed, the two judges discussed the misspelling until a classification was agreed upon. Results of this analysis indicated that 91.7 percent of the misspellings of hearing subjects were considered orthographically regular and that 96.0 percent of the misspellings of the deaf subjects were considered to be so.

The results of this error analysis thus suggest that deaf spellers are sensitive to structural constraints of the orthography. That they are able to appreciate these constraints is shown by their production of misspellings that are permissible letter sequences in the language, and by the tendency of their substitution errors to be predominantly vowel substitutions.

In spite of their general conformity with the principles of English orthography, the misspellings of deaf subjects were generally not phonetically equivalent with the target words. Inconsistency with the phonetic representation was revealed by the analysis indicating fewer phonetically acceptable substitution errors by deaf than hearing subjects and by the analysis indicating that a few of the misspellings of the deaf subjects represent an inaccurate ordering of the segments of a word. These findings suggest either that deaf

²The greater number of substitutions on vowel segments than consonant segments in spelling is consistent with research on misreading: this research on misreading has shown that (hearing) readers are much more likely to have difficulty in correctly reading vowel segments than in correctly reading consonant segments (Fowler et al., 1977; Liberman et al., 1971; Shankweiler and Liberman, 1972).

spellers have less accurate representations of the phonetic structure of individual words in their lexicons than do hearing spellers. that they do not use the phonetic information in their lexicons when spelling, or that they use this information less accurately than do hearing spellers. Research by Dodd (1980) with deaf children is relevant in distinguishing between these alternatives. Dodd found that the deaf children tended to accurately spell consonant segments that they accurately pronounced. (No analysis of vowel segments was undertaken in that study). This suggests that the former of the three alternatives presented here may best explain the performance of deaf spellers; that is, the nonphonetic spellings they make may tend to reflect a difficulty in incorporating into their lexicons accurately specified phonetic representations of individual words.

Spelling proficiency in relation to other language factors

For the purpose of examining the relationship between spelling and reading, subjects' scores on the reading comprehension test and their percent correct on the spelling production task were compared. This analysis was based on the data of all 37 hearing subjects tested and all 27 deaf subjects tested. Table 3 shows the mean percent correct in the spelling task for deaf and hearing subjects together with the mean standard scores on the Gates-MacGinitie Reading Test. Recall that a standard score of 50 on the Gates-MacGinitie test represents a reading level of grade 10.1. Overall, the hearing subjects were more proficient readers, $t(62) = 10.22, p < 0.001$, and spellers, $t(62) = 3.23, p < 0.01$, than the deaf subjects. For hearing subjects, the reading scores correlated, although only weakly so, with spelling performance, $r = 0.356, t(35) = 2.25, p > 0.05$. The direction of correlation suggests that the greater the subject's reading ability, the greater the spelling proficiency. The

Table 3. Mean accuracy on the spelling production task and mean standard scores on the Gates-MacGinitie reading comprehension test

	Hearing (N = 37)	Deaf (N = 27)
Spelling	77.5%	69.6%
S.D.	9.7	9.7
Range	47-98	53-92
Reading	64.8	45.9
S.D.	7.4	7.2
Range	42-78	33-60

same trend was true for the deaf subjects, although the resulting correlation was not significant, $r = 0.275$, $t(25) = 1.43$, $p > 0.05$.³ A question of interest is how the speech production capabilities of the deaf subjects relate to reading achievement and spelling proficiency. To address this question, speech intelligibility ratings were obtained for the deaf subjects from Gallaudet College. Scores were not available from the five subjects which a score of 1 represents speech that is readily understood by the general public and a score of 5 represents speech that cannot be understood by listeners. For the 22 deaf subjects whose data were involved in this analysis, the mean speech intelligibility score was 3.89 (S.D. = 0.96, Range = 2-5). These speech intelligibility ratings were not significantly correlated with either reading achievement, $r = -0.002$, or spelling proficiency, $r = 0.398$, $t(20) = 1.94$, $p > 0.05$.

Discussion

As in earlier work, deaf spellers in the present experiment were by no means always inferior in spelling accuracy to their hearing counterparts (Cromer, 1980; Gates and Chase, 1924; Templin, 1948). Although the hearing subjects, overall, were somewhat more accurate than the deaf subjects on the spelling production task, both groups displayed a wide range of ability levels. The degree of overlap in the distribution of scores for the group was notable in light of the degree of auditory impairment in the deaf group: all of these subjects were selected for profound deafness extending from infancy. The results provide a convincing demonstration that it is possible for persons with such a background to learn to spell as accurately as many hearing persons at the college level.

To examine the extent to which apprehension of the linguistic regularities of the orthography is dependent on the spoken language, the error patterns of deaf and hearing subjects were compared. In earlier research with hearing adults, Fischer (1980) has shown that a word's difficulty from the standpoint

³Although the present study was not designed to assess differences between deaf subjects with deaf parents and deaf subjects with hearing parents, this question is of some interest as it is generally found that deaf children of deaf parents outperform deaf children of hearing parents on reading tests (Meadow, 1968; Vernon and Koh, 1971). No significant difference was obtained here as a function of parents' hearing status for either reading, $t(25) = .78$, $p > 0.05$, two-tailed, or spelling, $t(25) = 0.48$, $p > 0.05$, two-tailed, probably due to the fact that the present sample was restricted to college students—those persons who, by definition, are already the more academically successful deaf persons.

of spelling is chiefly a reflection of the word's formal properties and only secondarily a reflection of its frequency of occurrence. The results here are in complete agreement with Fischer's in that spelling performance was heavily influenced by level of orthographic transparency for both deaf and hearing spellers. Consistent with this evidence that deaf spellers are able to appreciate the structural constraints of the orthography, we found that the misspellings of deaf subjects tend to be orthographically regular in the sense that only legal strings are produced (see also Hanson, 1982). In sum, these data indicate that it is possible for prelingually, profoundly deaf individuals to develop a sensitivity to the phonological and morphological constraints of written English.

Deaf and hearing spellers further exhibited a similar pattern of results on the recognition task in that the greatest benefit occurred on irregular words. These were the words in which the correct spelling could not be completely derived by linguistic principles (the level III words). Thus, consistent with Fischer's findings (1980), these results suggest that visually presented alternative spellings is of primary benefit in allowing the speller to access rote and/or visual information that is otherwise difficult to retrieve.

Thus far, ways in which deaf and hearing subjects resemble each other have been discussed. Now, how they differ must be considered. First, they differ in that deaf subjects appear to benefit more than hearing subjects from having the visual alternatives presented. It appears, therefore, that deaf spellers are somewhat less able than hearing spellers to access stored visual knowledge and to use it in productive spelling. That is, deaf spellers, to a greater extent than hearing spellers, seem to have knowledge about a word's spelling that they are not able to retrieve in productive spelling, but which they can access when visual alternatives are available.

The groups differ in a major way in the kinds of errors they produce. Our findings strongly confirm earlier indications that deaf subjects, unlike hearing subjects, produce many strings that are not phonetically equivalent to the target word, i.e., nonphonetic misspellings (Dodd, 1980; Hanson, 1982; Hoemann *et al.*, 1976). In the present research, nonphonetic errors occurred nearly three times more frequently with deaf subjects than hearing subjects, even when the comparison was restricted to groups of deaf and hearing subjects matched on overall level of spelling performance.

It is important to note that the misspellings made by the deaf subjects in this study differ markedly from error patterns that are often labeled 'visual' or 'orthographic'; that is, misspellings in which the letter strings only grossly approximate the target word and that indicate a failure to appreciate the syllabic and segmental structure of words (see, for example, Bodor, 1973; Bub and Kertesz, 1982; Seymour and Forpodas, 1980; Wapner and Gardner,

1979). Such misspellings retain some of the characteristics of how the target word looks, as in the example of misspelling *broom* as *beoom* (Wapner and Gardner, 1979). The presence of such an error suggests that the speller does not appreciate how the orthography maps onto the spoken language. In contrast, deaf spellers have been found to be able to perform a phonemic analysis of words (Dodd, 1980), and their misspellings here and elsewhere have been shown to be consistent with the structural constraints of English morphology in preserving the rules governing syllable structure within words (Hanson, 1982). Moreover, if the deaf subjects here had not been sensitive to variations that exist in orthographic transparency they would have performed with comparable accuracy on level I, II, and III words. It would seem, then, that the nonphonetic misspellings of the deaf subjects arise not because these spellers are unable to appreciate the mapping between the written and spoken language, but rather may arise from difficulty in the establishment of an accurate phonetic representation of specific words.

The suggestion here that deaf spellers may have difficulty in the establishment of an accurate phonetic representation of words is in contrast to their ability, so apparent in the findings of this study, to appreciate phonological constraints of the language. Several factors may contribute to such awareness for deaf spellers, of which the most likely candidates are speech-related factors, reading, and fingerspelling.

Turning first to speech-related factors, speech production skills were examined here. The speech intelligibility ratings of the present subjects indicated that, as a whole, they had speech that was judged by skilled listeners to be nearly unintelligible. Although the skills of the individual subjects varied, the present study found that speech production skills were not significantly correlated with spelling proficiency. Since subjects with poorly intelligible speech were often good spellers, this suggests that acquisition of linguistic sensitivity may not necessarily require an ability to produce speech that *listeners* can readily understand, but only a means of analyzing word structure that the *individual* can use for acquiring the linguistic principles relating to that structure. Such a means of analysis might also be provided by lipreading (Dodd and Hermelin, 1977) and/or by whatever residual hearing each profoundly deaf person might possess.

Alternatively, just as hearing persons, through experience in reading, may induce phonological and morphological structure from the orthographic representation of written words (Liberman et al., 1980), so might deaf readers similarly induce these structural facts. The relationship between the level of performance in reading and spelling is a matter of some interest. The comparison between reading comprehension and spelling proficiency indicated only a tenuous relationship in either population. The low correlations ob-

tained were not artifactual, however. Both deaf and hearing subjects displayed a considerable range of talent on both reading and spelling measures, sufficient to permit a valid assessment of correlation. Moreover, for the hearing subjects the results obtained here are consistent with correlations obtained between reading comprehension and spelling reported for standardized tests (Dunn and Markwardt, 1970). Higher correlations between reading and spelling tend to be obtained when the reading measure is word recognition, particularly for persons in the process of acquiring reading, such as children in the primary grades and adults enrolled in literacy classes (Dunn and Markwardt, 1970; Jastak and Jastak, 1965; Perin, 1982). The low correlations reflect the possibility that reading comprehension and spelling rely, in part, on different cognitive/linguistic abilities. For example, the reader can manage with a rather tacit knowledge of structural features of the orthography because context at various levels is provided in the text. The speller, on the other hand, must make explicit use of these features.

For the deaf subjects, in particular, there was a dissociation between reading achievement and spelling proficiency. Not only was there no significant correlation obtained between the two tasks, but, as shown in Table 1, the deaf subjects tended to be much poorer readers than the hearing subjects of comparable spelling skill. Thus, while deaf persons appear to be at a disadvantage in acquiring reading when compared with hearing persons, it is of interest that no comparable disadvantage seems to occur for spelling.

For deaf persons with experience in manual communication, reliance on fingerspelling might also provide a means of acquiring an appreciation of the structure of the orthography. Fingerspelling is a manual communication system in which words are spelled out by the sequential production of letters of a manual alphabet. Much as readers might induce phonological rules from reading, deaf persons might also induce these rules from fingerspelling.

Fingerspelling may also serve deaf spellers as a productive system. The deaf subjects were observed to fingerspell extensively during the experiment as a way of trying out spellings on their hands before writing their answers. The role of fingerspelling in writing words cannot be inferred with certainty here, but two possibilities may be suggested. First, fingerspelling may provide visual feedback that could be used much like the alternative spellings of the recognition task. The fact that subjects sometimes fingerspelled under the table (thus blocking their view of their hands) suggests, however, that the feedback may not always, or even mostly, be visual. It suggests that kinesthetic feedback may be used instead. This feedback could serve both as a check of a particular word's spelling against a stored representation of the word, and also to monitor legal letter sequences.

In summary, deaf spellers in the present research were found to display an

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- ability to appreciate the structure of English orthography. This finding is inconsistent with the hypothesis that deaf spellers are limited to rote memorization or visual retention as spelling strategies. Obviously, it cannot be assumed that all deaf spellers (or hearing spellers) are sensitive to the linguistic structure reflected in the orthography. It is relevant here that the present subjects were all college students; it might be expected that persons with little education would rely on different strategies. The present results are important, however, in indicating the extent to which acquisition of linguistic structure is possible given limited acquaintance with the spoken language.

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Résumé

Un test en deux parties ou l'on demande aux sujets d'orthographier des mots a été administré à des étudiants entendants et des étudiants sourds pour voir la relation entre le langage parlé et la capacité d'accéder aux régularités linguistiques de l'orthographe. La capacité d'orthographier les mots varie en fonction du degré auquel la représentation orthographique peut être dérivée de la structure linguistique de l'Anglais. Les deux groupes de sujets sont sensibles aux régularités sous-jacentes de l'orthographe. Les résultats sont meilleurs avec les mots linguistiquement dérivables qu'avec les mots irréguliers. Les sujets sourds et les sujets entendants font preuve de précision orthographique plus grande dans la tâche de reconnaissance à choix multiples que dans la tâche de production; particulièrement pour les mots irréguliers. Une analyse des erreurs révèle une différence dans les processus sous-jacents pour les sujets sourds et pour les sujets entendants. Les sujets sourds font moins d'erreurs phonétiquement précises que les sujets entendants. Dans leurs erreurs ils tendent à respecter les contraintes de formation de la phonologie et de la morphologie anglaise. Les résultats suggèrent que les sujets sourds sont capables de développer une appréciation des propriétés structurales de l'orthographe mais que leur orthographe n'est pas guidée, au même point que chez les entendants, par une représentation de la structure phonétique des mots.