Variability in Deaf Children’s Spelling: The Effect of Language Experience

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French-speaking hearing and deaf children, ranging in age from 6 years 10 months to 14 years 7 months were required to spell words including phoneme-to-grapheme correspondences that were either statistically dominant or nondominant. Of interest was whether the nature of linguistic experience (cued speech vs. sign language) and the precocity of such experience (early vs. late exposure) determines accuracy in the use of phoneme-to-grapheme knowledge. Cued speech is a system delivering phonemically augmented speechreading through the visual modality. Hearing and deaf children exposed to cued speech early at home relied on accurate phoneme-to-grapheme correspondences, whereas children exposed to cued speech later and at school only, and children exposed to sign language, did not. A critical factor in the development of the phonological route for spelling seems to be early and intensive exposure to a system making all phonological distinctions easily perceivable.

Most of the spelling errors made by hearing children are compatible with the word phonological form. They reflect incomplete knowledge at three possible levels: word-specific orthographic information (e.g., “brane” /brein/ for brain in English, or “trin” /tri/ for train in French), contextual rules (e.g., “woz” for was in English, or “janbon” /jiban/ for jambon in French), and morphological relationship (e.g., “spelld” for spelled in English, or “peti” /pati/ for petit in French). By contrast, most of the spelling errors made by deaf youngsters reflect an incomplete knowledge of the word phonology (e.g., “vingear” for vinegar in English, “moule” /mulal/ for moulin /mulal/, and “escorle” /eskoral/ for escalier /eskoral/ in French).

Why do deaf spellers make phonologically inaccurate errors? One hypothesis is that hearing is a necessary condition for the acquisition of phoneme-to-grapheme correspondences (Gates & Chase, 1926). In this view, the sensory deficit (i.e., profound hearing loss) necessarily leads to a cognitive deficiency (i.e., the lack of use of the phonological route for spelling). An alternative hypothesis is that deaf children acquire a phonological system through the speechreading input (Dodd, 1976, 1987). Deaf children’s speechreading skills have been identified as the best predictors of their early reading and spelling development (Dodd, McIntosh, & Woodhouse, 1998). However, the speech information seen on the lips is inherently underspecified (i.e., ambiguous), due to the similarity in appearance of speech elements sharing the same place of articulation and to the invisibility of features such as voicing and nasality (Erber, 1974; Walden, Prosek, Montgomery, Scherr, & Jones, 1977). Any given lip movement can potentially map onto more than one phoneme. Consequently, the deaf children’s phonological representations tend to be inaccurate, and underspecified. This situation does not preclude deaf children’s use of phoneme-to-grapheme relationships, but strongly hinders the benefit they can get from that use (Burden & Campbell, 1994; Dodd, 1980; Leybaert & Alegria, 1995).

If deaf children’s spelling is limited by the inherent ambiguity of speechreading, the addition of complementary visual information that resolves this ambiguity could improve their ability to use the relationship between phonemes and graphemes. A recent study of the spelling of deaf children educated early and precociously with cued speech (CS) provides evidence for this hypothesis (Leybaert, 2000). In CS, the speaker complements speech (speechreading for the deaf receiver) with manual cues. A cue consists of two parameters: handshape and hand placement around the mouth. Handshapes (eight in the French CS system) disambiguate the consonants, and hand placement (five in French) disambiguate the vowels. Consonants (or vowels) assigned to the same handshape (or hand placement) are easy to discriminate by speechreading, whereas those difficult to discriminate belong to two different handshapes (or hand placements). In CS, all the phonemic distinctions of spoken language can be naturally perceived by sight. The production of a consonant–vowel (CV) syllable requires a single cue (a particular handshape at a specific hand placement) that carries information about both the consonant and the vowel. Syllabic structures like vowel–consonant (VC), CVC, and CVN need additional cues to reveal the supplementary phonemes (see Cornett...
& Daisey, 1992, and Charlter & Leybaert, 2000 for more complete
descriptions of CS in English and in French, respectively, and
Messing, 1999, for a discussion of the differences between CS and
sign language [SL].

Children who have been exposed to CS early and intensively at
home (i.e., CS-home children) develop a spelling production sys-
tem strongly guided by phonology. Their misspellings are most of
the time phonologically accurate. By contrast, those who have
been exposed to CS later and less intensively at school only (i.e.,
the CS-school children) make more phonologically inaccurate
effects (Leybaert, 2000). The spelling performance of the CS-home
children may reflect the effect of early and intensive exposure to
CS. However, intensive CS exposure was confounded with the
total amount of language exposure in Leybaert’s (2000) study.

Children who have SL as a first language generally outperform
deaf children from hearing parents in reading and spelling acqui-
sitions (Strong & Prinz, 1997; Stuckless & Birch, 1966). However,
the relation between SL knowledge and reading skill in English
language is not yet well understood. Indeed, the phonological units
of SL do not have any systematic relationship with the units of
the language children learn to write, and the two languages do not
share a grammar.

This relation can be due largely to the fact that
early signers have a fully developed language base, which gives an
advantage over children whose parents do not effectively commu-
nicate with them (Chamberlain & Mayberry, 2000). Another possi-
ble explanation is that knowledge of SL helps the reader in
establishing a relationship between the written word and seman-
tics. Semantic knowledge combines with orthographic and phono-
logical traces to increase the likelihood of successful word recog-
nition (Seidenberg & McClelland, 1989). An additional account
is related to fingerspelling, used in SL to represent words from
spoken languages. Fingerspelling could help native signers to
become aware that printed words are made up of segments, and to
develop a knowledge of the phoneme-to-grapheme correspon-
dences (Akamatsu, 1985; Padden, 1991; Padden & Hanson, 1999).

The spelling mechanisms used by deaf signers have been little
studied up to now. Hanson argued that deaf signers use their
phonological knowledge for spelling (Hanson, Shankweiler, &
Fischer, 1983). However, Hanson et al.’s participants were very
skilled readers compared to the average of the deaf population,
leaving open the question of how deaf who are less skilled readers
proceed for spelling. Recently, Sutcliffe, Dowker, and Campbell
(1999) showed that younger children from signing schools make
very little use of phoneme-to-grapheme knowledge. Given that
their participants did not have a great deal of exposure to SL at
home, it is possible that their results are related to the language
delay that generally affects deaf children from hearing parents. The
present experiment thus aimed at determining whether the nature of
linguistic experience (CS vs. SL) and the precocity of such
experience (early vs. late exposure) determines the use of
phoneme-to-grapheme knowledge for word spelling.

We tested the effect of grapheme dominance, a statistical char-
acteristic of the phoneme-to-grapheme correspondences (Alegria
&Mousty, 1994, 1996; Leybaert, 2000). In French, as in English,
the phoneme-to-grapheme correspondences are highly inconsist-
ent. There are one-to-many relations from phonemes to graph-
emes (Peereman & Content, 1999; Ziegler, Jacobs, & Stone, 1996;
Ziegler, Stone, & Jacobs, 1997). For example, the phoneme /l/ in
English can be spelled EW (as in new), UE (true), O (who), OO
(too), and so on. Similarly, the phoneme /ɛ/ at the end of French
words can be spelled IN (as in matin), AIN (pain), EIN (rein), YM
(thym), and so on. Nevertheless, as the phoneme /l/ is associated
in English more often to EW (Ziegler et al., 1997), the phoneme /ɛ/
at the end of French words is associated most frequently to IN
(Véronis, 1986). The dominant correspondence thus corresponds to
the more frequent one (e.g., /ɛ/# → IN), while the nondominant
corresponds to the less frequent correspondence (e.g., /ɛ/# →
AIN).

The spelling accuracy of dominant and nondominant correspon-
dences, and included in high-frequency and low-frequency words,
provides important information about the procedures used to spell.
Indeed, spelling of dominant correspondences can be derived
through the application of dominant rules, whereas spelling of
nondominant correspondences can be achieved only through ac-
to the word’s orthographic representation. Children who rely
on phoneme-to-grapheme correspondences thus show an effect of
grapheme dominance (i.e., dominant graphemes better spelled than
nondominant graphemes), an effect of word frequency (i.e., graph-
emes included in high-frequency words better spelled than graph-
emes included in low-frequency words), and an interaction be-
tween dominance and frequency (i.e., the effect of frequency is
less marked for dominant than for nondominant graphemes). By
contrast, in children who do not use phoneme-to-grapheme corre-
spondences, spelling for dominant as well as for nondominant
graphemes requires access to the word orthographic representa-
tions (Alegria & Mousty, 1994). These children thus show similar
performances for dominant and nondominant graphemes, an effect
of word frequency, and no interaction between dominance and
frequency.

If early exposure to a fully accessible language is a critical
condition for the acquisition of phoneme-to-grapheme mappings,
children educated with CS at home and children educated with SL
at home should exhibit a larger effect of dominance than children
educated with CS or SL only at school. Alternatively, if exposure
to CS per se is the critical factor, both groups of children educated
with CS should display a larger effect of dominance than both
groups of children educated with SL. Finally, if both conditions are
necessary, children educated with CS at home should display a
larger effect of dominance than the other three groups of deaf
children. Overall, we predicted this latter outcome, on the basis of
previous research showing that CS-home children use the
phoneme-to-grapheme relationships more extensively than CS-
school children, and showing that CS-home children reached greater accuracy in rhyming tasks than CS-school, SL-home, and SL-school children (Charlier & Leybaert, 2000; Leybaert, 2000). We also predicted that the effect of grapheme dominance would be intermediate in the CS-school groups and lower in SL groups.

We also expected a majority of phonologically accurate errors for CS-home children as for hearing children, and a mix of phonologically accurate and inaccurate errors for children of the other three groups. Phonologically accurate errors reveal that children have segmented the word into phonemes, have established the correspondence between the phonemes and the graphemes, but do not know the graphemes appropriate to spell that particular word. Phonologically inaccurate errors reveal either that children have used the phonological route unsuccessfully, or that they have not used that route at all (Treiman, 1993).

Finally, two analyses of errors were performed at the word level. The first aimed at determining whether the misspellings consisted of substitution between words, which attests to a difficulty in the process of selection of the appropriate orthographic representation. We expected to observe such errors in CS-school, SL-home, and SL-school groups, in which the phonological knowledge, which normally constrains the choice of the appropriate orthographic representation, is less available. The second analysis looked at the percentage of orthographically illegal errors. Regardless of their phonological accuracy, misspellings could be either orthographically legal or illegal. Sensitivity to the legal sequences of vowels and consonants seems to be acquired through a visual analysis of written words (Gibson, Shurcliff, & Yonas, 1970; Treiman, 1993).

A similar proportion of legal misspellings in deaf than in hearing participants has been observed in studies on good readers (Hanson et al., 1983; Hanson, 1986, 1995), whereas more illegal misspellings in the deaf participants were observed in studies involving less skilled readers (Sutcliffe et al., 1999). It is thus interesting to examine whether our four groups of deaf children would exhibit a similar rate of orthographically legal responses to that of the hearing children.

Method

Participants

We tested 67 deaf children and 32 hearing children. Deaf children were recruited from five different specialized schools or centers for rehabilitation of language in France and Belgium and in deaf camps. All deaf children met the following criteria: (a) bilateral profound sensorineural hearing loss > 90 dB in the better ear across three frequencies of the speech range (0.5, 1. and 2 kHz); (b) no other significant handicapping conditions; and (c) hearing loss onset prior to 18 months of age. It was not the policy of the schools to allow us to test children’s IQ. However, none of the children had any known associated disabilities, and each was judged by the school’s psychologist to be within the normal range of intelligence.

Sixty-three children were equipped with two acoustical hearing aids worn during the experiment, and the other 4 had a cochlear implant.

Using the speech therapists and school records, we determined the hearing status of the parents, as well as the nature and precocity of exposure to CS or SL. The deaf children differ in language approach (CS vs. SL) and in degree of exposure to language (early at home vs. late at school). The matching of different groups of deaf children, and of deaf with hearing children, is always a difficult problem. Besides language approach, deaf children may also differ in many other variables, including hearing status of the parents, the parents’ reasons to choose a particular language approach, the amount of reading exposure at home, and the degree of mainstreaming in ordinary school for hearing children. Given the difficulty of obtaining samples of deaf children corresponding to our design, the fact that the children were tested in different environments (at school and in deaf camps), and given the lack of direct contact with the parents, it was not possible to control for all these variables. We thus decided to match the different groups on a measure of word recognition level, in order to minimize the possible differences related to exposure to print. Indeed, this matching ensures that all children have achieved approximately the same reading level, whatever the degree of implications of their parents in their reading achievement could be. However, because of this matching on word recognition level, the CS-home and the hearing children were on average 2–3 years younger than the other three groups of deaf children. To control for the age difference issue, two older groups of CS-home and hearing children were included in the study.

The CS-home younger group included 20 children (mean age = 8 years 2 months) who received the French version of CS at home since a mean age of 24 months, meaning that at least one of their parents used it in daily communication. All but one had two hearing parents. Seventeen were mainstreamed in regular schools for hearing children, where they were provided with CS by interpreters, and the other 3 were enrolled in special schools for the deaf. The CS-school group consisted of 18 children (mean age = 10 years 10 months) who were provided with CS from a mean age of 49 months during several hours per day at school and inconsistently in their home environment. Sixteen had hearing parents. Fifteen were enrolled in special schools for the deaf and the other 3 were mainstreamed in regular schools for hearing children. The SL-home group consisted of 14 children (mean age = 11 years 1 month) who had deaf parents and who were enrolled in special schools for the deaf where teaching is provided in French SL or in signed French. The SL-school group consisted of 10 children (mean age = 11 years 7 months) who had hearing parents and who were enrolled in special schools for the deaf where French SL or signed French is used by the teachers. A control group of 16 younger hearing children (mean age = 8 years 11 months) was constituted. In addition, two groups of children were included who were matched with the CS-school, SL-home, and SL-school groups for age level. The CS-home older group consisted of 5 children, with a mean age of 11 years 9 months, and the control group of older hearing children consisted of 16 children with a mean age of 11 years 3 months. All children’s background characteristics are summarized in Table 1.

Pretest

A paper-and-pencil lexical decision task was administered to all participants. It consisted of 100 words (50 words and 50 pseudowords) presented on one page, in three columns, in a pseudorandomized order, fixed for all participants. Children were told that among the words they would see, some really exist and can be found in a dictionary, whereas others have been invented. Children were instructed to cross the invented words and to do nothing for the real words. They were asked to process as many items as possible within a fixed time frame of 90 s. Participants first did a training exercise consisting of eight items, on which they received feedback. The number of items processed minus the number of errors on pseudowords was used as a participant’s reading score. The number of items processed was used as an indication of reading speed, while errors on pseudowords reflected reading accuracy. Erroneous rejections of words were not taken into account because they could have been due to limited reading vocabulary instead of reading inaccuracy. The CS-home younger, hearing younger, CS-school, SL-home, and SL-school children were matched on this lexical decision raw score, F(4, 64) < 1, whereas the two groups of older children had higher scores (see Table 1).

Materials

Materials consisted of 51 French words, with each word containing one of the three phonemes investigated: (a) /s/ at beginning of words, before the
letters E and I; (b) /k/ at the beginning of words, before the letters A and O; and (c) /i/ at the end of words. For each phoneme, words containing the dominant transcription (respectively, #/s/E, I —» S, #/k/A, O —» C, and /e/ —» AIN) were selected. The word at the beginning of words, before the letters A and O; and (b) I at the end of words. For each phoneme, words containing the nondominant transcription (respectively, #/s/E, I —» C, #/k/A, O —» Q, and /e/ —» AIN) and words containing the nondominant transcription (respectively, #/s/E, I —» C, #/k/A, O —» Q, and /e/ —» AIN) were selected. The word frequency was determined by consulting BRULEX, a database containing approximately 30,000 French words (Content, Radeau, & Mousty, 1990). One third of the words were high frequency (mean log frequency = 3.7), one third were of medium frequency (mean log frequency = 2.9), and one third were of low frequency (mean log frequency = 2.7). The 51 words were thus allocated to six conditions, based on the crossing of two variables: grapheme dominance (dominant vs. nondominant) and frequency (three levels). At each frequency level, the dominant graphemes included 9 words each, and the nondominant graphemes included 8 words, because only two words were found that contained the /k/ —» Q correspondence and that were known by the deaf children. For dominant graphemes, the scores were averaged over 9 items; for nondominant graphemes, the scores were averaged over 8 items (see Appendix for the complete set of stimuli).

Procedure
Participants were given test booklets and were asked to write the words suggested by a drawing or by a short sentence context. A part of the word was already written in some cases, so that children had only to write the correspondence under investigation. Hearing and deaf children were tested in their own classroom. Hearing students were given oral instructions. Deaf students were given the instructions in their preferred mode of communication. If children did not succeed in discovering a target word, an alternative definition, or the sign from SL, was provided. Target words were not pronounced to either the hearing or deaf participants. Children were allowed as much time as they needed to complete the spelling test.

Scoring
For the three graphemes under investigation, a correct response was credited if the child had correctly spelled the grapheme, independently of how the rest of the word was spelled. For example, for the #/s/E, I —» S dominant correspondence in the word serrure, productions like “serrur,” “serrur,” “sirrur,” and “sarrur” were considered as correct, whereas productions like “cerrur,” “trrur,” “crrur,” and “ertrur” were scored as incorrect. For the #/k/A, O —» C nondominant correspondence in the word cinéma, productions like “cinéma,” “cénema,” “céma,” and “canema” were considered as correct, whereas productions like “sinéma,” “sinnema,” “sémena,” and “minémá” were scored as errors. The absence of a response to a target was considered as an omission. In each condition, the number of correct responses was obtained by the following formula: (number of correct responses/number of items in that condition minus the number of omissions) ÷ 9.

Misspellings at the grapheme level were classified into two main categories. Phonologically accurate errors were those in which the pronunciation of the misspelled grapheme was identical to that of the target phoneme. For dominant graphemes, phonologically accurate errors mean using a nondominant grapheme (e.g., “quamation” for camion, “cinge” for singe, and “lapain” for lapin); for nondominant grapheme, they mean using the dominant grapheme (e.g., “siel” for siel, “coi” for qui, and “pin” for pain). Phonologically inaccurate errors were those in which the pronunciation of the misspelled grapheme was not identical to that of the target phoneme. This category included phoneme substitutions errors (in which the target phoneme was replaced by another phoneme, e.g., “pêpé” for pépin, “soucreucrle” or “loucreucrle” for couvercle, and “tiropp” for sirropp), as well as other errors (which involve a change in the word’s phonological structure by omission, addition of one or several phonemes, e.g., “main” for moin, “ooquillage” for coquillage, “sitieste” for sieste, and “moulre” for moulin).

In addition, we examined whether the misspelling was a French word (e.g., “villa” or “ville” for vilain) or not. Finally, the misspellings were also scored for their orthographic legality. Regardless of their phonological accuracy, misspellings could be either orthographically legal (i.e., the sequence of letters is permissible in French words) or illegal (i.e., the sequence of letters does not occur in French words). The following examples are misspellings coded as orthographically unacceptable: “srrure” and “crurre” for serrure, “qurante” for quatre, “quarante” for quarante, “socsserole” for casserole, and “clél” for sel.

Results

Number of Correct Responses for Dominant and Nondominant Graphemes

Table 2 shows the mean number of correct responses (and the corresponding mean percentage of correct responses) for dominant and nondominant graphemes, in each of the three levels of frequency, for the groups of hearing younger, CS-home younger, CS-school, SL-home, and SL-school participants matched for reading level (hereafter, “younger readers”), as well as for the two

Table 1
Background Characteristics of Hearing, CS-Home, CS-School, SL-Home, and SL-School Participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hearing young</th>
<th>CS-home young</th>
<th>CS-school</th>
<th>SL-home</th>
<th>SL-school</th>
<th>Hearing older</th>
<th>CS-home older</th>
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<tbody>
<tr>
<td>No. males</td>
<td>8</td>
<td>11</td>
<td>8</td>
<td>10</td>
<td>6</td>
<td>8</td>
<td>3</td>
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<tr>
<td>Mean chronological age (months)</td>
<td>107 (14)</td>
<td>98 (12)</td>
<td>130 (19)</td>
<td>135 (20)</td>
<td>141 (24)</td>
<td>137 (3)</td>
<td>145 (11)</td>
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<td>Status of the parents</td>
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<td>2 Hearing (%)</td>
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<td>2 Deaf (%)</td>
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<td>1 Hearing + 1 Deaf (%)</td>
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<td>Hearing loss (dB)</td>
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<td>Ordinary (%)</td>
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<td>Special (%)</td>
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<tr>
<td>Reading score</td>
<td>38 (15)</td>
<td>42 (19)</td>
<td>43 (19)</td>
<td>43 (10)</td>
<td>47 (21)</td>
<td>56 (12)</td>
<td>57 (15)</td>
</tr>
</tbody>
</table>

Note. Standard deviations are in parentheses. CS = cued speech; SL = sign language.
groups of hearing older and CS-home older participants (hereafter, "older readers"). The pattern of accuracy data varied across the groups (see Table 2). Hearing and CS-home children were clearly better at spelling dominant than nondominant graphemes over the three levels of word frequency, and the effect of word frequency was more marked for nondominant than for dominant graphemes.

In the two groups educated with SL, there was no clear effect of dominance, F(1, 19) = 14.03, p < .005; frequency, F(2, 38) = 49.44, p < .0001; and the Dominance X Frequency interaction, F(2, 38) = 7.69, p < .0001. In the CS-school group, the effect of dominance was marginally significant, F(1, 17) = 4.26, p = .055. The effect of frequency was significant, F(2, 34) = 20.89, p < .001, whereas the Dominance X Frequency interaction was not, F(2, 34) = 1.67. The two groups of SL children exhibited the following pattern of results: no effect of dominance, F(1, 13) = 2.09 for SL-home and F(1, 9) = 1.34 for SL-school (both ps > .10), a significant effect of frequency, F(2, 26) = 40.32, p < .001, and F(2, 18) = 23.98, p < .001, respectively, and no interaction between dominance and frequency, F(2, 26) = 2.04, and F(2, 18) = 2.92, respectively.

**Older Readers**

The data of the older hearing and CS-home participants were entered in a 2 (group) × 2 (dominance) × 3 (frequency) ANOVA. This analysis yielded significant effects of dominance, F(1, 19) = 10.16, p < .005; of frequency, F(2, 38) = 22.53, p < .0001; and of the Dominance X Frequency interaction, F(2, 38) = 19.66, p < .0001. Neither the effect of group, nor the interactions involving the group factor, were significant.

**Analyses of Misspellings**

Given the small number of errors involved in each of the six conditions, the errors of each type were summed over the six conditions, and expressed as number of responses and percentage of the responses in Table 3. The spelling errors at the grapheme level revealed strong differences between the groups. The most frequent errors in hearing children consisted of phonologically inaccurate errors, that is, using the nondominant grapheme instead of the dominant grapheme (e.g., "siel" for ciel). The same tendency was observed in CS-home children. In the CS-school group, the effect of dominance was strongly stronger for low frequency words (M = 1.8 items) than for medium (M = 0.6 items) or high frequency words (M = 0.9 items; see Table 2). There was no significant Frequency X Group interaction, F(8, 146) = 1.94, p = .06, but there was a significant Dominance X Frequency X Group interaction, F(8, 146) = 2.12, p < .05.

To explore the Dominance X Frequency X Group interaction, a 2 × 3 ANOVA with repeated measures on dominance (dominant vs. nondominant) and frequency (high, medium, and low frequency) was performed in each group. In hearing children, all effects proved to be significant: dominance, F(1, 15) = 8.53, p < .01; frequency, F(2, 30) = 33.94, p < .0001; and the Dominance X Frequency interaction, F(2, 30) = 9.13, p < .001. The CS-home group exhibited similar significant effects: dominance, F(1, 19) = 14.03, p < .005; frequency, F(2, 38) = 49.44, p < .0001; and the Dominance X Frequency interaction, F(2, 38) = 7.69, p < .0001. In the CS-school group, the effect of dominance was marginally significant, F(1, 17) = 4.26, p = .055. The effect of frequency was significant, F(2, 34) = 20.89, p < .001, whereas the Dominance X Frequency interaction was not, F(2, 34) = 1.67. The two groups of SL children exhibited the following pattern of results: no effect of dominance, F(1, 13) = 2.09 for SL-home and F(1, 9) = 1.34 for SL-school (both ps > .10), a significant effect of frequency, F(2, 26) = 40.32, p < .001, and F(2, 18) = 23.98, p < .001, respectively, and no interaction between dominance and frequency, F(2, 26) = 2.04, and F(2, 18) = 2.92, respectively.

To compare the misspellings of the different groups, separate one-way ANOVAs were carried out on the number of phonolog-
Table 3

<table>
<thead>
<tr>
<th>Correct responses and types of errors</th>
<th>Hearing/younger</th>
<th>CS-H/younger</th>
<th>CS-school</th>
<th>SL-home</th>
<th>SL-school</th>
<th>Hearing/older</th>
<th>CS-H/older</th>
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<tr>
<td><strong>Grapheme level</strong></td>
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<td>Correct responses (max. = 51)</td>
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Note. CS-H = cued speech at home; SL = sign language.

Phonologically accurate errors and phonologically inaccurate errors. Post hoc tests (Newman-Keuls, at the .05 level) were used to determine which groups differ from each other when the ANOVA revealed a significant group effect. In the younger readers, there was a significant effect of group on percentage of phonologically accurate errors, $F(4, 73) = 7.83, p < .0005$, with both groups of SL children making fewer phonologically accurate errors than hearing children and than CS-home children, and CS-school children making fewer phonologically accurate errors than CS-home children. The two groups of older readers did not differ regarding the number of phonologically accurate errors, $F(1, 19) = 3.21, p > .05$; however, the CS-home children made more phonologically inaccurate errors than their hearing peers, $F(1, 19) = 57.08, p < .001$.

The misspellings at the word level are summarized in the bottom of Table 3. Separate one-way ANOVAs were carried out on number of word substitutions and number of misspellings that were orthographically illegal. Post hoc tests (Newman-Keuls, at the .05 level) were used to determine which groups differ from each other when the ANOVA revealed a significant group effect. The groups of younger readers significantly differed on percentage of word errors, $F(4, 73) = 11.70, p < .0001$: SL-home and SL-school groups made a higher proportion of such errors than the hearing group, the CS-home group, and the CS-school group. The five groups did not differ regarding the percentage of errors that were orthographically illegal ($F < 1$). The two groups of older readers did not differ regarding the number of word errors, nor regarding the number of orthographically illegal errors.

Discussion

Our experiment was designed to investigate the possible influences of deaf children’s nature and precocity of linguistic experience on the use of phoneme-to-grapheme relationships. We hypothesized that exposure to CS entails a use of accurate phoneme-to-grapheme relationships, all the more so because exposure is early and intensive. The effect of grapheme dominance and the interaction between the effect of grapheme dominance and word frequency should be more marked in groups of CS-home children than in groups of CS-school, SL-home, and SL-school children. The majority of spelling errors should be phonologically accurate in CS-home groups as in hearing children.

In line with our predictions, only the hearing children and the CS-home children exhibited a significant effect of dominance and a significant interaction between dominance and word frequency. Dominant graphemes were better spelled than nondominant graphemes, and the effect of dominance was larger for low frequency words than for medium or high frequency words. As predicted also, the CS-home children and the hearing children made a high and similar proportion of phonologically accurate errors. When required to spell a word for which they do not have a fully detailed orthographic representation, hearing and CS-home children start from accurate phonological representations (Charlier & Leybaert,
2000), and apply dominant correspondences between phonemes and graphemes.

Early acquisition of a natural language and language having the phonological structure of the spoken language are thus necessary conditions for the development of accurate use of phoneme-to-grapheme relationships. The fact of learning a language early in life cannot explain our results on its own, because SL-home children did not achieve a larger effect of grapheme dominance than SL-school children. Exposure to CS is also in itself insufficient to explain our results, as the CS-home children differed from the CS-school children. CS-home children also have a fairly sophisticated knowledge of the relations between phonemes and graphemes in French, as hearing children do. They knew that the phonemes have more than one possible spelling, and that one spelling is more common than others. The development of a spelling system sensitive to the statistical relationship between phonemes and graphemes is not precluded in the case of prelingual and profound deafness. It can be promoted by exposure to visual speech information, provided that all phonological distinctions can be easily perceived.

The CS-school, SL-home, and SL-school children performed differently in spelling than did the CS-home and hearing children. First, they displayed a similar effect of frequency on dominant and nondominant graphemes. Second, they made fewer phonologically accurate misspellings, indicating a lower ability to use accurate phoneme-to-grapheme mappings. Their performance may result from inaccuracy at the level of phonological representations, deficiency in segmentation of these representations, or a difficulty in attributing graphemes to phonemes. CS-school children and children educated with SL have underspecified representation of phonology in previous work (Charlier & Leybaert, 2000). Inaccuracy of their phonological representations hinders these children in applying phoneme-to-grapheme correspondences in the present study. Possibly, they need more exposure to print in order to acquire correct spelling for dominant as well as for nondominant graphemes.

It must be borne in mind that deaf children’s phonologically accurate responses likely do not constitute the only attempts to represent the word’s phonemes. As discussed by Treiman (1983) in the case of hearing first grade spellers, many phonologically inaccurate errors are almost surely attempts to represent the word’s phonology. A similar argument was developed about deaf children: Errors that are illegal in relation to the conventional phonological representation of hearing adults, may not be illegal when inaccurate errors are almost surely attempts to represent the word’s phonology. A similar argument was developed about deaf children entering these two types of schools could differ. However, the control of school background in a previous study did not change the general pattern of the results, at least for the comparison between CS-home and CS-school children (Leybaert, 2000). Our results also seem independent of parental deafness. The two groups of children educated with sign language achieved similar results, despite the fact that the parents of the SL-home children were deaf and most of the parents of the SL-school children were hearing. And the two groups of children educated with CS achieved different results despite the fact that most of the parents of these children were hearing. The parents of the CS-home children are perhaps more concerned with language acquisition and reading achievement than the parents of the other children. This could explain why the CS-home children reached a reading level appropriate for their chronological age, whereas the other deaf children were reading-delayed. However, differences in parents’ attitudes toward reading cannot explain that CS-home children use more phoneme-to-grapheme relationships than other deaf children matched for word recognition level. Finally, could the results of the hearing and CS-home younger groups be explained by a lesser exposure to print because of their younger chronological age? Compared to older children of the CS-home and hearing groups, younger children reached lower performances for nondominant graphemes, especially in the case of low frequency words, which attests that their orthographic lexicon is less developed. They thus made more phonologically accurate errors than the older children. However, the data of the older CS-home and hearing children differed from those of the chronological age-matched CS-school, SL-home, and SL-school groups. With older CS-home and hearing children, there was an interaction between dominance and frequency; there was no corresponding interaction for CS-home, SL-home, and SL-school groups. In addition, a majority of errors were phonologically accurate in the older CS-home and hearing
groups, but phonologically inaccurate in the CS-home, SL-home, and SL-school groups.

It thus seems reasonable to conclude that the spelling by deaf children is phonologically guided, to various extents, depending on their language experience. A critical condition ensuring adequate children is phonologically guided, to various extents, depending on systems like CS does not have the same effect on the use of phoneme-to-grapheme correspondences. Finally, the early advantage in language development displayed by deaf children born to deaf parents over deaf children from hearing parents, does not induce a larger use of phonology-to-orthography mappings. Possibly, there is a “missing link” between this early language experience and reading acquisition (Padden & Hanson, 1999).

Providing deaf children with inputs that could serve as a principled way of remembering the word spelling, such as CS or fingerspelling, could improve their spelling abilities (Hanson et al., 1983; Padden & Ramsey, 2000). This is not contradictory to the use of sign language as a primary language. Early experience with fingerspelling or CS may allow the development of metaphonological awareness before, or in interaction with, reading. We plan to test this hypothesis by studying deaf children who have a SL as primary language and who benefited from acquiring French, English, or any other traditionally spoken language via CS before they started learning to read. We would expect that the spelling by such children could be phonologically guided as is the spelling by hearing or CS-home children. The study of the development of metaphonological skills, reading and spelling, of profoundly, prelinguistically deaf children fitted with a cochlear implant is also on the agenda. The information provided by the implant could interact with that perceived through lip-reading and CS to set the stage for the development of phonological awareness. In sum, the reading and spelling difficulties of deaf children are long-lasting problems. Our research demonstrates that access to an input providing information about phonological contrasts is the critical question rather than deafness per se.

References


Appendix

Words Used in the Spelling Test

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Note. Mean log frequencies are in parentheses.

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