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The rhyming skills of deaf children educated with phonetically augmented speechreading

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Two experiments investigated whether profoundly deaf children's rhyming ability was determined by the linguistic input that they were exposed to in their early childhood. Children educated with Cued Speech (CS) were compared to other deaf children, educated orally or with sign language. In CS, speechreading is combined with manual cues that disambiguate it. The central hypothesis is that CS allows deaf children to develop accurate phonological representations, which, in turn, assist in the emergence of accurate rhyming abilities. Experiment 1 showed that the deaf children educated early with CS performed better at rhyme judgement than did other deaf children. The performance of early CS-users was not influenced by word spelling. Experiment 2 confirmed this result in a rhyme generation task. Taken together, results support the hypothesis that rhyming ability depends on early exposure to a linguistic input specifying all phonological contrasts, independently of the modality (visual or auditory) in which this input is perceived.

Profoundly deaf people rely mainly on vision to sustain language perception. Speechreading does allow the deaf person to perceive some of the phonological contrasts (place of articulation) but not others (articulatory mode; see Binnie, Montgomery, & Jackson, 1974; Erber, 1979; Walden, Prosek, Montgomery, Scherr, & Jones, 1977). Even if speechreading can lead to the development of phonological representations in the deaf (Dodd, 1987; Dodd & Hermelin, 1977), these representations might be too incomplete to support efficient cognitive processing. Indeed, orally educated deaf children are described as exhibiting poor memory span for written words (Conrad, 1979), little use of phonological

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coding in short-term memory (Campbell & Wright, 1990), limited sensitivity to phonological effects in serial recall tasks (Campbell & Wright, 1990; Conrad, 1979), deficits in rhyming (Campbell & Wright, 1988; Hanson & Fowler, 1987; Hanson & McGarr, 1989; Sterne, 1996), and little use of phoneme–grapheme correspondences in reading and spelling (Burden & Campbell, 1994; Harris & Beech, 1995; Leybaert & Alegria, 1995). This highlights the importance of the quality of the mental representations of speech.

If the deficits shown by deaf people in phonological processing originate in speechreading, not as visual coding but as partial coding, then any system that makes visible all the phonological contrasts of a given language should be able to generate phonological representations suitable for efficient cognitive processing. Several systems are devoted to complement speechreading with visual clues in order to deliver complete phonological information. One of these systems using manual clues to disambiguate speechreading is Cued Speech (CS), which was devised by Cornett (1967).

In CS, the speaker keeps one of his or her hands near the mouth while speaking. He or she complements speechreading by adding discriminating information called "Cues". A Cue is made up of two parameters: the hand shape and the hand position near the mouth. In the French version of CS, called Langage Parlé Complété (LPC)[1] there are eight different hand shapes and five different hand positions. Hand shapes disambiguate consonants whereas hand positions disambiguate vowels. A group of two or three consonants or vowels is assigned to each shape and each position in such a way that the phonemes easy to discriminate by speechreading share the same hand shape or hand position, whereas the phonemes that are difficult to discriminate belong to two different groups. For example, for consonants (C) the same hand shape is used for /p, d, ʒ/, another one for /b, n/, and so on, as these groups of phonemes are easy to discriminate between by speechreading. As far as vowels (V) are concerned, one position is used for /u, ɛ, ɔ/, another one for /œ, a, o/, and so on (see Figure 1). Each time the speaker pronounces a CV syllable he or she produces a Cue (a particular hand shape at a specific position) and in this way gives unambiguous visual information about the syllable and its constituent phonemes. Syllabic structures like VC, CCV, CVC need additional Cues to reveal the supplementary phonemes. Three important points should be stressed. First, Cues alone provide no useful information: No hand shape or hand position can be interpreted without taking the lip movements into account. Second, Cues do not give any direct phonetic information: Hand shapes and hand positions are artificially and arbitrarily designed without taking phonetic criteria into account. Third, rhyming syllables share the same hand position as a consequence of the system design.

Results of studies already conducted strongly suggest that the use of manual Cues has the expected effect of disambiguating speechread information. Nicholls and Ling (1982) found that the speech perception scores of profoundly deaf children using CS at school increased from about 30% for both syllables and words if presented with speechreading alone, to more than 80% if presented with speechreading plus Cues. Moreover, Périer, Charlier, Hage, and Alegria (1988; see also Alegria, Charlier, & Mattys, 1998) found a

[1] For the sake of clarity, CS will be used hereafter instead of Langage Parlé Complété to describe the experiments run in French.

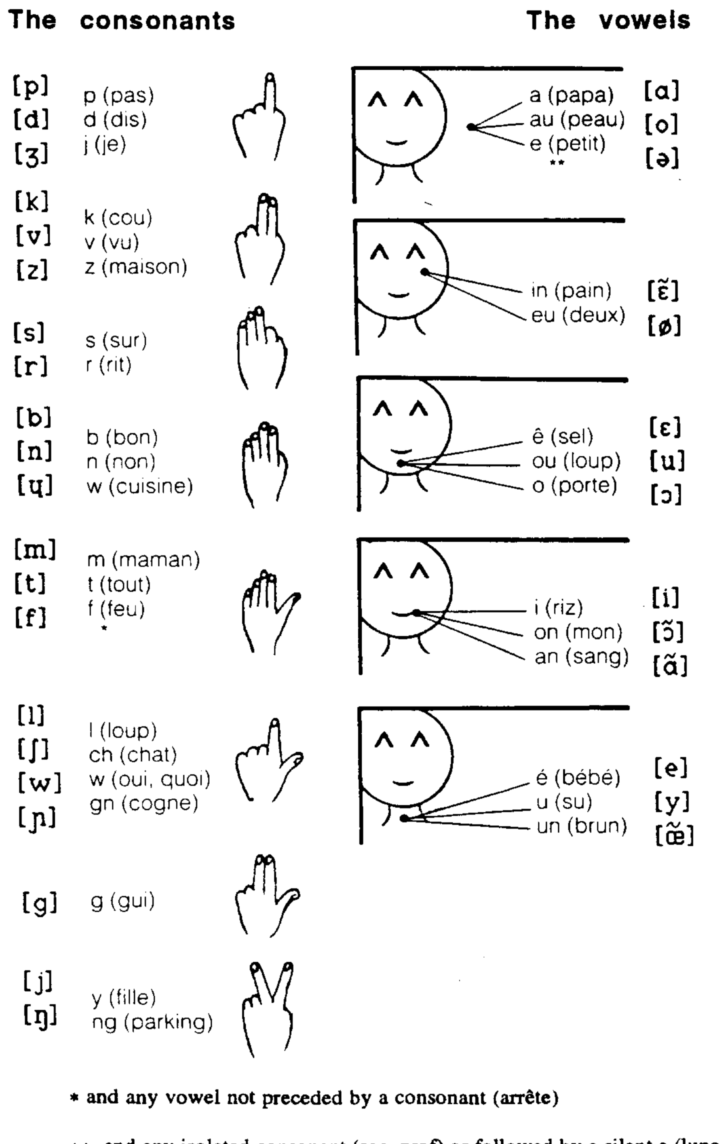

FIG. 1. French version of Cued Speech (reproduced with authorization of the Belgian LPC Association).

similar effect, which was stronger in children whose parents used CS at home than in children whose only contact with CS was at school.

The fact that CS improves speech perception does not necessarily imply that this system is able to generate accurate phonological representations. The present study is aimed at evaluating the accuracy of the phonological representations constructed by deaf children educated with CS. To this end, rhyming judgement and rhyming production tasks were used. These tasks require participants to access their phonological representations and to pinpoint the phonological similarity of sublexical units (i.e. the final vowel of the word or the vowel + coda). A person who does not possess accurate phonological representations is unable to judge or generate rhymes correctly. If children educated with CS exhibit a high level of rhyming performance, this would indicate that it is possible to construct accurate phonological representations from a visual input.

In hearing children the ability to produce and to judge rhymes spontaneously is already present between 2 and 3 years of age (Read 1978; Slobin, 1978), with some individual differences linked to the quality of their oral productions (Webster & Plante, 1995). The rhyming ability improves progressively until the age of literacy. While preliterate children detect rhymes on the basis of global phonological similarity, first-graders pay more attention to phonemes (Cardoso-Martins, 1994; Lenel & Cantor, 1981). Rhyming ability usually emerges spontaneously as a result of natural linguistic development and before any contact with literacy (Morais, Bertelson, Cary, & Alegria, 1986).

In deaf children, in contrast, rhyming ability is usually poor, appears late, and is often influenced by speechread clues or by word spelling. Dodd and Hermelin (1977) found that deaf children made use of the rhyme as a clue to help them memorize pairs of written words. They argued that deaf children's notion of rhyme is based on the visual speechread similarity between spoken words. This experiment, although of great interest, does not reveal whether deaf children make the distinction between rhyme and lip movement similarity. Indeed, all rhyming words inevitably end with the same lipread image (e.g. in French LIT/li/–NID/ni/; in English FROG/frɒg/–DOG/dɒg/). However, all the pairs of words ending with an identical lipread image do not necessarily rhyme (e.g. in French LIT/li/–NEZ/ne/; in English THIS/ðis/–THIN/θin/). In all studies conducted up to now, rhyme and speechread similarity have been confounded. This confound might weaken the relevance of the studies devoted to the analysis of deaf children's phonological accuracy through rhyming tasks.

Campbell and Wright (1988), Hanson and Fowler (1987), and Hanson and McGarr (1989) found that deaf children, educated orally or with sign language, relied on word spelling to perform rhyme judgement on written word pairs. Surprisingly enough, in Campbell and Wright's study this was also the case with pictured stimuli. The authors suggested that because speechreading alone does not allow deaf children to develop accurate phonological representations, they spontaneously rely more heavily on word spelling than do hearing people.

In all studies dealing with deaf children's rhyming sensitivity, clear inter-individual differences appear. The children who have better speech intelligibility and those who are better readers achieve better rhyming ability. This suggests that the quality of output representations might play a role in rhyming ability. Indeed, the rehearsal component of the phonological loop in hearing people is supposed to be involved in this task (Besner, 1987; Besner, Davies, & Daniels, 1981; Burani, Vallar, & Bottini, 1991; Johnston & McDermott, 1986; Wilding & White, 1985). It might be supposed that the articulatory component is essential in this rehearsal. However, children who are congenitally speechless (anarthric) or speech-impaired (dysarthric) show normal rhyming judgement (Bishop & Robson, 1989). This indicates that the articulatory component is not necessarily involved in rhyme judgement.

If this is the case, intelligible speech and phonological rehearsal are correlated in the deaf, not necessarily because the former determines the latter (as assumed by Conrad, 1979), but because both factors may be linked to a third variable—that is, the quality of the deaf person's phonological representations. Indeed, a complete mental representation of speech contrasts—as is generally present in hearing people—is necessary to produce intelligible speech. Input factors may be essential in determining deaf children's mental model of speech.

Within this perspective, the impact of deafness on cognition differs mainly as a function of the quality of the phonological input and not as a function of the quality of external speech per se. Deaf children who have only partial perceptual inputs during their early childhood (e.g. inputs limited to speechreading and the use of residual hearing) will have little possibility of accurately using phonological representations to perform tasks requiring them to judge a sound structure. This could be avoided if deaf children were exposed to an appropriate phonological input during the period in which the relevant representations are being developed. Systems that disambiguate speechreading, such as CS, should have a positive effect on the quality of phonological representations and, consequently, on children's rhyming ability. This idea is compatible with Gathercole and Martin's (1996) point of view, according to which the phonological rehearsal involved in rhyme judgement corresponds to the activation of representations derived from speech perception experience.

The two experiments reported here investigated the effect of the use of CS on rhyming ability. Experiment 1 involved a rhyme judgement task on pictured words. Experiment 2 examined children's ability to generate rhymes in response to written or pictured words. In order to explore the information sources that children relied on, two kinds of similarity were manipulated: speechread similarity (Experiment 1) and orthographic similarity (Experiments 1 and 2). The general method of investigation consisted in comparing hearing controls with groups of deaf children educated with different communication systems.

EXPERIMENT 1

Experiment 1 involved rhyme judgement on pairs of pictures by deaf children having CS at home, deaf children educated with CS at school only, orally educated deaf children, deaf children who learnt sign language early in their life, deaf children who learnt sign language at a late stage at school, and hearing controls. The subjects were forced to rely on their phonological representations of the words illustrated by the pictures, as these stimuli did not provide any direct phonological information. A high level of correct rhyme judgement was expected for the subjects who access accurate phonological representations directly from pictures. This is very likely the case for hearing children. The main question was whether it was also the case for the deaf children educated with CS at home. If these children developed abstract phonological representations from visual inputs specifying all the phonological contrasts, they might behave like hearing children and differently from deaf children educated orally or with sign language.

Deaf children educated with CS at home differ from orally educated deaf children in two ways: They have a clear phonological input and have learned a language early in their life. The inclusion of other groups of deaf children made it possible to control the effect of these two variables. If learning a language early in life is a sufficient condition for the emergence of the rhyming ability, children educated with CS at home and children educated with sign language at home should outperform children in contact with CS or sign language only at school, given that all children are in contact with an oral language on at least a daily basis at school. However, if the exposure to a phonologial input per se is the critical factor, both groups of children educated with CS (at home and at school) should outperform both groups of children educated with sign language (at home and at school). Finally, if both conditions (i.e. the early exposure to a language and to a phonological input) are necessary, children educated with CS at home should outperform all the other groups of deaf children.

A further aim of the present study was to discover whether children educated with CS at home develop their rhyming ability on the basis of the visual speech information that they have been exposed to, and not on the basis of their reading and spelling experience. Therefore, an attempt was made to test readers as well as pre-readers belonging to the different groups described above. It was expected that the children educated with CS at home are sensitive to rhyme even before they have any contact with written language. In order to tap the processes used to make rhyme judgements, two variables were manipulated: spelling similarity and speechread similarity. Campbell and Wright (1988) reported that hearing subjects were not sensitive to spelling when they had to decide whether or not two pictured words rhymed. By contrast, orally educated deaf youngsters were strongly affected by this variable in the same task. Therefore, an initial hypothesis was that the subjects who are able to access accurate phonological representations from pictures should not be affected by spelling similarity. This is likely to be the case for hearing children and perhaps also for children educated with CS at home. However, spelling similarity may affect the performance of other deaf children. Obviously, non-readers should not be affected by this variable.

A second hypothesis was that deaf children might be more sensitive than hearing controls to speechread similarity in rhyme judgement. Campbell and Wright (1990) demonstrated that speechread ability influenced deaf youngsters' phonological rehearsal system in a short-term memory task. Because the phonological rehearsal system is also involved in rhyme judgement, an effect of speechread similarity was expected in groups of deaf children. As CS disambiguates speechread information, the effect of speechread similarity might be less important in the children exposed to this system than in the children who are not CS users.

Method

Subjects

The different samples of subjects, whose characteristics are presented in Table 1, were selected from larger initial samples on the basis of a pre-test (see below). Only pre-lingually deaf children with congenital hearing loss or who had acquired hearing loss before 12 months of age were involved in this study. The mean hearing loss was calculated on 250, 500, 1000, and 2000 Hz, with 120 dB attributed to unperceived frequencies. Because the degree of hearing loss is usually highly correlated

TABLE 1
Characteristics of deaf and hearing subjects of Experiment 1

	Readers						Non-Readers	
	CS^{+}	*CS*$^{-}$	*Oral*	*SL*$^{+}$	*SL*$^{-}$	*Hearing*	*CS*$^{+}$	*Hearing*
N	16	18	29	12	20	12	5	10
Male	8	11	11	7	7	8	2	6
Female	8	7	18	5	13	4	3	4
Chronological Age[a]								
Mean	10;1	12;7	13;3	10;4	10;1	8;7	5;6	5;10
Range	(6;10–15;10)	(7;4–16;8)	(9;6–7;8)	(6;2–13;3)	(6;0–12;7)	(7;0–12;0)	(4;3–6.0)	(5;3–6;2)
Hearing Loss								
Mean	97.4	94.4	100.1	101.6	100.6	–	99.7	–
Range	(84–105)	(80–115)	(68–130)	(85–108)	(91–115)	–	(89–113)	–
2000Hz	109.7	101.9	113.6	116.0	115.5	–	104.0	–
Status of the parents[b]	16H/0D	18H/0D	29H/0D	OH/12D	20H/0D	–	5H/0D	
Intelligibility								
Mean	3.9	3.4	4.0	2.9	3.0	–	4.0	–
Range	2–6	1–6	2–6	2–5	2–6	–	1–6	–
Reading Level								
Mean	5.3	3.2	3.4	3.3	3.7	–	–	–
Range	3–6	2–6	1–6	1–5	1–6			

[a]chronological age is given in years; months.
[b]H = hearing parents; D = deaf parents.
Note: CS^{+}: deaf children educated with CS at home and at school; CS^{-} : deaf children educated with CS only at school; Oral: deaf children educated orally at home and at school; SL^{+}: deaf children educated with sign language at home and at school; SL^{-} : deaf children educated with sign language only at school.

with the ability to use phonological representations (see e.g. Conrad, 1979), particular care was taken to select only children suffering from profound hearing loss (i.e. a mean hearing loss of 90 dB or more at the better ear calculated on the thresholds at 500, 1000, and 2000 Hz) and to match the different groups of deaf participants as accurately as possible for the mean hearing loss (see Table 1). The deaf children were all equipped with two acoustic hearing aids worn during the experiment. Unfortunately, due to class-time constraints it was not possible to measure the participants' intelligence. However, all the deaf children were regularly monitored for intellectual, linguistic, and social development. None of them showed any noticeable deficit in these areas that was not explained by their early hearing loss.

The speech intelligibility and the reading level of the deaf children were evaluated by their speech therapist or their teacher with a 6-point graduated scale (1 being "very poor", 6 being "perfect").

Readers. The CS^+ group included 16 children (mean age: 10 years, 1 month), who received the French version of CS at home, meaning that at least one of their parents used CS in daily communication. CS had been introduced into this group at the mean age of 28 months. Some of these participants were also educated with CS at school, either by teachers in special schools for deaf people or by interpreters in mainstream situations. The CS^- group included 18 children (mean age: 12 years, 7 months), who had been educated with CS at school from a mean age of 56 months. The Oral group included 29 children (mean age: 13 years, 3 months) educated exclusively with the oral/aural method, both at home and either in a special school for deaf people or in a mainstream situation. In addition, two groups of deaf children who used sign language (SL) were included in this experiment. The SL^+ group consisted of 12 children (mean age: 10 years, 4 months) who were all native signers (i.e. they all had deaf parents who used sign language to communicate with them). They received an oral education mixed with sign language at school. The SL^- group consisted of 20 children (mean age: 10 years, 1 month) attending the same schools as the SL^+ group but having hearing parents and therefore communicating in French at home. A hearing control group of 12 children (mean age 8 years, 7 months) was selected. The hearing children were approximately matched to the deaf children for the school level (from second to fifth grade).

Pre-readers. An attempt was made to test children who had not yet learned to read. Hearing children and deaf children educated with CS, orally, or with sign language took part in the pre-test (see later). No child of the last two groups passed the pre-test. Therefore, only the groups of hearing children (mean age: 5 years, 10 months) and CS^+ children (mean age: 5 years, 6 months) were suitable for the experimental task. The deaf pre-readers had been exposed to CS since a mean age of 30 months. Further characteristics of the participants are presented in Table 1.

Materials

A total of 35 pairs of words (mono- or bisyllabic) were selected from the usual vocabulary of deaf children. The selection of materials was constrained both by the limited vocabulary of young deaf children and by the fact that words had to be pictured. Therefore, the number of pairs varied between the four experimental conditions:

1. R^+O^+: 7 rhyming pairs ending with a similar spelling (e.g. in French CHAISE/ʃɛz/–FRAISE /frɛz/; in English: DOG/dɒg/–FROG/frɒg/).
2. R^+O^-: 11 rhyming pairs ending with different spellings (e.g. in French TASSE/tas/–GLACE /glas/; in English, COULD/kʊd/–GOOD/gʊd/).

3. R^-SR^+: 7 non-rhyming pairs ending with a similar speechread image (e.g. in French LIT/li/–NEZ/ne/; in English CAUGHT/kɔːt/–GOOD/gʊd/).

4. R^-SR^-: 10 non-rhyming pairs ending with different speechread images (e.g. in French ROBE /rɔb/–BALLE/bal/; in English: SHOE/ʃuː/–SOCK/sɒk/).

The complete list of experimental pairs is presented in the Appendix. The cards containing the pictures were 10 × 15 cm in size. The stimuli were randomly mixed and presented in a fixed order to all participants.

Procedure

A pre-test aimed at eliminating the children who did not understand the task, was administered to each participant individually. The notion of rhyme was introduced to children with two cards, one showing men who were friends and the other showing men who were not friends. The experimenter (B. Charlier) showed the first rhyming pair and said, "You see, these two words are friends. Do you know why?". If the child gave a response based on a pragmatic or semantic criterion, she added "Yes, you are right, but I said they are friends because they end similarly when spoken; they sound the same at the end." Further examples of "friends" (i.e. rhymes) were provided in order to make it clear that rhyming pairs had to share the final vowel plus any phonemes that might follow it. When the child had responded to a rhyming pair correctly, the experimenter presented him or her a non-rhyming pair. Then five further trials were presented to the child who had to classify them by him- or herself. The children who had correctly classified the pictures were asked to justify their choices.

Only the subjects who classified the five pairs correctly and were able to justify their classification on the basis of a phonological criterion were included in the experiment. Some children were excluded because they persisted in using a pragmatic criterion—for example, in French LAPIN /lapɛ̃/ (rabbit) and RAISIN /rɛzɛ̃/(grapes) are friends because rabbits like to eat grapes— and they did not show any ability to compare words on a phonological basis. For this reason, five children were excluded from the CS^+ group (all younger than 6 years old), five from the CS^- groups (between 5 years, 11 months and 9 years, 10 months old), one from the oral group (8 years, 4 months old) and three from the hearing group (younger than 6 years old). It is noteworthy that, among the children who failed in the pre-test, those excluded from the CS^+ or from the hearing group were all younger than 6 years old, whereas those excluded from the other groups of deaf children were older.

The children who passed the pre-test successfully were then given the 35 experimental picture pairs and asked to classify them as rhyming ("friends") or non-rhyming ("non-friends"). The experimenter noted the pairs of pictured words in each category.

Results

Separate analyses were carried out for readers and pre-readers.

Readers

The mean percentage of correct responses of the hearing, CS^+, CS^-, oral, SL^+, and SL^- groups of readers is presented in Table 2. A mixed analysis of variance (ANOVA) was performed on these results, with the group as the between-subjects factor (CS^+, CS^-, oral, SL^+, SL^-, hearing) and type of material (R^+O^+, R^+O^-, R^-SR^+, and R^-SR^-) as the within-subjects factor. There were significant main effects of group, $F(5, 101) = 19.3$,

TABLE 2
Mean percentage of correct responses and corresponding standard deviations in rhyme judgement as a function of type of pairs and group of subjects

		R^+O^+		R^+O^-		R^-SR^+		R^-SR^-	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Readers	Hearing	95.8	7.6	97.0	5.9	97.7	5.5	99.2	2.9
	CS^+	97.4	5.6	94.9	8.0	93.8	9.0	100	0.0
	CS^-	86.4	14.4	73.9	16.3	68.3	25.2	95.6	7.1
	Oral	92.2	9.8	71.6	22.9	73.8	24.3	83.5	6.1
	SL^+	89.3	17.4	58.2	31.1	74.7	15.4	96.7	6.5
	SL^-	82.9	13.7	66.6	21.1	58.6	22.0	92.0	8.9
Pre-readers	Hearing	91.3	14.0	91.0	12.7	78.6	23.6	94.0	10.7
	CS^+	100	0.0	94.4	8.2	89.0	18.7	100	0.0

Note: Legend of the groups: see Table 1. R^+O^+: rhyming pairs with similar spelling; R^+O^-: rhyming pairs with different spellings; R^-SR^+: non-rhyming pairs with similar speechread image; R^-SR^-: non-rhyming pairs with different speechread image. *M* = mean. *SD* = standard deviation.

$p < .0001$, and type of material, $F(3, 303) = 39.3$, $p < .0001$, together with a significant group by type of material interaction, $F(15, 303) = 3.45$, $p < .001$. Post hoc tests (Bonferroni/Dunn, all means) showed that significant differences (at $p < .01$) appeared between the CS^+ group and each of the other groups of deaf children (CS^-, oral, SL^+, and SL^-) as well as between the hearing group and these same groups (CS^-, oral, SL^+, SL^-). The comparison between the CS^+ and the hearing groups was not significant.

Further analysis showed that the effect of type of material was significant in all groups except for the hearing group; hearing: $F(3, 33) < 1$; CS^+: $F(3, 45) = 2.91$, $p < .05$; CS^-: $F(3, 51) = 9.74$, $p < .001$; oral: $F(3, 84) = 15.79$, $p < .001$; SL^+: $F(3, 33) = 9.63$, $p < .001$; SL^-: $F(3, 57) = 15.63$, $p < .001$. Contrasts aimed at testing spelling similarity and speechread similarity effects were calculated separately for each group of deaf children because of the significant group by type of material interaction. The decrease in performance for orthographically different rhyming pairs compared to orthographically similar rhyming pairs ($R^+O^- < R^+O^+$) was significant in the oral ($p < .0005$), SL^+ ($p < .0005$), SL^- ($p < .005$), and CS^- ($p < .05$) groups but not in the CS^+ group ($p > .10$). Non-rhyming pairs with a similar speechread image were identified less accurately than non-rhyming pairs with different speechread images ($R^-SR^+ < R^-SR^-$) in all the groups (CS^+: $p < .01$; CS^-: $p < .0005$; oral: $p < .0005$; SL^+: $p < .05$; SL^-: $p < .0005$). However, an examination of Table 2 reveals that the difference between R^-SR^+ and R^-SR^- conditions was weaker in the CS^+ group (6.2%) than in the other groups of deaf children: CS^- (27.3%), oral (27.7%), SL^+ (22.0%), SL^- (33.5%). Moreover, the proportion of children showing a speechread similarity effect was smaller in the CS^+ group (37%) than in the other groups of deaf children: CS^- (78%), oral (69%), SL^+ (83%), SL^- (90%). An ANOVA on the difference scores between R^-SR^+ and R^-SR^- revealed a significant group effect, $F(4, 90) = 4.00$; $p < .005$. Post hoc tests (Bonferroni/Dunn, all means) indicated that all the groups differed from the CS^+ group at $p = .05$.

Pre-readers

The mean accuracy for the hearing and CS^+ groups of pre-readers is given in Table 2. These results were subjected to an ANOVA with group as the between-subjects factor (hearing, CS^+) and type of material (R^+O^+, R^+O^-, R^-SR^+, R^-SR^-) as the within-subjects factor. This analysis did not reveal any group effect, $F(1, 13) = 1.95$, but did indicate a significant type of material effect, $F(3, 39) = 2.86$, $p < .05$, and no group by type of material interaction, $F(3, 39) < 1$. Contrasts computed on the two groups pooled together showed a significant decrease in performance for the non-rhyming pairs with a similar speechread image compared to the performance for control pairs ($R^-SR^+ < R^-SR^-$, $p < .05$). No difference between the two rhyming conditions was observed ($R^+O^+ = R^+O^-$). This indicates that both hearing and deaf pre-readers are influenced by speechread similarity but not by spelling similarity.

Rhyming Proficiency in Relation to Other Language Factors

For each group of readers, Spearman rank correlations were calculated between the mean accuracy in the experimental task on one hand, and chronological age, hearing loss, speech intelligibility level, and reading level on the other. The small number of pre-readers meant that such correlations could not be performed for these groups.

There was a significant correlation between chronological age and accuracy in the experimental task in the oral group ($r = .30$, $p < .05$) and SL^- group ($r = .56$, $p < .005$): the older the participants, the better their rhyming skills. No correlation appeared between mean hearing loss and mean accuracy in the rhyme judgement task. The correlation between speech intelligibility and mean accuracy was significant in the CS^+ group ($r = .42$, $p < .05$) and in the oral group ($r = .55$, $p < .01$): the better the speech intelligibility, the better the rhyming skills. There was a trend to a correlation in the same direction in the CS^- group ($r = .32$, n.s.) but, inexplicably, in the opposite direction for the two SL groups (SL^+: $r = -.41$, n.s.; SL^-: $r = -.23$, n.s.) It is interesting to note that speech intelligibility tended to be correlated with hearing loss in all the groups (CS^+: $r = -.32$, n.s.; CS^-: $r = -.53$, $p < .01$; oral: $r = -.367$, $p < .05$; SL^+: $r - -.18$, n.s.; SL^-: $r = .475$, $p < .05$).

Discussion

As demonstrated in this experiment, deaf participants are able to make rhyme judgement on pairs of pictures, a task that requires access to phonological representations. However, clear-cut differences appear between the six groups: The hearing and CS^+ groups do not differ from each other, and both reach a higher degree of accuracy than all the other groups of deaf participants who do not differ from each other (hearing = $CS^+ > CS^-$ = oral = SL^+ = SL^-). As mentioned before, the hearing and CS^+ children share two characteristics: They have been exposed to early linguistic experience and have been provided with fully specified phonological information. The fact of learning a language early in life can not explain our results on its own. Indeed, SL^+ children who learnt sign language early in life do not achieve better rhyming scores than SL^- children who learnt sign language late and only at school (of course, SL^+ children have probably developed better rhyming abilities in sign language than have SL^- children). On the other hand, exposure to CS is also in itself insufficient to explain our results. Indeed, although CS^+ children outperform CS^- children, the CS^- children do not differ from orally educated, SL^+ and SL^- deaf children. This pattern of data suggests that early language acquisition and the fact that this language has the phonological structure of a spoken language are necessary conditions for the natural development of rhyming ability.

In the present experiment, the performance of the CS^-, oral, SL^+, and SL^- groups is significantly lower for pictures representing rhyming words with different spellings. This spelling effect confirms the results obtained by Campbell and Wright (1988). It indicates that the deaf subjects who are educated orally or with sign language or with CS only at school use their knowledge of spelling to support rhyme judgement, probably because their phonological representations are not precise enough. The prediction that the CS^+ children identify rhyming words without any effect of spelling similarity is confirmed. Confronted with two pictures, these children do access the corresponding phonological representations. This makes them different from the other groups of deaf children in this experiment as well as from other deaf people evaluated in the literature.

The hypothesis that deaf children use speechread similarity as a clue when making rhyme judgement is strongly supported by the data: The pictures representing words sharing the same speechread image mislead all the groups of deaf children. However, the performance of the CS^+ group is less impaired by speechread similarity than is that of the other groups of deaf participants, supporting the view that exposure to CS allows the development of more precise phonological representations.

As expected, the rhyming ability of hearing and CS^+ children is not dependent on their acquisition of reading and writing, as pre-readers belonging to these groups are able to make rhyme judgement. This also indicates that rhyming ability develops differently in CS^+ children than in other deaf children. Indeed, this is the first published demonstration that pre-reader deaf children are able to understand the notion of rhyme. This suggests that in deaf children sensitivity to rhyme could precede reading acquisition, provided that the children are exposed to visual information that specifies all the phonological contrasts. A striking observation is that the global level of performance of pre-readers exposed to CS at home is indistinguishable from that of hearing peers.

An unexpected, but interesting, result is that both hearing and deaf pre-readers are sensitive to speechread similarity. This might indicate that the phonological representations of pre-readers are not as detailed as those of readers, even in the case of hearing children (see Fowler, 1991; Metsala & Walley, 1998; Walley, 1993). However, in hearing children this under-specification seems to be limited to the pre-readers, whereas it persists in deaf children, as evidence by the data obtained from the deaf readers.

No difference appeared between orally educated and sign-educated children in Experiment 1. One possible explanation is that despite the differences in their linguistic background all the children are in contact, to some extent, with spoken language. All are trained in speechreading and probably derive phonological representations from this visual input. Similarly, it is interesting to note that the use of CS only at school does not lead children to develop a different rhyming ability from that found in orally or sign-educated deaf children.

EXPERIMENT 2

Experiment 1 showed that children educated with CS at home have rhyming skills close to those of hearing children. However, this does not allow us to claim that they manipulate rhymes as accurately as do their hearing peers. Experiment 2 was designed to assess their rhyming ability with a rhyme generation task. The generation task is probably more difficult than the judgement task because it involves a larger range of possible responses. Hanson and McGarr (1989) demonstrated the difficulty of the generation task in deaf college students who produced only 50% correct rhymes in response to written words. We therefore considered it interesting to investigate the effect of CS on rhyme generation. In Experiment 2, CS^+ and CS^- children were compared to hearing control groups, which were matched for reading level. Deaf children with an oral or a signed linguistic background were not included because Experiment 1 did not show any difference between them and CS^- children.

In order to get some insight about the source of information used by the subjects, two variables were manipulated. The first was rhyme consistency. Consistent items are those for which the orthographic rhyme has only one pronunciation (e.g. in French POMME: The rhyme -OMME can only be pronounced /ɔm/; see Peeremam & Content, in press; Ziegler, Jacobs, & Stone, 1996). In this case, the spelling provides a reliable clue to find correct rhyming responses: the words ending with the same spelling pattern always rhyme. By contrast, inconsistent items are those for which the orthographic rhyme is inconsistent in terms of spelling-to-sound (e.g. in French FILLE: The rhyme -ILLE can be pronounced either /ij/ as in BILLE or /il/ as in VILLE). In this case, the spelling is misleading: Words spelled with a same orthographic pattern can have a different pronunciation from that of the target.

The second variable was modality of presentation of the targets: written words versus pictures. For written targets, all the subjects could be influenced by the presented word spelling, thus showing a consistency effect. For pictured targets, differences between groups were expected. Hearing and CS^+ children who are able to generate rhymes on the basis of the accurate phonological representation of the target would not be misled by the spelling, which was not presented in the picture. By contrast, the CS^- children who access inaccurate phonological representations might rely on the word spelling, leading them to generate more errors for inconsistent than for consistent targets.

The nature of responses gives us some insight into the strategies used. Correct responses are of two types: orthographically similar to the target (e.g. in French PAIN–BAIN) or orthographically different (e.g. in French BLÉ–NEZ). Hanson and McGarr (1989) have argued that genuine rhyming ability is more clearly evidenced by orthographically different responses, because these responses cannot be generated on the basis of an orthographic strategy. They found only 17% of this kind of response in deaf college students. In the present study, a higher proportion of orthographically different responses was expected in hearing controls and in CS^+ children than in CS^- subjects. Finally, a qualitative analysis of the errors was performed.

Method

Subjects

New groups of CS^+, CS^- and hearing children were recruited. The CS^+ group included 20 children (mean age: 11 years 4 months), who had been educated with CS from a mean age of 39 months. The CS^- group included 20 children (mean age: 16 years 10 months), in contact with CS at school from a mean age of 85 months. None of the children had any noticeable intellectual or cognitive deficits that were not explained by their early hearing loss although, one of the CS^+ children was mentioned as being dysarthric.

As the present experiment was concerned with rhyme generation as a function of a variable (spelling-to-sound consistency) associated with the reading ability, the deaf children were matched with hearing children having the same reading level. The children's reading ability was evaluated by the Lobrot Test, a sentence completion test of 36 incomplete sentences (Lobrot, 1973). The children had to choose which of five possible words completed the sentence appropriately and to fill in as many sentences as they could in a fixed time of 5 min. The score is the number of correct responses. Because some of the CS^- subjects had a lower reading level than any of the CS^+ subjects, two hearing control groups of 20 children each were formed. The characteristics of the deaf groups and the hearing controls are presented in Table 3.

TABLE 3
Characteristics of deaf and hearing subjects of Experiment 2

		CS^+	*Hearing 1*	*CS^-*	*Hearing 2*
	N	20	20	20	20
	Male	8	12	12	8
	Female	12	8	8	12
Chronological Age[a]					
	Mean	11;4	10;6	16;10	10;4
	Range	(7;1–18;2)	(7;9–11;10)	(9;11–21;3)	(9.0–11;3)
Hearing Loss					
	Mean	100.0	–	88.4	–
	Range	(89–114)	–	(66.3–116.3)	–
	2000				
Intelligibility					
	Mean	4.1		3.5	
	Range	1–6		1–6	
Reading Score					
	Mean	27.3	26.9	21.6	21.7
	Range	(14–35)	(14–35)	(10–36)	(9–35)

[a]Chronological age is given in years; months.

Note: CS^+: deaf children educated with CS at home and at school; Hearing 1: control group matched with the CS^+ group for reading level; CS^-: deaf children educated with CS only at school; Hearing 2: control group matched with the CS^- for reading level.

Materials

The stimuli for the experiment consisted of 40 French words, of two categories:

1. A total of 20 were consistent items: The orthographic rhyme of the final syllable was entirely consistent in terms of spelling-to-sound, giving an unambiguous clue to the pronunciation (e.g. in French POMME: The rhyme -OMME can only be pronounced /ɔm/).
2. A total of 20 were inconsistent items: The orthographic rhyme of the final syllable was inconsistent in terms of spelling-to-sound and thus could lead to different pronunciations (e.g. in French FILLE: the rhyme -ILLE can be pronounced either /ij/ as in BILLE or /il/ as in VILLE[2].)

In each condition, ten words were presented as pictures alone and the other ten as written words (+ pictures). In this latter type of presentation, pictures were added to the written words in order to guarantee that the meaning was clear. Indeed, the participants who used grapheme–phoneme correspondences sometimes failed to identify the referent. For example, faced with the word PAON (/pã/), they would generate the phonological form /paɔ̃/. The picture of a peacock was therefore added in order to guarantee the correct identification of the written word. The order was fixed: The picture list was presented first, followed by the written word (+ picture) list. In each list consistent and inconsistent items were randomly mixed. Stimuli were presented to each subject in the same order on four pages. The stimuli were presented on the left of the page, and the subjects had to write rhyming responses at the right.

The stimuli were selected in such a way that the words were known to deaf children and could be represented pictorially. Similar rhymes were presented in both conditions (pictures and written words). In addition, the stimuli presented in picture form were matched with those presented as written words in terms of frequency of use. The complete list of stimuli is shown in the Appendix.

Procedure

The task was a collective paper-and-pencil test. The children were asked to write two rhyming words for each target. They were explicitly told that the name of the stimulus was not considered as a correct response. Before the experiment, the subjects were reminded that "rhyme" meant words that sounded the same at the end, independently of the way that they were spelled. Examples of rhymes were provided in order to make it clear that rhyming words must phonetically share the same final vowel and any consonants that might follow it. The subjects were trained to generate rhymes in response to three pictured words.

Hearing and deaf children were tested in their respective classrooms. If they did not succeed in identifying the name of the picture, they could ask for a definition of the word. An oral definition was then provided to hearing children and the sign (from sign language) was produced for the deaf participants. Targets were never pronounced by the experimenter (J. Leybaert or B. Charlier).

[2] In 16 cases, the whole rhyme was inconsistent. In two cases, only the orthographic vowel of the rhyme was inconsistent (the vowel -OEU could be pronounced /œ/ as in COEUR and SOEUR or /ø/ as in NOEUD). In the remaining two cases (BANC and DOIGT) the orthographic rhyme ended with a mute grapheme that is pronounced in other French words (i.e. the C is mute in BANC /bã/ but is pronounced in ZINC /zɛ̃k/; the T is mute in DOIGT /dwa/ but could be pronounced in VINGT /vɛ̃t/).

Scoring

Percentage of Correct Responses. The answers were first scored in terms of rhyming or non-rhyming responses. The scoring was conservative: A response was scored as a correct rhyme only if the final vowel and any consonants that might follow it were phonologically similar to those of the target. For example, the response OSE /oz/ to BOSSE /bɔs/ was scored as incorrect because there is no word in French ending with the spelling -OSE and rhyming with /ɔs/.

Sometimes the subjects did not follow the instructions: They gave the name of the picture as the response or gave only one response to the target. Also, in a few cases, the subjects failed to identify the target word and gave responses rhyming with a semantically related word. It was decided to classify such cases as omissions and not to take them into account in the analysis.

Nature of the Responses. Correct rhyming responses were divided into two categories. When the rhyme of the response was orthographically identical to that of the target, the response was considered as orthographically similar (e.g. in French POMME–HOMME; CUISINE–TARTINE; PAON–FAON). When the rhyme of the response differed by one letter or more from that of the target, the response was considered as orthographically different (e.g. in French POMME–ROME; NEZ–CLÉ; PAON–ENFANT).

For the purposes of error analysis, a hierarchical classification based on the orthographic and phonological link with the target was adopted. The first criterion was orthographic similarity: The responses were either *orthographically similar* (e.g. in French FILLE /fij/–VILLE /vil/, Category 1) or spelled differently. In this latter case, the vowel was considered in order to distinguish the responses sharing the same phonological vowel from those with a different phonological vowel. The responses sharing the same phonological vowel were further split into *vowel phonologically similar–orthographically similar* (e.g. in French SAC /sak/–PARC /park/, Category 2) and *vowel phonologically similar–orthographically different* (e.g. in French FROID /frwa/–WAF /waf/, Category 3). The responses with a phonologically different vowel were in turn split into *vowel phonologically different–orthographically similar* (e.g. in French SOEUR /sœr/–NOEUD /nø/, Category 4) and orthographically different. In this latter case, the phonological similarity of the consonant following the vowel was considered. The responses sharing the same phonological consonant were split into *consonant phonologically similar–orthographically similar* (e.g. in French POMME /pɔm/–FEMME /fam/, Category 5) and *consonant phonologically similar–orthographically different* (e.g. in French BOSSE /bɔs/–BÉATRICE /beatris/, Category 6). Finally, the responses including a phonologically different consonant were split into *consonant phonologically different-orthographically similar* (e.g. in French FILLE /fij/–ELLE /ɛl/, Category 7) and *orthographically and phonologically unrelated (Category 8).*

Results

Percentage of Correct Responses

Table 4 shows the percentage of correct rhyming responses for pictures and words for the CS^+ group, the CS^- group, and their corresponding control groups. Two mixed ANOVAs were performed in order to compare each deaf group with its control group. Hearing status (deaf or hearing) was the between-subjects factor, and modality of presentation (pictures or words) and spelling-to-sound consistency (consistent or inconsistent) were the within-subjects factors.

CS^+ participants differed from their hearing controls on overall accuracy, $F(1, 38) = 5.58$, $p < .05$. There was also a significant effect of spelling-to-sound consistency, $F(1, 38)$

TABLE 4
Mean percentage of correct responses and corresponding standard deviations in rhyme generation as a function of target type and group of subjects

	Pictures				*Words*			
	Consistent		*Inconsistent*		*Consistent*		*Inconsistent*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Hearing 1	92.1	13.9	92.5	13.5	89.3	17.8	88.9	13.3
CS^+	83.2	15.1	79.9	14.2	88.2	11.5	76.0	18.9
Hearing 2	92.4	11.4	92.2	8.9	94.4	9.1	86.8	14.9
CS^-	61.8	22.9	52.5	23.5	63.8	23.6	48.3	22.1

Note: Legend of the groups: see Table 3. *M* = mean. *SD* = standard deviation.

= 8.16, $p < .05$. This interaction between hearing status and spelling consistency was significant, $F(1, 38) = 8.10$, $p < .05$, with CS^+ subjects being more affected by spelling consistency than were hearing subjects. The modality of presentation was not significant ($F < 1$). The interaction between modality of presentation and spelling consistency was marginally significant, $F(1, 38) = 3.74$, $p = .061$, thus indicating a tendency towards a larger effect of spelling consistency for words than for pictures. The modality of presentation did not interact with hearing status ($F < 1$), and the three-way interaction was also not significant ($F < 1$).

The second ANOVA on the CS^- children and their hearing controls revealed a significant effect of hearing status, $F(1, 38) = 48.49$, $p < .001$. There was a significant effect of spelling consistency, $F(1, 38) = 24.67$, $p < .001$, which interacted significantly with hearing status, $F(1, 38) = 6.80$, $p < .05$. CS^- children were more affected by spelling consistency than were their hearing controls. Modality of presentation did not produce a significant effect ($F < 1$), but interacted with spelling consistency, $F(1, 38) = 6.56$, $p < .05$, thus indicating a greater effect of spelling consistency for words than for pictures. The three-way interaction was not significant ($F < 1$).

Although CS^- and CS^+ children differed from their hearing controls, it is obvious from Table 4 that CS^+ children outperformed CS^- children. CS^+ children also achieved better reading scores than CS^- children. Therefore, in order to compare the two groups directly, a mixed analysis of covariance (ANCOVA) was performed with group (CS^+, CS^-) as the between-subjects factor, modality of presentation (pictures or words) and spelling consistency (consistent or inconsistent) as the within-subjects factors, and reading score as the covariate. This analysis revealed a significant effect of reading, $F(1, 37) = 12.70$, $p < .001$, and a significant effect of group, $F(1, 37) = 13.76$, $p < .005$. Thus, even with adjusted scores for the reading level, CS^+ children outperformed CS^- children in rhyme generation.

Nature of the Responses

Table 5 shows the percentage of correct responses based on orthographic similarity with the target. Hearing subjects gave more orthographically different responses than orthographically similar responses. CS^+ children gave approximately the same proportion of responses of both types. CS^- children gave more orthographically similar than orthographically different responses. The CS^+ group did not differ from its control group in the proportion of orthographically similar responses, $t(38) < 1$. However, CS^+ children differed from their hearing controls for orthographically different responses, $t(38) = 2.89$, $p < .05$. The CS^- group slightly differed from its control group for orthographically similar responses, $t(38) = 2.10$, $p < .05$, but to a greater extent for orthographically different responses, $t(38) = 8.43$, $p < .001$.

Table 6 indicates that most of the errors in each group of participants belonged to Category 2: The vowel was phonologically and orthographically identical but the coda was different (e.g. in French SAC /sak–PARC /park/). Errors of this category were equally frequent in CS^+ participants and in their hearing controls, $t(38) = -.07$, but were more common in the CS^- group than in their hearing controls, $t(38) = 3.77$, $p = .001$.

TABLE 5
Mean percentage of different types of responses as a function of groups of subjects

		CS^+	*Hearing 1*	*CS^-*	*Hearing 2*
Correct Responses	Orthographically similar	40.9	38.6	32.9	40.3
	Orthographically different	41.1	52.3	23.9	51.2
Incorrect Responses		17.9	8.9	43.2	8.5

Note: Legend of the groups: see Table 3.

TABLE 6
Percentage of errors classified into each category

	CS^+	*Hearing 1*	*CS^-*	*Hearing 2*
Category 1 (FILLE–*VILLE*)	1.5	0.4	2.2	1.6
Category 2 (SAC–*PARC*)	4.5	4.4	11.0	3.5
Category 3 (FROID–*WAf*)	0.3	0.0	0.1	0.0
Category 4 (SOEUR–*NOEUD*)	2.8	0.2	3.8	0.3
Category 5 (POMME–*FEMME*)	1.0	0.0	2.7	0.4
Category 6 (BOSSE–*BEATRICE*)	0.5	0.0	0.7	0.3
Category 7 (FILLE–*ELLE*)	0.0	0.1	0.5	0.2
Category 8 (unrelated)	3.8	1.5	16.7	1.3
Lack of response	3.6	2.3	5.6	1.0
TOTAL	17.9	8.9	43.2	8.5

Note: Legend of the groups: see Table 3. For a description of the categories, see main text.

Errors belonging to Category 3 (vowel phonologically identical but orthographically dissimilar) were rare in deaf children and absent in hearing children.

Errors that were orthographically similar (vowel and/or consonant) to the target but were pronounced differently were of some interest. Such errors occurred in Category 1 (e.g. in French FILLE /fij/–VILLE /vil/), Category 4 (e.g. in French SOEUR /sœr/–NOEUD /nø), and Category 7 (e.g. in French FILLE /fij/–ELLE /ɛl/). It is interesting to note that these errors appeared in both the CS^+ group and the CS^- group but not in hearing groups. Finally, errors with the coda phonologically identical (Categories 5 and 6) were rare, but a little bit more abundant in deaf than in hearing children.

Rhyme Production Proficiency in Relation to Other Language Factors

Some children were clearly more skilled than others in the rhyme generation task. For hearing children, the percentage of correct responses ranged from 70.0% to 100.0%, with one outlying case who achieved only 43.5% correct responses. For deaf children, the percentage of correct responses ranged from 60.2% to 97.0% in the CS^+ group and from 25.0% to 95.0% in the CS^- group. Spearman rank correlations were calculated within each group between the mean accuracy level in the experimental task, on the one hand, and chronological age, mean hearing loss, speech intelligibility level, and reading level on the other hand. As in Experiment 1, no correlation appeared between accuracy in the experimental task and chronological age in the two CS groups. The correlation between accuracy and hearing loss at 2000 Hz was significant for the CS^- group ($r = -.54$, $p < .01$, the more profound the hearing loss, the lower the accuracy) but not for the CS^+ group ($r = -.17$, n.s.). A significant correlation was also obtained between mean accuracy and speech intelligibility for the CS^- group ($r = .71$, $p < .001$); the poorer the intelligibility, the lower the accuracy), but not for the CS^+ group ($r = .22$, n.s.). As in Experiment 1, the correlations calculated between speech intelligibility and hearing loss were significant for the CS^- group (mean hearing loss: $r = -.63$, $p < .01$; hearing loss at 2000 Hz: $r = -.67$, $p < .001$; the more profound the hearing loss, the poorer the intelligibility). For the CS^+ group, these correlations did not reach the significance level when calculated on the entire sample (mean hearing loss: $r = -.13$; hearing loss at 2000 Hz: $r = -.36$) but were higher when the dysarthric child was not taken into account (mean hearing loss: $r = -.25$; hearing loss at 2000 Hz: $r = -.55$, $p < .01$). Finally, the correlation between accuracy in the experimental task and reading level was significant only for the CS^- group; this correlation shared the same tendency in the other three groups without being significant, indicating that reading ability tended to be related to phonological sensitivity.

Discussion

The aim of Experiment 2 was to investigate whether deaf children educated with CS rely on accurate phonological representations to support rhyme generation. The CS^+ group, like hearing children, achieved a high level of accuracy and produced a high percentage of correct responses that were orthographically different from the target. However, the mean accuracy of CS^+ children was slightly lower than that of their hearing controls. The results of the CS^+ results contrast with those of CS^- participants who achieved only a limited level of accuracy and produced fewer words that were orthographically different from the target rhyme. It is interesting to note that the results of CS^- children are similar to those reported by Hanson and McGarr (1989) for college deaf students educated with sign language.

The data indicate that, unlike their hearing controls, CS^+ children are sensitive to spelling consistency when generating rhymes. Indeed, they exhibit a consistency effect when responding to pictures as targets and particularly, when responding to written words as targets. This parallels the data of the CS^- group, who also exhibit a greater consistency effect than their hearing controls, for both pictures and words.

The level of accuracy and the proportion of correct responses that are orthographically different from the target suggest that CS^+ children do use phonological coding to generate rhymes whereas, conversely, the effect of consistency suggests they are more sensitive to spelling than are hearing participants. Certain observations made during the experiment indicate that the use of word spelling is not the only factor responsible for the consistency effect. While searching for rhyming words, children sometimes pronounced the targets aloud, indicating that they were accessing the phonological codes. For some inconsistent targets, they gave non-standard pronunciations followed by answers that rhymed correctly with those pronunciations. For example, for the target "fusil" in French, they might pronounce /fyzil/ instead of /fyzi/ and answer "asile" /azil/ or "ile"/iː l/. Of course, these responses are scored as incorrect because they do not rhyme with the standard pronunciation. These non-standard pronunciations seem to reflect the characteristics of the phonological representations that might have been derived from the spelling of the word. This observation indicates that the effect of spelling consistency is an ambiguous indicator of whether or not deaf children use their phonological representations to generate rhymes.

The analysis of errors shows that in all the groups, the most frequent error (apart from unrelated ones) takes the form of words sharing only the vowel—orthographically and phonologically—with the target but not the consonant. These answers often differ from a correct response only in that a final consonant is erroneously added (e.g. in French SAC /sak/–PARC /park/) or omitted in the response (e.g. in French SAC /sak/–LA /la/). The total number of errors that phonologically share the vowel with the target (Categories 1, 2, and 3) represent about one third of the errors for CS^+ and CS^- children and about half of the errors observed in their hearing controls. These errors can be considered as approximate rhyming responses. They confirm that deaf children tend to focus on the vowel in their phonological representations when trying to find rhymes, sometimes not taking into account the pronunciation of the consonant. Moreover, in all the groups, most of the responses (correct or incorrect) are orthographically different, thus indicating that participants rely on their phonological representations and not on spelling to generate rhymes.

GENERAL DISCUSSION

The question addressed by this paper is whether a system that visually provides all the phonological contrasts of speech allows deaf children to develop accurate phonological representations. This question was examined by comparing the rhyming performance of deaf children educated with CS with that of deaf children from other linguistic backgrounds and with hearing controls. CS is a system that complements speechreading with manual gestures in order to deliver complete phonological information.

In the rhyme judgement task using pictures, deaf children educated with CS at home achieve a high level of performance, as do their hearing controls. Such a level of rhyming ability has not previously been reported in profoundly deaf children. Up to now, all studies (Campbell & Wright, 1988; Hanson & Fowler, 1987; Sterne, 1996) have involved literate participants and have drawn the conclusion that deficits exist in this population. The rhyming scores, both average and individual, of children educated with CS at home are within the range of the scores of normally hearing participants. Unlike the other deaf children, and contrary to the data of the literature, they are not influenced by word spelling when they have to decide if two pictured words rhyme.

In children educated with CS at home, the ability to judge rhymes is present before learning to read, as is the case in hearing children (Bradley & Bryant, 1983). The performance of deaf pre-readers supports the idea that the ability to judge phonological similarity can emerge spontaneously in the course of language development, even in the absence of any reading tuition. This seems to be true only for the children benefiting from a phonologically well-specified and intensive linguistic input: Only the children educated with CS at home were able to perform the experimental task with a high level of accuracy.

In the rhyme generation task, children educated with CS at home achieve a high level of accuracy, with a high proportion of correct responses that are orthographically different from the target. Here, too, deaf children educated with CS at home differ from the deaf children who have been studied in the literature (Hanson & McGarr, 1989).

Despite their high level of performance, children educated with CS at home differ from their hearing peers in several aspects. In rhyme judgement, they are affected by speechread similarity. The effect of speechread similarity has not yet been described in the literature. It appears in all deaf children but is weaker in deaf children educated with CS at home. The same effect appears in normally hearing pre-readers. Keeping in mind that speechreading is part of the speech perception process in deaf people as well as in hearing people (Campbell & Dodd, 1980; Campbell, Dodd, & Burnham, 1998; McGurk & MacDonald, 1976), an initial explanation could be that the speechread representation is activated by both deaf and hearing children during rhyme judgement. This suggests that cross-modal phonological representations suffer from lack of accuracy in deaf as well as in hearing pre-readers (Fowler, 1991; Metsala & Walley, 1998; Walley, 1993). Whereas these representations become more accurate with age in hearing children, this refining process could be slower in deaf children (Leybaert, 1998a). A second explanation could be that children are misled by the word pairs that share certain articulatory features, given that speechread similarity is confounded with articulatory similarity. If this is the case, deaf children—even those educated with CS—could be impaired in the rehearsal process because they do not benefit from an auditory feedback from their own productions. Future experiments should be conducted to test these two hypotheses.

In rhyme generation, all deaf children are affected by word spelling, whatever their educational background. This result seems to contradict the results of the rhyme judgement task in which children educated with CS at home are shown not to be sensitive to spelling. The discrepancy can be explained in different ways. First, the written response, not required in rhyme judgement with pictures, may have induced an orthographic strategy in the rhyme generation task. Second, deaf subjects may be influenced by the presented spelling of written word targets. A third explanation could be that deaf subjects derive the pronunciation of some of the target words from their spelling and have stored this inappropriate pronunciation in their phonological lexicon. This might have played a greater role in the rhyme generation task than in the judgement task because the targets used in the judgement task are easier and more frequent. One way to test this latter hypothesis would be to show pictures of incongruent words to deaf subjects and observe their pronunciation. By obtaining a large number of pronunciations derived from spelling, it would be possible to confirm the hypothesis of incorrect or non-standard phonological representations (e.g. in French, the pronunciation /paɔ̃/ instead of /pɑ̃/ for PAON; in English, the pronunciation /gɛʳ/ instead of /giəʳ/ for GEAR).

Although there are certain differences between children educated with CS at home and hearing children, the main results of the two experiments allow us to answer our initial question in the affirmative. Indeed, the rhyming ability shown by these deaf children leads us to conclude that systems that visually specify all the phonological contrasts, as CS does, permit the development of accurate phonological representations. The most important implication of such a conclusion is that the development of phonological representations does not necessarily depend on the acoustic input, but rather on the delivery of accurate phonological input, independently of the sensory modality. These data point to the linguistic, abstract, and amodal, nature of phonology. The combination of speechread information and visual information delivered by handshapes is necessary and sufficient to transmit information about phonemic distinctiveness (Leybaert, Alegria, Hage, & Charlier, 1998).

The present data contradict the idea that rhyming sensitivity is determined by quality of external speech (Conrad, 1979). In the two experiments, children educated with CS at home do not differ from the other groups of deaf children with regard to their degree of hearing loss or their speech intelligibility. However, their performance in rhyming tasks clearly differentiates them from the other deaf subjects. What primarily makes them different is the nature of the linguistic input that they have received. This input—phonetically augmented speechreading via the visual channel, CS in this case—did not affect the quality of their speech production mechanisms directly (Ryalls, Auger, & Hage, 1994). The data presented here indicate that it appears to affect the accuracy of the children's mental representations of speech, which, in turn, support accurate rhyming. These data are therefore compatible with Gathercole and Martin's (1996) hypothesis stating that the representations derived from the speech perception process, rather than those derived from speech production, are involved in rhyming tasks.

The accuracy of the linguistic input should be one of the priorities in educational programmes for deaf children. An important constraint, however, lies in the fact that phonetically augmented speechreading has to be used early at home to lead to the development of accurate speech representations. Indeed, the children educated with CS only at school do not exhibit a high level of rhyming ability. Children exposed to CS at home often differ on two variables from their peers educated with CS at school only: quantity of phonological representations and precocity of linguistic experience.

The expansion of the phonological lexicon may force the development of a more economical way of storing phonological information, in narrower units (Fowler, 1991; Metsala & Walley, 1998; Nittrouer, Studdert-Kennedy, & McGowan, 1989; Walley, 1993). A certain number of stored utterances might also be needed in order to allow children to extract regularities at the phonological level (i.e. to notice that different words end with a common rhyme). For these two reasons the volume of phonological representations may determine the development of rhyming ability. Children exposed to CS at home differ from other deaf children on this variable. They have developed more representations of words in their lexicon than have orally educated children of the same chronological age, who are language delayed (Hage, 1994; Hage, Alegria, & Périer, 1991). Quantity of phonological representations cannot, however, be the only determinant of the development of analytical processes of language. Indeed, deaf adults who were skilled readers and who may be supposed to have stored a large number of phonological representations were found to exhibit deficiencies in tasks requiring manipulation of rhyme (Hanson & Fowler, 1987; Hanson & McGarr, 1989). Regularities at the phonological level can obviously only be extracted if the representations are sufficiently detailed and accurate.

There is a second factor that points to a difference between children exposed to CS at home and their peers. This is the precocity of their linguistic experience. The parents who use CS generally begin to do so before their child is 2 years old. In contrast, the starting age of exposure to CS at school is at least 3 years, and generally 6 years. This could explain the difference between the results of children educated with CS at home and those in contact with CS only at school. Several authors have discussed the existence of a critical period for the development of analytical language-specific processes (Emmorey, Bellugi, Friederici, & Horn, 1995; Locke, 1997; Marcotte & Morere, 1990; Mayberry, 1995; Mayberry & Eichen, 1991; Neville, 1991; Neville et al., 1997). Children exposed to CS only at school might not have received a sufficiently consistent linguistic experience at an early age, especially before the age of 2 years. When they later learn more words, mainly on the basis of exposure to written language, it could be too late for phonological, metaphonological, and grammatical processes to develop accurately. Therefore, these children could be limited to the global processing of linguistic stimuli.

The present data do not allow us to evaluate the role played by each variable: quality of the linguistic input, quantity of phonological representations, and precocity of the linguistic input. Clearly, further experimental research is needed to determine whether the individual contribution of these variables can be identified in terms of their effect on rhyming skills. One way to evaluate the effect of precocity on the accuracy of phonological representations would be to compare children exposed to CS at home from different starting ages. If precocity is the critical factor, the children educated early with CS would possess different rhyming skills from those exposed to this system at a later age.

The results of these two experiments could have a significant impact. There is now a large consensus that the quality of phonological representations affects several cognitive abilities: rhyming, remembering, and reading (Campbell, 1991). The first experimental investigations in these three domains have revealed that children educated with CS at home show characteristics similar to those of hearing children: rhyme and length effects in the ordered recall of pictures (Charlier, 1994; see also Leybaert & Charlier, 1996), a similar reading level to their hearing peers matched for chronological age (Wandel, 1990), and a similar use of phoneme–grapheme correspondences when spelling (Leybaert, 1998b). These data, together with those provided by the current research on sign language, suggest that deafness per se is not the causal factor of the cognitive deficits usually associated with it, but that such deficits are caused by a lack of linguistic experience.

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APPENDIX

Stimuli used in Experiment 1

Rhymes		*Non-rhymes*	
R^+O^+	R^+O^-	R^-SR^+	R^-SR^-
MOUCHE/BOUCHE	LIT/RIZ	MOUTON/MOTO	NEZ/COU
TRAIN/MAIN	FEU/NOEUD	PIED/PAIN	MOULE/GANT
ANE/BANANE	DOS/SEAU	LIT/NEZ	LUNE/FLEUR
TABLE/SABLE	PAIN/CHIEN	CLE/TRAIN	BANANE/SOLEIL
CHAISE/FRAISE	LOUP/COU	ROUE/FEU	MAIN/SEAU
COEUR/FLEUR	SOLEIL/OREILLE	BUS/BOUCHE	POULE/MANTEAU
POULE/MOULE	DENT/GANT	PORTE/BOUTON	ROBE/BALLE
	MER/VERRE		RIZ/PAIN
	MOTO/MANTEAU		LOUP/TRAIN
	NEZ/CLE		CLE/TASSE
	TASSE/GLACE		

Note: R^+O^+: rhyming pairs with similar spelling; R^+O^-: rhyming pairs with different spellings; R^-SR^+: non-rhyming pairs with similar speechread image; R^-SR^-: non-rhyming pairs with different speechread image.

Stimuli used in Experiment 2

Congruent		*Incongruent*	
picture	*word*	*picture*	*word*
TARTINE	PISCINE	SOURIS	TAPIS
CLOU	TROU	CHAMP	BANC
MANTEAU	BATEAU	NID	RIZ
MAISON	COCHON	FUSIL	SOURCIL
POMME	HOMME	COEUR	SOEUR
MER	VER	SIX	DIX
BROSSE	BOSSE	FILLE	AIGUILLE
DE	THE	NEZ	PIED
MAIN	BAIN	FAON	PAON
SAC	LAC	DOIGT	FROID