Reading Mechanisms in Orally Educated Deaf Adults

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This study was aimed at determining the reading mechanisms used by deaf adults who had completed secondary or higher education. Our main hypothesis was that they used a reading strategy consisting of identifying (some of) the key words of sentences and deriving an overall representation of their meaning. All the predictions derived from this hypothesis were supported by the results. In addition, an orthographic test showed that they possessed an orthographic lexicon richer than hearing group of the same reading level. This is in harmony with the key word strategy. Finally, most of the deaf participants (12 out of 14) reached scores in metaphonological tasks slightly under the level reached by the hearing group. It is speculated that the mechanisms of reading and spelling at play in deaf adults are based on phonological representations of words.

It is well established that deaf persons generally present important reading and spelling difficulties. Thirty years ago, in a carefully conducted study, Conrad (1979) examined the reading level reached by nearly all the students leaving special schools for hearing-impaired children in England and Wales from 1974 to 1976. The median reading age for the subgroup presenting hearing losses greater than 86 dB was 7 years, which is the zero level of the test. That is to say, 50% of the students were very poor readers. Conrad suggests that a reading age of 11–12 years might be considered as being sufficient to use reading as a tool for learning from written material. Less than 15% of his sample reached this reading level. Studies conducted more recently support Conrad’s findings (Allen, 1986; Harris, 1994; Lichtenstein, 1998; Marschark and Harris, 1996; Musselman, 2000; Paul and Jackson, 1994; Perfetti and Sandak, 2000).

In spite of this situation concerning average reading ability in deaf students, there are considerable individual differences, and some deaf readers achieve a much higher competence than others. It is important to analyze the reading mechanisms used by these persons in the same way as an examination of how good golf or tennis players operate, which might help to understand their secrets and determine potential causes of the poor level of play of others. In the present study, a group of deaf adults who attended at least secondary-level education were selected in order to examine their reading mechanisms individually. It was hypothesized that this could reveal which were the good reading mechanisms. It is obvious that a reading age established with a test can be obtained using different reading strategies. For example, Conrad (1979) used the Wide-span Reading Test (Brimer, 1972), which consists of a series of pairs of sentences, one of which has a missing word that has to be found in the other sentences. The overall score obtained in this test says nothing about the way in which it was reached. The main aim of this study was to explore the underlying reading mechanisms in order to determine their relationships with an overall reading level. As well, we would like to explore the notion that successful deaf readers share some common features that characterize them as a specific group.

Current theories about reading mechanisms in hearing people point out two notions which are worth examining separately in the context of deaf reading. The first concerns the direct impact of linguistic knowledge at lexical and syntactic levels on reading ability. Indeed, individual differences in reading comprehension in deaf students are mainly due to this
factor. Obviously, it is impossible to fully understand a sentence if the reader does not know (some of) the words it contains and its syntactic structure. It might be hypothesized that deaf readers, not entirely familiar with some of the words of a sentence, have to extract its meaning by using the words they know. These words are generally the most frequent content words of the sentence. This procedure allows them gain an approximate understanding of the meaning of the sentence. One of the aims of this study was to examine the use of this procedure, which we shall name the key word strategy.

The second point concerns the availability of phonological representations of words in the mental lexicon. A great number of cognitive activities, including reading, rely on phonological coding. The main reason is that phonological codes are a central device in working memory, which has ubiquitous functions in human cognition. Hearing literature shows that when higher-level linguistic factors like vocabulary and syntax are controlled, individual differences at the phonological level are the most important determiners of reading ability (Alegria, 2003; Leybaert, 1993; Musselman, 2000; Perfetti and Sandak, 2000).

It might be asked whether deaf persons do possess phonological representations of words. Convergent evidence from numerous experimental paradigms, for example, short-term memory, rhyming decision tasks, and spelling, among others, have demonstrated that at least for some profoundly deaf persons, this is clearly the case and that this is not an exceptional situation (Alegria, Leybaert, Charlier, and Hage, 1992; Beech and Harris, 1997; Campbell, 1994; Charlier and Leybaert, 2000; Hanson, Shankweiler, and Fisher, 1983; Harris and Beech, 1998; Leybaert and Alegria, 1995, but see Harris and Moreno, 2004 for a critical discussion, and Perfetti and Sandak, 2000, for a well-documented examination of positive and negative evidence concerning phonological coding in the deaf). Moreover, important correlations have been found between phonological coding in these tasks and reading ability. Conrad, in his study of 1979, designed some short-term memory tasks aimed at determining whether the participants coded the words to memorize phonologically or orthographically. The results showed that the former group reached a reading age of about 2 years above the latter group even after controlling for hearing loss and nonverbal intelligence. However, it is worthwhile noting that about half (50.1%) of the participants presenting a hearing loss greater than 86 dB used orthographic codes in the short-term memory task.

Rhyming decision tasks (saying whether two words rhyme or not) as well as rhyme production tasks (giving a word which rhymes with a given target) have revealed important individual differences among deaf participants. Some showed a clear ability to respond correctly to the rhyming questions (Campbell and Wright, 1988; LaSasso, Crain, and Leybaert, 2003; Leybaert and Charlier, 1996), whereas others seemed to use orthographical representations of the words to give the response (rhyming pairs like *hat-hat* were easier than nonrhyming pairs like *bear- here*; Campbell and Wright, 1988). Importantly, this was observed when the stimuli were written words but also when pictures were used. The authors concluded that orally educated deaf youngsters have not developed correct phonological representations of words and rely strongly on their orthographic representations, which are activated even when pictures were used as stimuli.

The third source of evidence concerning phonological coding in the deaf is word spelling. A possible procedure to spell a word consists of activating its phonological code and translating it into the sequence of letters according to systematic rules. Similar results, however, may be obtained using whole orthographic representations without the participation of any phonological codes or translation rules. Individual differences in this task are also important. Some results have suggested that deaf spellers undoubtedly used phonological representation of words to write them down. The evidence supporting this conclusion was that words spelled consistently, that is to say that a sequence of letters may be derived from their phonological representation using consistent spelling rules (i.e., /rat/ spelled “rat”), were better spelled than words presenting inconsistencies (i.e., /siti/ which might be spelled “sity” instead of “city”; Hanson et al., 1983; Leybaert and Alegria, 1995; Sutcliffe, Dowker, and Campbell, 1999). In addition, a proportion in no negligible case of misspellings was pseudo-homophones of the target word (i.e., “sity”).
The data examined so far suggest that some deaf persons do possess phonological codes and use them in a similar manner to the way hearing readers do. This means that auditory information is not a *sine qua non* condition for the development of phonological representation. A purely visually based phonology is conceivable via lipreading alone or with Cued Speech (Campbell, Dodd, and Burnham, 1998) and maybe on the basis of sign language through the insertion of finger spelling (Haptonstall-Nykaza and Schick, 2007). Obviously, these representations of words might be used in reading on at least two levels: written word identification on the one hand and sentence comprehension via working memory on the other hand. Some other deaf persons seem to use word representations they have stored in their mental lexicon without phonological bases. Data reviewed suggest that they are poorer readers than the phonological coders. In the present study, the participants’ orthographic lexicon will be evaluated, and its relationships with their phonological abilities as well as their reading level examined.

**Method**

**Participants**

Fourteen deaf adults (10 female) with a profound prelingual hearing loss took part in this study. The degree of deafness was Type I (from 91 to 100 dB loss; two participants), Type II (from 101 to 110; 10 participants), and Type III (from 111 to 119; two participants) (BIAP, 1997). At the time, only five of the participants wore hearing aids, and none of them had had cochlear implants. They were selected to participate because they were supposed to be “good readers.” The criterion adopted was that they all had reached a postcompulsory level of education; moreover, they read daily for information (newspapers, magazines, and manuals) and for pleasure. In Spain, compulsory education corresponds to 10th grade. After this, students can choose between two paths, a “technical” level, which leads to qualifications such as hairdressing, printing, dress-making, etc., or a classical “secondary” level, which after 2 years gives access to university. Technical studies can be done in 2 years (low technical level) or 4 years (high technical level).

At the time of this research, four participants had reached the low technical level, two participants high technical level, five participants secondary level, and finally three participants university level. Their ages ranged from 20 to 46 years (mean: 33.5 years). The language used in their homes was oral, except for four participants who had deaf parents and used sign language. Nevertheless, they all knew and used sign language, except three participants. All had been educated in special schools for the deaf using pure oral communication methods without sign language or augmentative tools such as Cued Speech. The only exception was participant number 1, who attended secondary education at a bilingual (sign and oral) school.

A group of 125 students without hearing loss were considered as a comparison group. They were between 7 and 12 and attended school grades corresponding to their chronological age: 27 in 2nd grade; 23 in 3rd grade; 27 in 4th grade; 25 in 5th grade; and 23 in 6th grade. This group was chosen as a comparison group in line with our main aim, which was to examine the reading mechanisms used by deaf adults who have the same reading level as ordinary hearing children. It would be interesting to use different comparison groups such as hearing adults with low literacy levels, foreigners with a small command of Spanish, or even dyslexic children, each of which would allow us to explore different questions concerning reading mechanisms. This notion will be examined in the Discussion section.

**Measures**

The aim of this work was to evaluate the level of reading ability of the participants and, even more importantly, to determine the reading mechanisms they used to attain it. A series of tasks were designed to examine these questions. The participant could complete all of them without talking. The responses to be given always consisted of choosing one item from among several options. The tasks were explained to the participants using their preferred way of communication, oral and/or sign language.

*Reading ability test.* For each participant, global reading ability was assessed with a forced-choice sentence
completion test (Carrillo and Marin, 1997). The test consists of 64 sentences with a missing word. Four alternatives were proposed for each sentence, and the participant had to choose the correct one. All the incorrect alternatives were orthographically similar to the target; two were pseudowords and the third one was a real word (e.g., for the correct response “problem” the pseudoword foils were “probrema” and “proglema,” and the word foil was “protesta”). Subjects completed as many sentences as they could in 5 min. The subject’s score was the number of correct responses. As the participant moves from the first sentence onwards, the complexity of the task increases; sentences become longer, words less frequent, and syntactic, cognitive and pragmatic aspects of the sentences more complex: for example, the first sentence was “Tu pelota es de color … rogo, roco, robó, rojo” (The color of your ball is … red”), and the last one “Ten mucho cuidado para que la máquina no caiga al agua, ya que no es … sumergible, sumengible, sumergible, sustituirle.” (Please be very careful the machine doesn’t to fall into the water, because it is not … submersible …) Before the test began, four examples were shown to the participant. This was repeated as many times as necessary until he or she had understood the task. This reliability of this test has been recently evaluated using the test–retest technique on 376 primary school children with an interval of about 1 month between tests (Cuadro, Costa, Trias, and Ponce de León, 2008). The correlation was substantial and significant ($r = .880, p < .001$). The Cronbach alpha for the present sample as well as the split-half technique also reached high values (alpha = .966 and $r = .986$).

**Semantic strategies detection test (SSDT).** The objective of this test was to detect the use of semantic strategies when reading sentences instead of using precise syntactic procedures. The semantic strategy might consist of identifying some key words of the sentence and deducing the sentence meaning solely on this basis (Soriano, Pérez, and Domínguez, 2006).

The test consisted of 64 sentences with a missing word. Four alternatives were proposed for each sentence, and the participant had to choose the correct one. All the incorrect alternatives were semantically similar to the target word: for example, in the sentence “Luis lee muy …” “Luis reads very …”), the correct response was “bien” (well) and the foils were “libros” (books), “biblioteca” (library), and “periódico” (newspaper). The procedure followed in applying this test was the same as with the reading ability test (RAT). As was the case in the RAT, the difficulty of the task increased from the first sentence onwards. The procedure was exactly the same as for the RAT. The reliability of this task evaluated by the Cronbach alpha and the split-half technique also presented high values (alpha = .971 and $r = .988$).

**Orthographic decision task.** The aim of the task was to evaluate the quality of the participants’ orthographic representations. In each trial, they were given two written items, a word and the corresponding pseudo-homophone. They had to decide which one was written correctly (e.g., genio [the correct spelling]—jenio [a pseudo-homophone], both pronounced /xenio/). The test consisted of 40 items made up of a frequently used word paired with a pseudo-homophone.

**Metaphonological tasks.** Three tasks were designed to evaluate the phonological abilities of the participant. They evaluated simultaneously the presence of phonological representations of words and the ability to access and to manipulate them. The term metaphonology, and not simply phonology, is used to describe the abilities involved in these tasks because the participants have to do an explicit activity with phonological representations. It might be admitted that discriminating between two different words or pseudowords is an automatic phonological activity (i.e., recognizing that /rat/ and /kat/ are two different words). Being able to say that they consist of three phonemes and that they differ solely in the initial one is a typical metaphonological task. The concept of metaphonological ability has been developed in relation with the acquisition of reading and spelling since pioneering work by Liberman, Shankweiler, Fisher, and Carter (1974). These authors asked the child to count the number of syllables or phonemes, from one to three, of an utterance given by the experimenter (i.e., but 1, butter 2, and butterfly 3). A vast literature has established strong relationships between these
abilities and reading (for a complete account, see Rayner, Foorman, Perfetti, Pesetsky, and Seienberg, 2001). In the present study, two metaphonological tasks were based on the number of syllables, and the third task required the participant to determine the word stress. The method adopted was inspired by the Bradley and Bryant (1983) “oddity task” in which three drawings were presented to the participants, two of which shared one phonological feature (i.e., having two syllables) not shared by the third (which had only one syllable). The participant had to point out the odd item. This task has been widely used in relation with reading ability, and it was particularly adapted to evaluate metaphonological ability in deaf persons because it does not involve speech production or comprehension.

The test consisted of three series of 15 items. In each task, three drawings in color representing common items possessing well-known names were presented to the participant. As said before, two of them shared a feature and the third did not. The participant’s task consisted of pointing out the “odd one out.” Three conditions were designed depending on the rule that determined the oddity.

**Condition “1-2 Syl”**. The drawings’ names were of either one or two syllables, and the odd item differed in this aspect from the other two (e.g., “flor-mesa-rey” [flower–table–king]). The items had been chosen to avoid the correlation that exists between the number of syllables and the number of letters. In the previous example, “mesa” (bisyllabic) and “flor” (monosyllabic) share the same number of letters. An orthographically based strategy may mistakenly bring the participant to choose “rey” (monosyllabic) as the odd item because it has three letters. The reliability of this task evaluated by the Cronbach was alpha = .582.

**Condition “2-3 Syl”**. This condition was identical to the 1-2 Syl, but the items were of two and three syllables (e.g., “espada-dragón-globo” [sword–dragon–balloon]). The same caution was used to avoid confusion between number of syllables and number of letters (“espada,” the odd item, is a three-syllable word which has six letters, the same number of letters as the two-syllable word “dragon”). The reliability of this task evaluated by the Cronbach was alpha = .740.

**Condition “Stress”**. In this condition, the items had the same number of syllables but the odd one out differed from the two others by the position of the stress (e.g., “cristal-tacón-goma” [glass–heel–rubber]). The reliability of this task evaluated by the Cronbach was alpha = .793.

**Procedure**

The deaf participants were tested individually in three sessions. The first was devoted to the evaluation of their overall reading ability (RAT), and the orthographic decision task (ODT). In the second session, the semantic strategies detection test (SSDT) was presented to the participants, and the third session was devoted to metaphonological tasks. The comparison group was tested collectively in sessions one and two and individually in session three.

**Results**

**Global Reading Assessment (RAT)**

The global level of reading was evaluated using RAT of Carrillo and Marin. Table 1 shows the mean number of correct responses given by the participants in 5 min. The deaf adults as a group gave 49.6 correct responses, a score that corresponds to grade 5.4. This indicates that the deaf adults considered to be “good readers” remained at a level attained by normally hearing children by the end of primary school. An analysis of variance (ANOVA) done on the individual scores of the five groups of normally hearing children (grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>n</th>
<th>CR</th>
<th>PE</th>
<th>n</th>
<th>LE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hitting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td>27</td>
<td>25.74 (1.38)</td>
<td>9.0</td>
<td>24</td>
<td>39.41 (7.02)</td>
</tr>
<tr>
<td>3rd</td>
<td>27</td>
<td>31.30 (1.78)</td>
<td>4.1</td>
<td>20</td>
<td>50.85 (7.88)</td>
</tr>
<tr>
<td>4th</td>
<td>27</td>
<td>40.15 (1.66)</td>
<td>2.9</td>
<td>17</td>
<td>49.60 (10.56)</td>
</tr>
<tr>
<td>5th</td>
<td>27</td>
<td>45.92 (1.71)</td>
<td>2.0</td>
<td>11</td>
<td>28.78 (9.80)</td>
</tr>
<tr>
<td>6th</td>
<td>27</td>
<td>53.78 (1.61)</td>
<td>1.1</td>
<td>10</td>
<td>26.66 (11.70)</td>
</tr>
<tr>
<td>Deaf</td>
<td>14</td>
<td>49.57 (3.28)</td>
<td>1.71</td>
<td>9</td>
<td>68.55 (14.28)</td>
</tr>
</tbody>
</table>

*Note.* n represents the number of participants contributing to the calculation. CR, mean number of correct responses (maximum 64); PE, mean percentage of errors; LE: percentage of lexical errors. Standard errors in parentheses.
2nd to 6th) and the deaf group as between-subjects factor shows a significant Group effect, $F(5, 132) = 37.08, p < .001$. Subsequent posthoc examination of contrasts (Scheffé) showed that the deaf group did not differ from 4th, 5th, and 6th groups of hearing participants at the conventional $p = .05$ level but did differ from 3rd and 2nd graders ($p < .0001$).

In addition to the previous analysis considering the number of correct responses per subject, it was interesting to examine the errors committed. Obviously, the cases are different if they have obtained the same number of correctly read sentences and therefore the same score, from a larger total number of sentences or from a smaller total number. In the former case, there are more errors than in the latter case. Their mean percentage per group appears in Table 1. In the hearing group they were about 9% in 2nd grade but decreased to less than 4% from 3rd grade onwards. The deaf participants produced a low number of errors. An ANOVA on individual percentage of errors with Group as between-subjects factor shows a significant Group effect, $F(5, 132) = 11.82, p < .001$. Posthoc examination of contrasts between groups (Scheffé) showed that 2nd graders significantly differed from all of the other groups ($p = .009$ in the less significant case). No significant differences were observed between the five other groups.

Finally, it was interesting to examine the type of errors. It must be recalled that besides the correct response to each sentence, three foils were included, all of which were orthographically similar to the correct response but only one of which was a real word (the lexical foil). The tendency to choose the lexical foil was calculated among the participants who made at least one error. Table 1 represents the mean percentage of lexical errors per group. Deaf participants tended to produce more lexical errors than hearing participants as a group: 68.56% and 41.34%, respectively. An ANOVA done on individual scores of the six Groups as between-subjects factor failed to reach the conventional level of significance (Group effect, $F(5,85) = 1.85, p < .111$). However, a direct comparison of the hearing participants as a whole with the deaf group revealed a significant difference, $F(1,89) = 4.25, p = .042$. These results suggest that, as predicted, deaf participants used a lexical strategy to read sentences to a greater extent than hearing participants did. We shall take up this notion again in the Discussion section.

Semantic Strategy (SSDT)

Table 2 represents the mean number of correct responses obtained by groups in the SSDT. The mean score of the deaf group was 34.6, which corresponds to a reading level of grade 4.4. An ANOVA done on the six groups of participants as between-subjects factor shows a significant Group effect, $F(5, 132) = 56.92, p < .001$. Subsequent posthoc examination of contrasts between Groups (Scheffé) showed that the deaf participants did not significantly differ from 3rd, 4th, and 5th graders at $p = .05$ level but produced better scores than 2nd graders ($p < .001$) and poorer than 6th graders ($p < .027$).

Table 2 represents the mean percentage of errors per group. In the hearing groups, this score was relatively high in 2nd graders (23%) but fell to below 5% from 3rd grade onwards. The deaf participants produced 15% of errors, which falls between 2nd and 3rd grade. An ANOVA done on the individual number of errors per Group as between-subjects factor shows a significant Group effect, $F(5, 132) = 9.87, p < .001$. Posthoc analysis of contrasts (Sheffe) showed that the deaf Group did not significantly differ from any of the five hearing Groups. The global significance effect obtained comes from the fact that 2nd graders performed significantly more poorly than all of the other groups of hearing participants ($p < .001$ in each case).

**Table 2** Mean number of correct responses and mean percentage of errors in the semantic strategies detection test per group

<table>
<thead>
<tr>
<th>Grade</th>
<th>n</th>
<th>CR (M, SD)</th>
<th>PE (M, SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hearing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td>27</td>
<td>16.44 (1.10)</td>
<td>22.99 (4.78)</td>
</tr>
<tr>
<td>3rd</td>
<td>23</td>
<td>26.65 (1.76)</td>
<td>4.89 (1.60)</td>
</tr>
<tr>
<td>4th</td>
<td>26</td>
<td>32.07 (1.57)</td>
<td>3.88 (1.19)</td>
</tr>
<tr>
<td>5th</td>
<td>25</td>
<td>39.64 (1.56)</td>
<td>2.71 (1.09)</td>
</tr>
<tr>
<td>6th</td>
<td>23</td>
<td>44.73 (1.53)</td>
<td>2.99 (1.50)</td>
</tr>
<tr>
<td>Deaf</td>
<td>14</td>
<td>34.64 (3.49)</td>
<td>15.02 (4.14)</td>
</tr>
</tbody>
</table>

Note. CR, mean number of correct responses (maximum 64); PE, mean percentage of errors. Standard errors in parentheses.
Relationships between Levels of Reading Evaluated by RAT and SSDT Tests

The coefficient of correlation between the two reading tests, SSDT and RAT, was $r = .954$ and $r = .780$ in hearing and deaf groups, respectively, indicating that both tests involved similar abilities. The linear regression equations (SSDT as a function of RAT) had similar slopes in both groups of participants (0.927 and 0.829 in hearing and deaf groups, respectively) but differed in their intercept (−2.468 and −2.640), the hearing participants’ intercept being higher than the one obtained by the deaf participants. This indicates that the deaf participants produced more semantically motivated errors than the hearing readers when their overall reading level evaluated by the RAT was controlled. Twelve out of the fourteen deaf participants had scores in the SSDT below the regression line of the hearing group. Participant 9 was the only one who showed a score clearly above the hearing participants’ regression line. It is interesting to contrast this participant with P2 who had a rather good score in the RAT but the poorest one in the SSDT. This results show that similar (and even high) results in a global reading test can be obtained using radically different reading strategies. We shall return to this question in the Discussion section.

Orthographical Abilities (ODT)

The notion that reading in deaf adults strongly relies on identifying (at least some of) the key words in sentences requires the availability of an important orthographical lexicon. It was hypothesized that this must be greater in deaf adults than in hearing children matched at global reading ability level. In order to evaluate this issue, the ODT was given to the participants. Table 3 represents the mean number of correct responses per group of participants. The mean score of the deaf group was almost 100% correct (39.8 on 40), higher than the score obtained by 6th graders. An ANOVA done on individual scores of the six groups of participants as between-subjects factor shows a significant Group effect, $F(5, 132) = 17.04$, $p < .001$. Subsequent posthoc examination of contrasts (Scheffe) showed that the deaf group performed better than 2nd and 3rd graders ($p < .0001$ in both cases) but did not differ significantly from the three other groups of hearing participants.

Metaphonological Abilities

Three tasks: “1-2 Syl,” “2-3 Syl,” and “Stress” were designed to evaluate the availability of phonological representations of words and the ability to manipulate them. Table 3 represents the mean number of correct responses per group in each task.

In the 1-2 Syl task, the score of the deaf group was 9.8 (chance level 5 and maximum 15), which corresponds to grade 3.3. An ANOVA done on individual scores of the six groups as between-subjects factor shows a significant Group effect, $F(5, 132) = 8.71$, $p < .001$. Posthoc examination of contrasts (Scheffe)
showed that the deaf group did not differ significantly from any of the hearing groups.

In the 2-3 Syl task, the score of the deaf group was 11.1, which corresponds to grade 3.1. An ANOVA done on individual scores of the six groups as between-subjects factor shows a significant Group effect, $F(5, 132) = 7.70, p < .001$. Posthoc examination of contrasts (Scheffe) showed that, as was the case in the 1-2 Syl task, the deaf group did not differ significantly from any of the hearing groups.

In the Stress task, the mean score of the deaf group was 6.4, which failed to differ from the level which would be obtained by chance. Indeed, 10 out of the 14 participants had scores that fell between the confidence limits at $p = .05$ (5.00 ± 2.17). An ANOVA done on individual scores of the six groups of participants as between-subjects factor shows a significant Group effect, $F(5, 132) = 19.47, p < .001$. Posthoc examination of contrasts (Scheffe) showed that the deaf group performed significantly below 4th graders and above ($p < .01$ in all of the cases).

At the end of the metathenologica tasks, deaf participants were asked to explain how they did the task. First of all, let us say that two of them refused to continue the “Stress” task after a few trials, saying that it was too hard. They were attributed a score of 5/15 points, which corresponds to chance level. Among the others, some of the answers they gave reflected the use of spelling strategies (counting letters, e.g., in the syllabic tasks). As mentioned before, the material was created in such a way that this strategy did not allow them to do the task correctly. In the syllable-based conditions, some participants sometimes mentioned that they considered that “two vowels together belong to two different syllables,” which is not always true (e.g., puerta [door] was incorrectly split as pu-er-ta [three-syllable] instead of the correct puer-ta [two-syllable] split). This purely orthographic strategy, however, cannot explain the results because it brought erroneous responses only in four cases in condition 1-2 Syl and in one case in condition 2-3 Syl. Another orthographically based pseudorule given sometimes was that “two consecutive consonants in a word belong to two different syllables,” which is false in numerous cases. Finally, an interesting case concerning the stress-based condition was participant P3, who achieved 100% of correct responses, a totally exceptional score in this task, where deaf participants as a group did not differ from the chance level. She said that she used the rules that permit one to correctly place diacritic marks in Spanish written words (these rules are totally reliable for plurisyllabic words). For example, “if a written word ends with “n,” “s” or a vowel and it does not have a diacritic mark, then the stress is on the penultimate syllable.” It might be useful to remember that the stimuli presented to the participants were pictures. Therefore, in order to perform the task using spelling rules, they had to retrieve the orthographic representations of words and operate with them, applying rather complex orthographic rules to determine the position of the stress. It is interesting to add that this participant needed a considerable amount of time to perform the task. This was never the case in the hearing participants’ group.

Intertask Correlations

As previously mentioned, the two reading tests, RAT and SSDT, were strongly connected to each other, so that individual scores in both tests were collapsed to calculate correlation between reading (in italics to reflect the collapsed score) and the other abilities evaluated in the experiment. As expected, reading was correlated with spelling (ODT) in the hearing participants considered as a group ($r = .453, p < .001$). This correlation could not be estimated in the deaf group because, despite great differences in reading, almost all of them reached the ceiling level in spelling.

As expected, the three metaphonological tasks were correlated with each other. In the deaf group the correlations were $r = .877$, $r = .430$, and $r = .281$ (1-2Syl*2-3Syl, 1-2Syl*Stress, and 2-3Syl*Stress respectively). The corresponding values in the hearing group were $r = .506$, $r = .430$, and $r = .503$. As was done with reading scores, the metaphonological results had been collapsed to calculate their correlations with reading and spelling. In the hearing group, the correlation with reading was $r = .563 (p < .001)$ and with spelling $r = .392 (p < .001)$. In the deaf group, the correlation of reading with metaphonology was $r = .410 (p = .200)$. Regression lines of hearing and deaf
participants had similar slopes (0.073 and 0.057, respectively) but differed in their intercept, which was higher in the hearing than in the deaf group (8.539 and 7.646, respectively). This difference in intercept value was due to two participants whose scores in the metaphonological tasks were exceptionally low. If these participants were excluded from calculations, the intercept reached 9.762, slightly higher than the hearing group’s intercept. So that the results obtained by this restricted deaf group were similar to those of the hearing group, indicating that they possessed phonological representations of words and that they were able to manipulate them.

Relationships between the Characteristics of Deaf Participants and their Reading Ability

The age and level of studies\(^1\) reached by the deaf participants were significantly correlated with reading: \(r = -0.727\) (\(p < .005\)) and \(r = 0.583\) (\(p < .030\)), respectively. The same analysis considering metaphonological scores showed nonsignificant \(r\)-values of –0.220 and 0.371.

The use of audio-prosthesis did show differences in reading. The mean reading scores were 52.20 and 36.50, respectively, in subjects wearing (\(n = 5\)) or not wearing audio-prostheses (Mann–Whitney’s \(U\) test (\(n = 9\), \(U = 4.0\), \(p = .01\) one-tailed). The degree of deafness was not related to the reading level: 36.75, 41.80, and 49.00, respectively, in Type I, Type II, and Type III degree of deafness. Finally, four participants were members of deaf families. Their reading score was 41.62, not significantly different from the mean score of the other 10 participants who came from hearing families: 42.30.

Discussion

The aim of the present study was two-fold. On the one hand, we wanted to establish the level of reading ability reached by deaf persons who were regular readers, and on the other hand, to determine as precisely as possible, which were the reading mechanisms they used.

In order to fulfill the first aim, we selected a group of deaf adults who were attending post-compulsory education and who were supposed to be “good readers” on the basis that they had successfully done, or were attending, post-compulsory education and all of them read books and newspapers daily for pleasure and information. The results they obtained in the RAT corresponded to the last years of primary school. This level might be reasonably considered as sufficient to make use of reading as a tool to extract information from relatively simple texts. Below this level, reading remains insufficiently well-mastered to be exploited (Conrad, 1979). Individual differences between participants were important. Two of them read below 3rd grade, whereas six others had a level equal to or greater than 6th grade. Not surprisingly, the relationships between the reading level and the educational level were quite strong, as shown by the correlation between these two variables (\(r = 0.609\)). It is not possible to derive causal relationships from mere correlations between the reading and educational levels. However, it likely that it is low reading ability that limits the educational level that can be attained and not the other way round.

The second point of interest was to examine the reading mechanisms used by the participants. It was hypothesized that at the lowest levels of reading the participants, both deaf and hearing, might use a reading strategy that consists of identifying some of the words of the sentence, the key words, and deriving an overall representation of their meaning. All the predictions derived from this hypothesis were fulfilled by the data collected. In the RAT test, besides the correct response, three foils were proposed to the reader, only one of them being a real word. The lexical foil was more frequently chosen by the deaf participants (it accounts for about 70% of the errors) than by the hearing readers (about 40%). Interestingly, the tendency to produce lexical errors in the hearing group showed a slight tendency to decrease as the school year progressed. This suggests that the tendency to choose a real word, which was greater in deaf than in hearing participants, is a primitive strategy that tends to disappear when more sophisticated procedures develop.

The most direct evidence concerning the use of the key word strategy to read sentences comes from the comparison of the results in the two reading tests, RAT and SSDT. It must be remembered that in the SSDT, all the foils were acceptable in the semantic context of the sentence. The results show that the
delay in reading shown by the deaf participants as a group was greater for the SSDT than for the RAT. The mean level of the group of deaf readers was grade 5.4 for the RAT and 4.4 for the SSDT. The clearest evidence, however, was where the regression lines considering SSDT as a function of RAT of both groups were sensibly parallel but differed in the intercept value, which was lower in the deaf than in the hearing group. This means that the SSDT was more difficult for the deaf participants even when their RAT level was controlled. The fact that both regression lines were parallel suggests that the difference between groups in the use of semantic strategies based on identifying some key words does not decrease when reading ability increases. It must be recalled that the correct response in the SSDT task must be chosen from among four options, all of them semantically acceptable. In order to decide which one was the correct response, the participant must use his or her morpho-syntactic knowledge. The reason why readers used the key word strategy must be that this knowledge was insufficient. Unfortunately, we did not examine the morpho-syntactic abilities of our deaf participants directly, but a vast literature has shown that they are severely handicapped (King and Quigley, 1985; Paul, 1998; and Niederberger, 2007 in French). In the same vein, Gaustad and Kelly (2004) have shown that deaf college students matched with younger hearing students for reading level were poorer in tasks involving morphological skills. It is likely that the deaf readers used more semantically based strategies than their hearing peers. The present data suggest that the key word strategy is a rather common way in which deaf readers process written sentences. The fact that this tendency does not decrease when reading ability increases is an indication that it might be a specific feature of deaf readers. More work considering different comparison groups will be useful to determine the reasons why readers adopt this strategy. For instance, hearing adults matched with deaf persons at reading level but who have either normal linguistic abilities at vocabulary, morphology, and syntax, or who possess reduced linguistic abilities, such as foreigners, might help to determine the precise role of poor linguistic ability in the adoption of the key word strategy.

The next point to be examined concerns the mechanisms at play when identifying the key words of a sentence. The data suggest that the deaf participants had a fairly large orthographical lexicon. Their performance in the task reached the ceiling level. It must be acknowledged that the hearing children also gained high levels of performance, indicating that the task was too easy. However, even at reading levels where hearing participants achieved scores between 55% and 80% of correct choices in the spelling task (recall that 50% was the chance level), the deaf participants’ scores were still 100% correct.

The notion that deaf readers possess a large orthographical lexicon is in harmony with the key word strategy, which requires the ability to identify at least some of the main words of the sentence. The question to be considered now is how these words have been stored in the participants’ lexicon. Current models of orthographical learning suppose that written words are first recognized via phonological decoding, which is the only procedure that permits the identification of new words. Successive encounters with these words progressively fix their orthographical representation, thus permitting subsequent direct identification. This mechanism has been called the self-teaching theory because it supposes that the reader teaches himself to read words just by repeatedly identifying them (Share, 1995, 1999). Numerous experiments have confirmed the basic feature of the model, which considers that orthographic knowledge develops using phonological decoding (Bowey and Muller, 2005; Kyte and Johnson, 2006; Nation, Angell, and Castles, 2007). According to this theory, orthographical representations of words are combined with their phonological representations. The notion of “amalgamation” proposed by Ehri (1992) nicely depicts this mechanism. It considers that orthographic strings are bonded to the phonemic representation of words “much as in chemical bonding” (Perfetti, 1992). In this context, orthographical and phonological representations are thoroughly attached to each other.

It is unclear whether this concept works in the same way in deaf readers as it does in hearing readers. Some researchers assumed that deaf readers without any phonological representation of words attach the sequence of letters directly to their meaning. Strictly speaking, this kind of representation of words are not orthographical but logographical, the latter differing
from the former in that they have been processed and stored without taking advantage of phonology, much as if they were drawings instead of speech-related material (Morton, 1980). It is difficult to decide whether the exceptionally good performance in the spelling task of some deaf persons, for example, those participating in this experiment, was based on logographical or orthographical representations.

Evidence from several experimental paradigms has shown that some deaf persons rely on phonological representations of words to carry out the tasks, whereas others do not. Those belonging to the former group, who present the classical rhyme effect in STM, produce phonologically motivated errors in spelling tasks and are able to decide whether two words rhyme or not independently of how they are spelled. It might be tentatively concluded that two kinds of deaf readers exist, characterized by their particular way of coding linguistic information: phonological coders and those who do not use phonology in their mental activities. It might be hypothesized that the latter group store written word representations as logographic codes, that is to say, memorizing them without exploiting the relationships between graphemes and their phonemic counterparts.

The present results are compatible with the concept that the majority of the deaf participants examined were phonological coders, and the lexical representations they demonstrated in the experiment were genuinely orthographical (not logographical). Obviously, the data do not provide conclusive evidence of this concept. Nonetheless, the results of the metaphonological tasks support it. In the group of hearing participants, significant correlations were observed between metaphonological abilities and reading as well as spelling. In the deaf group, the correlation with spelling could not be evaluated because spelling scores reached the ceiling level. Reading and metaphonological results were marginally correlated in the deaf group. Individual differences in the metaphonological tasks were important.

Twelve out of the fourteen deaf participants reached scores basically at the same level as the hearing participants did. Even the poorest deaf readers obtained scores in the metaphonological tasks similar to those of the normal hearing participants of the same reading level. It is hard to conclude that they performed the tasks without using phonological reorientations of words. Only two participants had scores that were clearly outside the distribution of metaphonological scores of their group (their mean number of correct responses was 4.02 standard deviations, below the mean score of the remaining group of 12 deaf participants). Besides, they occupied the lower third of the distribution of reading ability and they obtained the lowest educational level of the deaf participants’ group. We might speculate that they do have not sufficiently precise phonological representations, and so their reading and writing activities were based on logographical representation of words. This obviously needs more evidence, collected with specially designed tasks, to be definitively hypothesized. However, the rest of the group did not differ at a qualitative level from the group of hearing participants. They might be credited with possessing phonological representations of words and using them in reading and spelling.

Note

1. The studies level was quantified giving the score 1 to “low technical,” 2 to “high technical,” 3 to “low secondary,” 4 to “high secondary,” and 5 to “university” level.

References


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