Comprehension of texts by deaf elementary school students: The role of grammatical understanding.

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ABSTRACT

Background: The aim of this study was to analyze how the reading process of deaf Spanish elementary school students is affected both by those components that explain reading comprehension according to the *Simple View of Reading model*: decoding and linguistic comprehension (both lexical and grammatical) and by other variables that are external to the reading process: the type of assistive technology used, the age at which it is implanted or fitted, the participant's socioeconomic status and school stage.
Design: Forty-seven students aged between 6 and 13 years participated in the study; all presented with profound or severe prelingual bilateral deafness, and all used digital hearing aids or cochlear implants. Students' text comprehension skills, decoding skills and oral comprehension skills (both lexical and grammatical) were evaluated.
Results: Logistic regression analysis indicated that neither the type of assistive technology, age at time of fitting or activation, socioeconomic status, nor school stage could predict the presence or absence of difficulties in text comprehension. Furthermore, logistic regression analysis indicated that neither decoding skills, nor lexical age could predict competency in text comprehension; however, grammatical age could explain 41% of the variance. Probing deeper into the effect of grammatical understanding, logistic regression analysis indicated that a participant's understanding of reversible passive object-verb-subject sentences and reversible predicative subject-verb-object sentences accounted for 38% of the variance in text comprehension.
Conclusions: Based on these results, we suggest that it might be beneficial to devise and evaluate interventions that focus specifically on grammatical comprehension.

What this paper adds

This article examines the text comprehension abilities of 47 deaf Spanish elementary school pupils aged 6-13 years. The study identified grammatical comprehension of spoken language as a key predictor of performance in reading comprehension differentiating it from the other variables tested, namely: decoding skills, lexical age and demographic variables. Further analysis identified that good reading comprehension was associated with understanding of two specific grammatical structures: reversible passive object-verb-subject (OVS) sentences and reversible predicative subject-verb-object (SVO) sentences. These findings suggest that specific interventions targeting grammatical constructions may pave the way to improving reading comprehension in deaf children.

1. Introduction

Mastery of reading is one of the fundamental core competencies of elementary education. Many research studies have demonstrated that the reading performance of deaf students is significantly lower than that of their hearing peers (Allen, 1986; Conrad, 1979; Marschark & Harris, 1996; Moreno-Pérez, Saldaña, & Rodríguez-Ortiz, 2015; Perfetti & Sandak, 2000; Pérez & Domínguez, 2006; Torres & Santana, 2005). This remains true in spite of advances in audiology during the last 20 years, which have significantly improved the prognoses for development and learning in deaf students. The early detection of hearing difficulties is now far more widespread and the advancements in both electro-acoustic and programmed technologies that have been applied to cochlear implants (CIs) and digital hearing aids (HAs) have improved both devices (Salesa, 2012), allowing many deaf children to achieve functional hearing. Following several decades of use of both these devices, it can now been observed in the present generation of deaf students that while many of their competencies are significantly better than those of previous generations, these students still lag behind their hearing peers in several areas. Ledeberg, Shick, and Spencer (2013), in their review of advances and limitations in oral and written language development among deaf children, noted that many of these children exhibit a particular weakness in grammatical development, and this weakness has a cascading effect on both reading and writing. Ledeberg et al. (2013) concluded that the average reading skills of deaf children of the present generation, while higher than those previously recorded, still lagged behind their hearing peers. In addition, these deaf children continued to exhibit the large inter-individual variations previously noted. While it seems clear that HAs and CIs have provided deaf children with better access to sound, their use has not necessarily resulted in normal language development to any widespread degree. This study analyzes those variables that predict a higher level of reading comprehension among deaf students thereby gathering useful data for intervention in cases of reading difficulties. The aims of this study are to evaluate the reading skills of deaf Spanish elementary school students and to analyze the factors that are associated with a higher or lower level of reading ability. In Spain, elementary education consists of 6 courses, organized in three stages, for students from 6 to 12 years of age.

A review of existing literature on reading and deafness noted that the majority of studies had been conducted on English-speaking populations. We identified two groups of variables that explained inter-individual differences in the reading performance of deaf students. One group are external to the reading process (use of CIs or HAs, age at the time of fitting or activation, family socioeconomic status and chronological age), the other group are internal (decoding, lexical comprehension and grammatical comprehension).

The use of CIs in preference to conventional systems is one factor that several studies have demonstrated improved reading outcomes in children when compared to conventional aids (Archbold, Harris, O'Donoghue, Nikolopoulos, White, & Richmond, 2008; Connor & Zwolan, 2004; Domínguez, Pérez, & Alegría, 2012; Geers, 2003, 2006; Geers, Nicholas, & Sedey, 2003; Kyle & Harris, 2006; Johnson & Goswami, 2010; Nicholas & Geers, 2008; Spencer, 2004; Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007; Watson, Archbold, & Nikolopolous, 2006). Other recent studies, however, have found no such difference between children with severe or profound hearing loss who use CIs and those with severe hearing loss who use digital HAs (Cupples, Ching, Crowe, Day, & Seeto, 2014; Fitzpatrick, Olds, Gaboury, McCrae, Schramm, & Durieux-Smith, 2012; Harris & Terlektsi, 2010; Szterman & Friedmann, 2014).

Another factor proposed to explain the variation among deaf children who use CIs is the age at time of fitting or activation. Many studies have demonstrated that early fitting has a significant positive effect both on linguistic development (Caselli, Rinaldi, Varuzza, Giuliani, & Burdo, 2012; Manrique, Cervera-Paz, Huarte, Martínez, Gómez, & Vázquez de La Iglesia, 2004; Nicholas & Geers, 2007, 2008) as well as on reading performance (Connor & Zwolan, 2004; Johnson & Goswami, 2010; Spencer & Oleson, 2008). A longitudinal research study conducted by Geers and Nicholas (2013) demonstrated high levels of language and literacy development in deaf children who were fitted with CIs at an early age. It was also observed that vocabulary-related skills are more easily acquired by deaf children than grammar skills.

Family socioeconomic status has also been identified as a possible explanation for the inter-individual differences observed in the reading performance of deaf students. Geers (2006) identified improved performance in deaf children whose parents had a higher socioeconomic status, and in a subsequent longitudinal study, Geers and Nicholas (2013) acknowledged that the high performance recorded in deaf children who participated in their study might be related to the high socioeconomic status of their families, which was higher than that of the general population.

In addition to the aforementioned factors, the possibility that the differences in reading achievement reported across studies may be related to the age of the participants cannot be omitted. Lags in reading development in children with hearing loss tend to widen with age (Geers & Hayes, 2011; Kyle & Harris, 2010; Kroese, Lotz, Puffer, & Osberger, 1986; Marschark & Harris, 1996). In their longitudinal study of the development of deaf children in school, Geers, Tobey, Moog, and Brenner (2008) demonstrated that, after 5 years using a CI, students displayed good reading performance while 7 years after first using the implant all of the students exhibited below average performance. Early and more recent research studies (Conrad, 1979; Karchmer & Mitchell, 2003) have shown that the average reading age of deaf adolescents is 9 years.

Considering those variables that are internal to the reading process, given the breadth of competencies that reading ability encompasses, it is to be expected that reading difficulties may arise from different factors. The Simple View of Reading model (Gough & Tunmer, 1986; Hoover & Gough, 1990), which sets the context for the present study, proposes that reading skills are the product of both decoding ability and linguistic comprehension. Implicit in decoding is the ability to rapidly translate a printed word into a representation that encapsulates the meaning of that word. As Hoover and Gough (1990) state, when first learning to read, a system based on suitable phonological representations is required. Linguistic comprehension is considered as the ability to use lexical information and to interpret sentences and discourses. While this model considers reading competence to be the product of both these aforementioned skills (decoding and linguistic comprehension), the authors assign different degrees of importance to each skill according to a student's level of schooling, conferring greater weight on decoding during the initial years and greater weight on linguistic comprehension in later years.

Having reviewed existing literature on reading in deaf students, it was observed that many studies focus on one of these two skills described by Hoover and Gough (1990) in their reading model. Some research studies focus on the role played by phonological awareness (Alegría, 2006; Cupples et al., 2014; Dillon, de Jong, & Pisoni, 2012; Domínguez et al., 2012; Geers, 2003; Geers & Hayes, 2011; Harris & Terlektsi, 2010; Medina, & Serniclaes, 2009; Webb & Lederberg, 2014), while others also consider linguistic abilities such as knowledge of *vocabulary* (Colin, Leybaert, Ecalle, & Magnan, 2013; Connor & Zwolan, 2004; Kyle & Harris, 2010; Villalonga, Padilla, & Burin, 2014). In addition to phonological awareness and vocabulary, some studies consider the non-verbal cognitive processes of visuospatial attention, visuospatial working memory and executive functioning (Daza, Phillips-Silver, Ruiz-Cuadra, & López-López, 2014), while others analyze the effect of grammatical comprehension on reading ability (Berent, 1988; Kelly, 1993, 1996; Miller, Kargin & Guldenoglu, 2013; Power & Quigley, 1973; Quigley & King, 1980; Szterman & Friedmann, 2014).

The phonological awareness developed by deaf children fitted with CIs is one of the factors most frequently linked to an improvement in their observed reading abilitity (Archbold et al., 2008; Cupples et. al., 2014; Domínguez et al., 2012; Johnson & Goswami, 2010). The development of vocabulary and grammar are however better predictors of reading competencies than phonological processing skills (Mayberry, Del Giudice, & Lieberman, 2011). In work conducted by Geers (2003) and Geers and Hayes (2011) vocabulary and grammar accounted for a higher percentage of variance in the reading ability of deaf students in elementary schools (47%) than phonological processing (26%). In high school these linguistic abilities are even more important, explaining 56% of the variance in reading ability as opposed to phonological processing which only accounts for 3.8% (Ledeberg et al., 2013). Both the aforementioned works by Geers (2003), Geers and Hayes (2011), and the meta-analysis of Mayberry et al. (2011) share a focus on text comprehension, rather than the reading of letters or words, and they assessed older children or adolescents.

The longitudinal study by Kyle and Harris (2010) assessed the development of reading in a group of 29 deaf children (some fitted with CIs and others with HAs) between the ages of 7-8 and 10-11. The comparison between three groups of children (exhibiting low, medium and severe difficulties) not only demonstrated that each group differed significantly in speechreading and vocabulary, it also revealed that vocabulary knowledge was the variable which was longitudinally related to word reading and sentence and text comprehension. In this study phonological awareness did not appear to be a precursor to the ability to read words, but rather the reverse, early reading ability was closely related to subsequent levels of phonological awareness; This led the authors to conclude, as in a previous study (Kyle & Harris, 2006), that deaf children could develop their phonological awareness through reading.

Before exploring the relationship between grammatical comprehension and the reading process, it is appropriate to consider some of the grammatical difficulties faced by deaf children.

Studies conducted by Quigley and others in the 1970s and 1980s (Power & Quigley, 1973; Quigley & King, 1980; Quigley, Montanelli, & Wilbur, 1976; Quigley, Wilbur, & Montanelli, 1976) noted a significant delay in awareness of English morphosyntax when comparing deaf students aged 10-18 years with hearing students aged 8-10 years. The grammatical structures that presented least difficulty to deaf students (negation, conjunction and question formation) were the same structures that hearing students found easiest. While both groups had difficulty with pronominalization, complementation, relativization and various aspects of the verbal system, the (younger) hearing students achieved higher scores than the deaf students, irrespective of the type of structure being tested. A particular characteristic of deaf students was their difficulty with constructions involving disjunction and/or alternation. Gaustad and Kelly (2004) also compared deaf college students with hearing middle school students and discovered that the deaf students scored lower than the hearing students in tasks that required morphological awareness (gerund and participle verb endings and derivational prefixes and suffixes).

Cannon and Kirby (2013) in their study of deaf or hard of hearing (DHH) students aged 5-12 who used American Sign Language as their primary mode of communication recorded similar difficulties to those reported 30 or more years ago, even highlighting problems in basic morphological skills such as noun pluralization when researchers and educators might have taken for granted that the children would have developed these skills. Drawing on the results of other studies such as those of Berent (1988, 1996), Cannon and Kirby noted that because English predominantly follows an SVO canonical order and many noun-verb-noun (NVN) strings in English correspond to SVO clauses, DHH students rely on a SVO strategy in which every NVN sequence is interpreted as an SVO string. Over-reliance on this strategy then leads to misinterpretation of sentences that do not follow this paradigm, e.g. passives. Likewise, in those grammatical constructions where elements are transposed, such as relative and complement clauses, or dislocated, as occurs with pronominalization, DHH students' tendency to misapply this SVO strategy may explain their errors. In spite of these difficulties, the results of new teaching methods appear promising. Cannon, Easterbooks, Gagné and Beal-Alvarez (2011) demonstrated that when LanguageLinks, a software program, was used to teach deaf children aspects of grammar, their comprehension of morphosyntactic structures improved. Another recent, noteworthy study is that of Edwards, Figueras, Mellanby, and Langdon (2011) which was also conducted with English-speaking deaf children aged between 8 and 12 who used CIs or HAs. This study evaluated participants' grammatical comprehension using the Test for Reception Of Grammar Version 2 (Bishop, 2003). The results were consistent with those of previous studies: deaf students had difficulty with relative clauses, reversible structures and relational structures such as ‘neither x nor y’ and ‘x but not y’. In general, the performance of deaf children was similar to that of hearing children aged 5-6 years.

Other researchers (Caselli et al, 2012; Duchesne, Sutton, & Bergeron, 2009; González, Silvestre, Linero, Barajas, & Quintana, 2014; Le Normand, 2004; Szagun, 2000, 2001) have also demonstrated difficulties in the grammatical development of deaf children who use HAs or CIs in languages other than English.

The study by González et al. (2014) of deaf Spanish children who used HAs or CIs reported that only 30% of these children achieved normalized language development. Difficulties with linguistic comprehension were very evident in both passives and subordinate phrases where the relationship between the elements was embedded rather than sequential, or where the usual sentence pattern was inverted. In terms of linguistic expression, more grammatical difficulties were observed in the output of children older than three years of age e.g. in sentences containing both a direct and an indirect object. Likewise, morphological errors in tense and person were evident in verbal inflections. The authors of this work were particularly interested in studies conducted on child speakers of other Romance languages, for example French or Italian. Le Normand (2004) described distinct types of morphological errors that characterized the spontaneous language of deaf French children fitted with CIs. These errors affected nominal inflections of number and gender and were very apparent in verbs (auxiliaries, compound forms, passives, periphrasis and the absence of verbal agreement in coordinate structures). Caselli et al (2012) observed specific deficits in linguistic comprehension and expression in a study of deaf Italian children fitted with CIs, particularly in the case of free morphemes such as articles and clitics. The authors attributed these deficits to perceptual problems, which still remained in spite of the children's use of CIs and noted that they related to morphemes that had scarce semantic content and were short and unstressed, making them difficult to distinguish from other parts of speech. Similarly, González et al (2014), noted that inflection markers in Spanish are more difficult to identify because they occur at the end of words, and are usually unstressed making them less audible even for users of HAs or CIs.

The literature reviewed above demonstrated significant similarities between deaf English-speaking children and deaf children who speak other Romance languages, namely: difficulties with relative clauses, passive constructions, and various aspects of the verbal system. Nonetheless, the particular characteristics of Spanish language make it necessary to investigate both the manner in which deaf children acquire Spanish and the effect this has on their reading comprehension.

Spanish and English grammar differ in both morphology and syntax. Spanish makes far greater use of inflection. For example the null subject that is a characteristic of Spanish, but not of English, requires verbal inflection to indicate person, where English uses a pronoun, e.g. ‘estamos comiendo’ vs. ‘we are eating’. The Spanish pronominal system is also more extensive than the English system, distinguishing gender in plural forms (‘ellos-ellas’ vs. ‘they-they’) as well as discriminating between reflexive and non-reflexive actions (‘la mujer se pone los zapatos-la mujer le pone los zapatos’ vs. ‘the woman puts on her shoes-the woman puts shoes on someone else’). At a syntactic level Spanish has a more flexible word order than English. The greater prevalence of morphological markers and referentials in Spanish makes the meaning of a sentence less dependent on the word order. The canonical order of SVO in Spanish (‘el hombre peina a la mujer’-‘the man combs the woman’s hair’) changes to OVS not only in the passive voice (‘la mujer es peinada por el hombre’-‘the woman’s hair is combed by the man’), but also in certain active constructions that have no English equivalent (‘a la mujer la peina el hombre’-‘ the woman’s hair is combed by the man’).

The influence of limited grammatical competence on the low level of reading comprehension of many deaf readers of previous generations has been established in studies such as those of Berent (1988), Kelly (1993, 1996), Power and Quigley (1973) and Quigley and King (1980). These studies included deaf students trained in oral sign language or total communication programs. Kelly (1996) demonstrated that if deaf readers did not possess a reasonable level of syntactic competence, they would have difficulty applying their lexical knowledge.

Few studies exploring this relationship between grammar and reading have been conducted on deaf students who use current assistive technologies and even fewer on deaf Spanish children. Szterman and Friedmann (2014) studied oral and reading comprehension of reversible relative clauses among 48 deaf elementary school children between the ages of 9 and 12 years, some fitted with CIs and others with HAs. Their results showed that students demonstrated a deficient understanding of these sentences not only when they listened to them, but also when the same sentences were presented in writing, without any time limit to read them. This study suggested that the difficulties in text comprehension exhibited by deaf children might be the result of a grammatical deficit. The most significant syntactic difficulties observed by the authors of this study related to the ability to detect changes in the thematic roles of agents and objects in sentences where these elements did not follow a canonical order. Additionally, they even recorded a group of deaf children who, although able to detect that a change in the canonical order of the sentences had occurred, failed to carry out the necessary mental re-arrangement of the elements of the sentences to achieve a proper understanding.

Research carried out by Domínguez and Alegría (2010), Domínguez et al. (2012), Domínguez, Carrillo, Pérez, and Alegría (2014), and Soriano, Pérez and Domínguez (2006), concluded that deaf Spanish children interpret text primarily by means of a keyword strategy through which they create a global meaning with minimal regard for morphosyntactic aspects. Even in the case of deaf adults who have a high reading level, Domínguez et al. (2014) noted that this unsophisticated reading strategy persists. These data, supported by other studies demonstrating a severe difficulty at a morphosyntactic level among deaf people, led them to suggest that deaf readers may use more semantic strategies than their hearing peers because their grammatical ability is poorer.

Research conducted by Miller (2000, 2005, 2006, 2010) and Miller et al. (2013) provided data consistent with the studies cited above and concluded that deaf readers at several school stages have a poorer understanding of semantically implausible (SI) sentences than of semantically plausible (SP) sentences. SI sentences contain apparently contradictory information that cannot be interpreted merely by processing the words that they are composed of; instead requiring the processing of their grammatical structure. SP sentences, by contrast, have an expected meaning; the reader can extract this meaning by processing the words, without having to process the grammatical structure. Following an analysis of the variables that explain differences in reading comprehension amongst deaf students engaged in higher education, Miller et al. (2013) found that neither phonological awareness nor word processing are related to the reading level of the participants. Significant variance was recorded, however, in the ability of readers with high, medium and low reading comprehension to understand SI sentences. This variance did not affect SP sentences. Moreover, when interpreting good performance by medium level readers in comprehending SP sentences, this study drew a similar conclusion to that drawn by Domínguez et al. (2014) in their study of deaf adult readers: namely that employment of a semantic strategy is effective and can, at least partially, compensate for deficiencies in grammatical processing. Miller et al. (2013) however drew attention to a group of young deaf individuals who dealt with written text in a non-strategic manner and only achieved a poor reading comprehension.

The present study is founded on the simple view of reading model, but draws on the hypothesis that, of the multiple components that explain reading comprehension, command of grammar is the most relevant when considering text comprehension. For this reason, the principal objective of this study was an examination of the effect of grammatical knowledge on text comprehension. Additionally, this study considered the effect of other external variables as described in the introduction, as well as other linguistic factors (decoding and vocabulary) on individual differences in text comprehension. This study had the following aims:

1. To determine the effect of external factors on the reading process: type of assistive technology (CI or HA), age at time of fitting or activation, socioeconomic status and school stage.

2. To determine the effect of both components that explain reading comprehension according to the simple view of reading model: decoding and linguistic comprehension (lexical and grammatical).

3. To analyze the effect of students' understanding of different types of grammatical structures on their reading comprehension.

2. Method

2.1. Participants

A total of 47 deaf students between the ages of 6 and 13 participated in this study. All students were prelingually deaf children with bilateral sensorineural hearing loss. Twenty-four of the students exhibited profound deafness and 23, severe. Twenty-one students used bilateral digital HAs and 26 used unilateral CIs without a contralateral HA. The age at time of fitting of the HA or activation of the CI in 13 of the students was before 2 years of age, in 16 students between 2 and 3 years of age and in the remaining 18 students between 3 and 7 years of age.

None of the participants exhibited any other disabilities and all attended state elementary schools with hearing classmates. Evaluation of the students' intellectual level, conducted by the schools, indicated normal cognitive development. Participants were distributed in three groups according to their school stage. In the Spanish elementary education system the first stage comprises students from 6-8 years, the second stage from 8-10 years and the third stage from 10-12 years old. Sixteen participants were in the first stage (mean age 7.6), 13 were in the second stage (mean age 8.8) and 18 were in the third stage (mean age 11.3) of elementary education. All 31 schools that the students attended approved the participation of each child in the study, and parents signed consent forms for every child evaluated.

All of the children had hearing parents, and their primary mode of communication was spoken Spanish. The socioeconomic status of each family was estimated based on the highest academic level achieved by either of the parents. A low level was assigned to families without formal education or with elementary education only; a medium level was assigned to those who had completed compulsory high school education or basic professional training; and a high level was assigned to those who had obtained a degree, had received specialized professional education or held a university qualification. Twenty-six participants came from families with a low socioeconomic status, 11 from a medium socioeconomic status and 10 from a high socioeconomic status.

Table 1 shows descriptive data of participants arranged according to the type of assistive technology used: HA or CI.

Table 1
Distribution of participants according to the type of assistive technology used: HA or CI.

	Type of assistive technology used	
	HA N = 21	CI N = 26
SCHOOL STAGE		

First	4 (19.1%)	12 (46.1%)
Second	7 (33.3%)	6 (23.1%)
Third	10 (47.6%)	8 (30.8%)
DEGREE OF HEARING LOSS		
Severe	19 (90.5%)	4 (15.4%)
Profound	2 (9.5%)	22 (84.6%)
AGE WHEN FITTED OR ACTIVATED		
0 to 2 years old	3 (14.3%)	10 (38.4%)
2 to 3 years old	8 (38.1%)	8 (30.8%)
3 to 7 years old	10 (47.6%)	8 (30.8%)
SOCIOECONOMIC STATUS		
Low	15 (71.4%)	11 (42.3%)
Medium	2 (9.5%)	9 (34.6%)
High	4 (19.1%)	6 (23.1%)

To determine whether differences existed between the characteristics defining the children with CIs and the children with digital HAs, a multiple logistic regression analysis was conducted. The use of a HA or CI was the dependent variable defining the two comparison groups, with the school stage, degree of hearing loss, age at time of HA fitting or CI activation, and socioeconomic status of the family as the independent variables.

Table 2
Multiple logistic regression parameters of school stage, degree of loss, age at time of HA fitting or CI activation, and socioeconomic status over type of assistive technology (CI or HA).

	B	SE	Wald	df	p	Exp(B)
School stage	-1.211	.669	3.277	1	.070	.298
Degree of loss	4.232	1.267	11.160	1	.001	68.865
Age at time of fitting or activation	-.171	.452	.143	1	.705	.843
Socioeconomic status	-.505	.711	.505	1	.478	.604
Constant	-6.265	3.295	3.615	1	.057	.002

The results in Table 2 demonstrate that deaf children who use HAs and those using CIs do not differ in relation to their school stage, the age at which they received the HA or CI or in respect of their the family socioeconomic status. The two groups do however differ in the degree of hearing loss. The group fitted with CIs presented the greatest hearing loss. The model summary data are shown in Table 3. The degree of hearing loss predicted 68% of the variance in the type of assistive technology (HA or CI) used.

Table 3
Model summary

Step	2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
1	28.542	.508	.680

The difference in the degree of hearing loss observed in child users of HAs when compared to CIs is understandable when one considers the criteria applied in Spain when proposing use of CIs. CIs are recommended for patients: who present with profound sensorineural hearing loss in both ears or profound hearing loss in one ear and a severe hearing loss in the other; when the benefit from a HA is insufficient or non-existent, and, additionally; when the patient or his/her family are motivated towards the use of CIs (Trinidad & Jaúdenes, 2011).

2.2 Measures

The three tests used were standardized with hearing children and administered as per the recommendations of each test. It was not necessary to adapt any test as a consequence of the hearing loss of the participants.

2.2.1 Reading Processes Evaluation Battery of Tests - Revised (PROLEC-R; Cuetos, Rodríguez, Ruano, & Arribas, 2007).

This test is designed to evaluate the standard reading skill set expected in children aged between 6 and 12 years and to detect possible difficulties in reading acquisition through evaluation of different components of the reading system. In those tests in which it is possible to do so, both accuracy and speed are taken into account in the calculation of the results. In languages such as Spanish that exhibit transparent orthography (where grapheme-phoneme conversion is governed by rules) the processing speed provides a clear differentiation between good and bad readers.

Calibration of this battery was achieved using a total of 1,000 schoolchildren in the first three stages of elementary education (from 6 to 12 years old) drawn from all of Spain. PROLEC-R battery has become the reading assessment test most used by Spanish speaking professionals, both in Spain and Latin America, and is also the test normally used in scientific investigations of reading difficulties in Spanish speaking children. The following tests from PROLEC-R battery were administered.

(1) Letter reading test. The objective was to test whether the child knows the letters in the Spanish alphabet and how to pronounce them−a requirement to be able to read them. The test is comprised of 20 items. Of the 27 letters that occur in Spanish, 7 were omitted: the vowel a, the vowels e, i and o (because they are used as warm-up exercises), the consonant h (because it is silent in Spanish) and the consonants k and w (because of their low frequency in Spanish). The child must name or pronounce all these letters. Direct scoring varies between 0 and 20, both precision (amount of recognized letters) and speed (time in seconds taken to complete the task) are taken into account.

(2) Word reading test. This test evaluates word recognition and whether it occurs quickly, a key process in order to be a good reader. It comprises 40 words: 20 high-frequency and 20 low-frequency. The criterion used to determine frequency was taken from the *Diccionario Frecuencias del Castellano Escrito en niños de 6 a 12 años* (Dictionary of Frequency of Written Spanish in Children from 6 to 12 years of age) (Martínez-Martín & García-Pérez, 2004). This draws on a corpus of 2.6 million words occurring in texts used by elementary school students and categorizes words appearing at least 189 times per million as high-frequency and words appearing 11 or less times per million as low-frequency. In both categories (high-frequency and low-frequency) the words are evenly matched both in length and in syllabic structure. Word length varies between two and three syllables (five and eight letters) as this is the average length of the most frequently occurring words in Spanish. The structure of the first syllable of each word varies in complexity, alternating between six types of structures or combinations of vowels (V) and consonants (C) specifically: CV, VC, CCV, CVV, CVVC and CCVC. Direct scoring ranges from 0 to 40, and considers both reading precision (the number of correctly pronounced words) and speed (the time in seconds taken to read all of the words). Understanding the meaning of the words is not scored.

*(3) Pseudo-word reading test***.** Through the reading of non-words, this test assesses ability to pronounce unknown words, which may involve different processes from those employed when reading known words. This test comprises 40 pseudo-words formed by changing one or two letters of each word in the word reading test so that both lists are equivalent in both length and syllabic structure. Likewise, direct scoring ranges from 0 to 40 and considers both reading precision (the number of correctly pronounced words) and speed (the time, measured in seconds, taken to read all of the words).

The similarity between the tests for word reading and pseudo-word reading permits direct comparison of the performance of each child in both tasks and an assessment of the effect of lexicality. Thus, a higher score when reading real words compared to pseudo-words points towards reading based on a lexical route; widespread errors when reading pseudo-words indicates a poor grasp of grapheme-phoneme conversion; similar scoring when reading both real words and pseudo-words, indicates that a child reads using a sub-lexical route.

(4) Text comprehension test. The purpose of this test is to check if the reader is able to extract the message contained in the text and to integrate it into their pre-existing knowledge. This requires a significant number of complex operations such as the activation of pre-existing knowledge related to the text, the drawing of inferences, etc. This capacity is measured by asking the child questions about the text, which they must try to answer.

In this test four texts are used: two narrative and two expository. Two of the texts (one narrative and one expository) are short (comprising approximately 90 words); the other two are long (comprising more than 130 words). The text content is unknown so that a student's prior knowledge cannot affect his or her performance. Each text has four questions, each with a maximum score of four points, so that scoring ranges from 0 to 16 points. All of the questions are inferential in nature, that is to say, concerning matters not explicitly described in the text and requiring the reader to draw inferences in order to understand them. In this way, the test attempts to avoid students answering by rote, without truly understanding the question.

For each test, the PROLEC-R Battery includes a scale to convert the total raw score into normative categories of normal, slight difficulty and severe difficulty, with regard to the child's current school grade. The criteria used to determine these categories are statistical. Thus, a child is considered to have no difficulties when their results are above the cutoff equivalent to the normative mean minus one standard deviation. By the same rule, children are assumed to have slight or severe difficulties when their results are between one and two standard deviations below the mean or more than two standard deviations below the mean, respectively.

2.2.2. Peabody Picture Vocabulary Test III (PPVT-III; Dunn, Dunn & Arribas, 2006).

This test evaluates the level of receptive vocabulary. The Spanish version comprises 192 items arranged in order of increasing difficulty. Each element consists of a sheet containing four black and white drawings and the candidate must select the image that best represents the meaning of a word read aloud by the evaluator. Using direct scoring, an 'equivalent age' score for lexical comprehension can be obtained.

2.2.3. Grammatical Structure Comprehension Test (CEG; Mendoza, Carballo, Muñoz, & Fresneda, 2005).

This test evaluates the comprehension of grammatical structure in children aged between 4 and 11 years inclusive. This test can also be utilized with children who present with language disorders or difficulties, such as hard of hearing children. It is noteworthy that, even though some of the test participants were older than the test ceiling age of 11 years, none demonstrated the level of performance characteristic of a typical 11 year old (i.e., none achieved a maximum score).

Each CEG item consists of a sheet with four images; the participant must indicate the image that he or she thinks matches a spoken sentence. The CEG comprises 80 items, grouped in 20 sets of four elements each. Each set evaluates the comprehension of a specific grammatical structure (see Appendix 1).

The CEG is based on the Test for the Reception of Grammar (TROG; Bishop, 1983), which was modified to overcome difficulties that arise from differences in English and Spanish grammar. The authors identified four significant differences in grammatical constructions between English and Spanish, which led them to introduce the following modifications:

1. Subject pronouns (they: 'ellos' or 'ellas') are superfluous in Spanish and rarely used–sentences that evaluated these pronouns were eliminated.
2. Sentences to evaluate plural pronominal constructions for masculine and feminine grammatical genders, non-existent in English (they: 'ellos' or 'ellas'; them: 'los' or 'las'), were added.
3. The entire set of spatial prepositions (in/on) within TROG was substituted with two items within a set of predicate SVCC sentences (subject, verb, adverbial of place): one containing 'encima' (on/above) the other containing 'debajo' (under/below). The reason for this substitution was that in Spanish the preposition 'en' has two different meanings ('on top of' and 'inside').
4. Spanish is more flexible than English with regard to word order and uses many more morphological and referential markers to indicate meaning in a sentence (relying far less on word order than English). To evaluate this diversity, two sets were added; one with a non-canonical order (Set M: OVS sentences with a focalized object, e.g., 'A la niña la pinta el niño') and the other with reversible passives, which are less colloquial (Set R: reversible passive OVS sentences, e.g., 'La niña es pintada por el niño'). Both of these sentences would be translated identically into English as 'the girl is painted by the boy'.

The CEG has two scoring systems. Global scoring counts the number of correct elements between 0 and 80. Set-based scoring assigns a score of 0 or 1 points per set; with one point assigned when all four items in the set are answered correctly−indicating mastery of the corresponding grammatical structure. Based on these direct scores, and using tables scaled by age, it is possible to compare the performance of a participant within his or her age group and estimate the age to which his or her performance corresponds (equivalent grammatical age, global age, or age by sets). Irrespective of the age of the child it is a requirement of the test that it be administered in its entirety.

The CEG test was calibrated by administering it to 1404 children aged between 4 and 11 years. The average age of the girls was 7.54 years (SD = 2.26) and the boys was 7.39 years (SD = 2.31). All of the children were enrolled in public or state-subsidized schools from different geographic regions within Spain including urban, semi-urban and rural areas. The test was not administered to children in bilingual regions or to children with possible problems in their linguistic development (children receiving speech therapy, children with disabilities, children with hearing problems, children whom at least one of their parents did not speak Spanish or children whose mother tongue was not Spanish).

2.3. Procedure

The tests were administered individually to each student in sessions lasting approximately 40 minutes, in schoolrooms reserved for this purpose, where the ambient conditions were sufficiently quiet for participants to hear the test sounds and to maintain their attention span. Each evaluation was conducted over two sessions. In the first session, the PPVT-III and CEG tests were administered; the PROLEC-R tests were conducted in the second session.

Using the data obtained in the text comprehension test, two groups were created according to the presence or absence of severe difficulties. A total of 44.7% of the participants (N = 21) demonstrated normal performance in text comprehension or slight difficulties in relation to their school grade, while 55.3% (N = 26) demonstrated severe difficulties.

3. Results

3.1. The effect of factors external to the reading process on difficulties in text comprehension

Table 4 shows the distribution of participants, with and without reading difficulties, based on the type of assistive technology (HA or CI) used, age when fitted or activated, socioeconomic status and school stage.

Table 4
Distribution of participants with and without reading difficulty in respect of variables external to the reading process.

	Text comprehension	
	With difficulty N = 26	Without difficulty N = 21

ASSISTIVE TECHNOLOGY		
HA	9 (34.6%)	12 (57.1%)
CI	17 (65.4%)	9 (42.9%)
AGE WHEN FITTED OR ACTIVATED		
0 to 2 years old	8 (30.8%)	5 (23.8%)
2 to 3 years old	8 (30.8%)	8 (38.1%)
3 to 7 years old	10 (38.4%)	8 (38.1%)
SOCIOECONOMIC STATUS		
Low	15 (57.7%)	11 (52.4%)
Medium	6 (23.1%)	5 (23.8%)
High	5 (19.2%)	5 (23.8%)
SCHOOL STAGE		
First	11 (42.3%)	5 (23.8%)
Second	7 (26.9%)	6 (28.6%)
Third	8 (30.8%)	10 (47.6%)

A binary multiple logistic regression analysis using the enter method was carried out in order to estimate the importance of each of these four variables (type of assistive technology, age when fitted or activated, socioeconomic status and school stage) when predicting which reading comprehension group (with difficulty or no difficulty) a student would belong to. As may be seen in Table 5, which presents the parameters of the regression analysis, none of the four variables introduced in the equation predicted which reading group (with difficulty or no difficulty) a student would belong to as the Wald statistic linked to each of the variables was not significant in any of the cases.

Table 5
Parameters of the multiple logistic regression analysis of type of assistive technology, age when fitted or activated, socioeconomic status and school stage over text comprehension.

	B	SE	Wald	df	p	Exp(B)
Type of assistive technology	-.622	.684	.828	1	.363	.537
Age when fitted or activated	.047	.380	.015	1	.902	1.048
Socioeconomic status	.315	.409	.591	1	.442	1.370
School stage	.430	.393	1.196	1	.274	1.537

Constant	-1.420	1.683	.711	1	.399	.242

3.2. The effect of decoding and linguistic comprehension on difficulties in text comprehension.

To assess the effect of the variables underlying the reading process on reading comprehension, various measurements were recorded and considered for both components of the simple view of reading model: decoding (reading of letters, reading of words and reading of pseudo-words) and oral comprehension (lexical and grammatical comprehension).

3.2.1. Decoding

Table 6 shows the distribution of participants in two groups (with difficulty and without difficulty in text comprehension) according to their performance in letter reading, word reading and pseudo-word reading tasks. Performance of these tasks is categorized in two groups, following the same protocol applied in the text comprehension task. In this way students who have severe difficulties (with difficulty) may be distinguished from those who display a normal performance or slight difficulties in relation to the school grade they are enrolled in (without difficulty).

Table 6

Distribution of participants with and without reading difficulty in relation to decoding measurements.

	Text comprehension	
	With difficulty N = 26	Without difficulty N = 21
LETTER READING		
With difficulty	5 (19.2%)	1 (4.76%)
Without difficulty	21 (80.8%)	20 (95.24%)
WORD READING		
With difficulty	4 (15.4%)	0 (0%)
Without difficulty	22 (84.6%)	21 (100%)
PSEUDO-WORD READING		
With difficulty	2 (7.7%)	2 (9.5%)
Without difficulty	24 (92.3%)	19 (90.5%)

As may be seen in Table 6, few participants display difficulties in tasks involving decoding, whether of letters, words or pseudo-words. Likewise, the distribution of participants with or without difficulty in some of these tasks does not seem to be linked to the presence or absence of difficulties in text comprehension. That is, an absence of difficulties in the decoding process does not appear linked to an absence of difficulties in text comprehension, given that participants are almost equally distributed in both groups. To assess the effect of decoding abilities on the reading process a binary multiple logistic regression analysis using the enter method was carried out using the variables letter reading, word reading and pseudo-word reading over the variable text comprehension (defined in two levels: with and without difficulty, in regard to the student's academic level).

As may be seen in Table 7, which shows the regression analysis parameters used, none of the three variables introduced in the equation predicted which reading competency group the student belonged to.

Table 7
Multiple logistic regression parameters for letter reading, word reading and pseudo-words reading over reading comprehension.

	B	SE	Wald	df	p	Exp(B)
Letter reading	.554	.517	1.150	1	.284	1.740
Word reading	.562	.67	.688	1	.407	1.754
Pseudo-word reading	-.425	.633	.451	1	.502	.654
Constant	-1.147	.895	1.643	1	.200	.317

3.2.2. Linguistic comprehension

Table 8 shows the mean scores and standard deviations in lexical age and grammatical age by level of text comprehension in members of the groups with difficulty and without difficulty.

Table 8
Mean score, standard deviation and range for lexical, grammatical and chronological age according to level of difficulty in text comprehension.

	With difficulty			Without difficulty		
	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range
Lexical age	5.53	1.64	2.5-8.6	6.96	1.42	3.9-9.9
Grammatical age	4.73	0.91	4-7	6.34	1.47	4-9
Chronological age	9.53	1.97	6.2-13.5	9.98	1.75	7.2-12.3

In order to estimate the effect of oral linguistic comprehension variables on reading comprehension a stepwise multiple logistic regression analysis of the variables lexical age and grammatical age over the variable text comprehension (defined in two levels: with difficulty or without difficulty according to the child's school grade) was carried out (see Table 9).

Table 9
Parameters of Logistic Regression.

	B	SE	Wald	df	p	Exp(B)
Grammatical age	1.708	.558	9.369	1	.002	5.518
Constant	-8.054	2.505	10.342	1	.001	.000

Table 10

Model summary

-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
47.197	.310	.415

Only the Wald statistic associated to the variable grammatical comprehension was significant; that is, of the two variables introduced in the model (lexical age and grammatical age) only grammatical comprehension had a significant effect. The odds ratio Exp(B) indicates that participants with a higher grammatical age are 5.5 times more likely to be included in the group without difficulty in text comprehension than the group with difficulty. The variance percentage accounted for by the model was 41% (Nagelkerke R^2). From the model data, the percentage of cases correctly classified shows that grammatical age placed 84.6% of participants with reading difficulties in the group with text comprehension difficulty and 71.4% of participants with no reading difficulties in the text comprehension group with no difficulty.

3.3. The effect of comprehension of several types of grammatical structures on text comprehension difficulties.

Given that grammatical comprehension was the only predictor of text comprehension, the relationship between comprehension performance of the 20 types of grammatical structures assessed by the test (see Appendix 1) and the variable text comprehension (defined in two levels: with difficulty and without difficulty in relation to the student's school grade) was analyzed. Spearman correlation analysis showed that several of the 20 types of grammatical structures evaluated by the test significantly correlated with students' reading comprehension level (see Table 11).

Table 11

Spearman correlation between comprehension of grammatical structures and comprehension of texts.

Comprehension of grammatical structures	Comprehension of texts
Set R: Reversible passive OVS sentences	.433*
Set G: Compound disjunctive sentences (compound subject or object)	.352*

Set D: Sentences with a predicate pronoun (reflexive and non-reflexive)	.393*
Set E: SVO sentences with a reversible predicate	.398*
Set H: Predicate SVCC sentences with an adverbial of place (above, under, in front, and behind)	.358*

*p<.05

Appendix 2 shows the test sentences used to evaluate each type of grammatical structure that correlated with text comprehension. A stepwise multiple regression analysis was carried out with the aim of determining the effect of understanding of the grammatical structures that correlate with text comprehension on reading comprehension. The dependent variable was performance in text comprehension which was defined in two levels (without difficulty and with difficulty, relative to the child's school grade). The independent variables were students' performance in comprehension of each of the grammatical structures that correlated with text comprehension (sets R, G, D, E and H). The results (see Table 12) show that of the five independent variables entered into the equation, two were significant predictors of text comprehension: comprehension of reversible passive OVS sentences (set R), and the comprehension of reversible predicate SVO sentences (set E). In the stepwise regression, the variable for comprehension of reversible passive OVS sentences (set R) was entered first into the equation and variable for comprehension of reversible predicate SVO sentences (set E) was entered as the second and final step. The odds ratio Exp(B) indicates that those participants who understand reversible passive OVS sentences (set R) have a 13.7 times greater probability and those who understand reversible predicate SVO sentences (set E) a 7.13 times greater probability of being included in the group without difficulty with regard to text comprehension than the group with difficulty.

Table 13 shows the model summary demonstrating that the percentage variance explained by the understanding of grammatical structures R and E was 38%.

Table 12

Parameters of stepwise multiple logistic regression of the comprehension of grammatical structures R, G, D, E, H on text comprehension.

Variables in the equation.

		B	SE	Wald	df	p	Exp(B)
Step 1	Set R	2.733	1.114	6.016	1	.014	15.385
	Constant	-.654	.342	3.657	1	.056	.520
Step 2	Set E	1.989	.914	4.734	1	.030	7.310

Set R	2.618	1.177	4.946	1	.026	13.715
Constant	-2.130	.846	6.337	1	.012	.119

Table 13
Effect of comprehension of the grammatical structures R and E on text comprehension.
Model summary

-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
49.002	.282	.378

4. Discussion

The present study analyzed the effects of different factors on text comprehension in deaf elementary school students.

The first data to consider relate to the level of text comprehension demonstrated by participants when compared with normative data for the test employed. The scores obtained by the study participants indicated that 26 of the 47 students tested demonstrated severe difficulties in text comprehension when compared with hearing students from the same school grade. Although this is a study of deaf children who use digital HAs or CIs, that is, who avail of technology that enables a far greater perception of language than was possible for deaf children of previous generations, the study still recorded a high percentage of students with severe difficulties in text comprehension.

The objectives of this study included the analysis of variables that are external to the reading process (type of assistive technology, age when fitted or activated, family socioeconomic status and school stage) as well as variables implicit in reading such as decoding and knowledge of language. Nonetheless, the central focus of attention was on the role played by grammatical knowledge in text comprehension by deaf students. A global analysis of the data confirmed the hypothesis initially posited, namely: from the variables that were analyzed, the only one that explained the difference in performance between students who had no difficulties comprehending texts and those who had difficulties was their grammatical comprehension age.

Analysis of the effect of external variables on text comprehension revealed that none of these variables were significant. These variables had been included because, as described in the introduction, several previous studies had alluded to them when trying to explain the large inter-individual differences observed in reading performance among deaf students.

Considering the effect of CI use versus HA, the recorded data were in line with that reported by Cupples et al. (2014), Fitzpatrick et al. (2012), Harris and Terlektsi (2010), and Szterman and Friedmann (2014), that is, there was no significant difference between those students who used CIs and those who used digital HAs in respect of their comprehension of texts. The reason that the children in this study who used CIs did not achieve better results than those who did not use such assistive technology may be because the degrees of hearing loss for each group (implanted and non-implanted) were different (as it is shown in the statistical analysis presented in Table 1). It therefore appeared that the use of one or other device, providing it is appropriate for the degree of hearing loss of the deaf child, did not determine the reading comprehension level.

The age at which a deaf child was fitted with a CI or HA was another factor that has been frequently linked with linguistic development and with better reading performance. In the present study this variable proved to be unrelated to the text comprehension. One reason that can be adduced to explain this fact is that the majority of participants in this study had not been fitted with assistive technology at an early age; only 13 of the 47 participants were implanted or received a digital HA before 2 years of age. Perhaps, had there been more cases of early implantation among the participants, data supporting a relationship between this factor and better performance in text comprehension would have been recorded. It is, however, noteworthy that in the smaller sample of participants who had been fitted with assistive technology at an early age (N = 13) the distribution of students in groups that did or did not have difficulties in text comprehension was very similar to the overall results.

In respect of family socioeconomic status, some studies like that of Geers (2006) recorded better reading performance in deaf children born to parents with a higher socioeconomic status. In the present study, family socioeconomic status was not shown to be a variable related to text comprehension. When analyzing these data it should be noted that the majority of the participants of this study were from a medium-low socioeconomic status (37 of the 47 participants) with only 10 participants coming from a high socioeconomic status. The lack of participants from a high socioeconomic status reduced the likelihood of encountering statistically significant differences with respect to other groups. It should be noted, however, that within this small group of high socioeconomic status participants (10 cases), there was an equal distribution between those that encountered comprehension difficulties and those that did not while in the groups with low or medium socioeconomic status more participants encountered comprehension difficulties than did not, although the differences were not large enough to make them statistically significant.

The last of the variables external to the reading process that was tested in this study was the school stage. This variable was included to determine whether, as suggested in certain works cited in the introduction, gaps in reading development in deaf children increase with age. Participants in the first school stage were younger than those in the second stage, who were in turn younger than those in the third stage. It was expected that this would be a factor marking significant differences between those groups who had difficulties comprehending texts and those who did not, that is, it was anticipated that fewer cases of difficulties would be recorded for students in the first school stage when compared to students in the second or third stages. The recorded data did not support this hypothesis, however; and the schooling stage was not statistically significant in explaining whether a participant fell within the group that did or did not encounter difficulties in text comprehension. It should be borne in mind that the exercise used to assess text comprehension was the same in all cases; the texts used and the questions posed to assess students' comprehension of them were the same for all school stages. In other words, deaf students' performance in text comprehension was lower than that of their hearing peers independent of their educational stage.

Analysis of the effect of decoding on text comprehension performance showed that none of the three skills measured (the reading of letters, words and pseudo-words) explained why participants fell into a group that did or did not have difficulty in comprehending texts. It is important to note that very few participants had difficulties with any of these tasks (six in the first exercise and four in the other two exercises). This good performance in reading mechanics could be attributed to participants' use of modern-day assistive technologies that enable better perception of spoken words, leading to adequate phonological skills that contribute to reading mechanics. It could also be considered, however, that since all of the participants had already had some reading experience, this had stimulated their decoding skills, and possibly also their phonological awareness. This interpretation is based on the conclusion drawn by Kyle and Harris (2006, 2010) that deaf children could develop their phonological awareness through reading. It should also be noted that deaf participants did not show any noticeable difference in performance when decoding words or pseudo-words, suggesting no preference in their use of lexical or sub-lexical routes when decoding written text. The results of this study were consistent with those of Moreno-Pérez et al. (2015) who did not find evidence that the low reading efficiency of the participants in their study was the result of decoding difficulties. Their study also showed good performance when reading words and pseudo-words. They attributed this to the fact that, in Spanish, decoding is mastered at a younger age, as a consequence of the transparency of the language.

In general, little difficulty in decoding was observed when compared to text comprehension. Clearly, the task of understanding a text involves more than decoding which, although a necessary skill, is not itself sufficient. The problem faced by participants of this study did not appear to be rooted in an inability to translate the printed input into a phonological representation that encapsulates the meaning. The data led us to relate the difficulties observed in reading comprehension among deaf children in recent generations to the difficulties reported in children with language delay. The work of Bishop, McDonald, Bird and Hayiou-Thomas (2009) and Kelso, Fletcher and Lee (2007) provided cases of children with specific language impairments who exhibited problems with reading comprehension, but had no problems with the mechanics of reading. In these studies it was noted that the processes of the mechanics of reading were not sufficient to explain reading efficiency; the reading limitations of certain students could not be explained by their level of decoding, rather one must be cognizant of their difficulties with oral comprehension.

The data obtained in this study on the effect of linguistic comprehension (lexical and grammatical) on text comprehension indicated that only those tests employed to evaluate grammatical understanding explained the observed variance in performance in text comprehension. When logistic regression analysis was applied, lexical age was not linked to the presence or absence of difficulties in text comprehension. Descriptive data, however, showed that the average lexical age of group participants with difficulty was lower (5.53) than that of the group without difficulty (6.96). It is interesting to note that participants demonstrated a higher average lexical age compared to the average grammatical age, both in the group with difficulty comprehending texts (5.53 and 4.73 respectively) and in the group with no such difficulty (6.96 and 6.34 respectively). In all cases, the average linguistic age (both lexical and grammatical) of the participants, whether they were experiencing difficulties or not, was less than the value that corresponded to their chronological age (with difficulty: 9.53, without difficulty: 9.98). Even with this low linguistic age, one group did, however, achieve a level of text comprehension commensurate with their educational stage. Since only grammatical age had a predictive value, it is conceivable that a certain level of grammatical competence is necessary in order to avoid difficulties in text comprehension. Relying solely on lexical knowledge may result in errors in text comprehension and using the keyword strategy may not be enough (Domínguez et al., 2014). Therefore, while they may have achieved a certain lexical level, readers who lack the necessary grammatical knowledge will fail to achieve a complete and correct comprehension of the written text. This leads one to question what the necessary level of grammatical knowledge would be. According to the data for the mean grammatical age of each group, a grammatical age of more than 6 years is the answer; it is at this mean grammatical age that the without difficulty group can comprehend texts. This is both the chronological and grammatical age at which children displaying normal development begin to comprehend texts.

No previous study has conducted as comprehensive an analysis as is presented here. The results of this study indicate that five types of grammatical structures correlate with reading comprehension. Of these, three are reversible: Set R (reversible passive object-verb-subject sentences); Set E (reversible predicate SVO sentences), and Set H (predicate SVCC subject-verb-adverbial sentences). This makes them good indicators of grammatical knowledge, since it is essential to use this knowledge to understand the correct meaning of these types, as semantic knowledge alone is not enough. These data are consistent with that of Miller et al. (2013), who found a connection between oral and reading comprehension of semantically implausible sentences. The other two types: Set D (reflexive and non-reflexive pronoun predicate sentences), and Set G (compound disjunctive clauses with a compound object or subject) are complex structures. Set D-type structures require mastery of the pronominal function; in Spanish an understanding of the pronouns *se* and *le* is essential to interpret who is the agent and who is the recipient in a sentence. The short length of these words and the fact that they are unstressed makes it more difficult to distinguish them in the flow of speech. Set G-type structures contain disjunctive clauses that require not only grammatical comprehension of the sentence, but also the application of logical operations of exclusion and inclusion. As early as the 1970s and 1980s, Quigley and others had demonstrated that difficulty with disjunctive and alternative structures was a particular characteristic of deaf students. More recently, Edwards et al. (2011) also indicated that relational structures, e.g.'neither x nor y' and 'x but not y', presented a particular difficulty for the deaf participants of their study.

Following analysis of the value of these five structures as predictors, only reversible passive OVS sentences (Set R-type) and reversible predicate SVO sentences (Set E-type), in that order, are determining factors that predict whether a participant will belong to the group with difficulty or without difficulty in text comprehension. The complexity of the structures in set R lies, in addition to the reversibility previously described, in the changes in agent and object because, in these type of sentences, the SVO canonical order is not followed, since they are passive sentences. These data are consistent with the results of Berent (1988, 1996) and with the interpretation of Cannon and Kirby (2013) concerning deaf students misapplication of the SVO structure when interpreting other types of sentences. The data also matched that of Edwards et al. (2011) who recorded that their deaf participants had difficulty with reversible structures. Regarding reading comprehension of sentences, Szterman and Friedmann (2014) concluded that the most significant grammatical difficulties faced by deaf participants in their study arose when detecting changes in the thematic roles of agent and object in sentences that did not follow a canonic order.

These conclusions regarding deaf students' difficulties in understanding reversible structures, disjunctive structures and structures that do not follow an SVO canonical order appear frequently in the majority of studies independent of the language of the participants. It should be pointed out that while the present study was limited to Spanish grammar and comprehension of Spanish texts, the results could be generalized to other languages that contain the same structures.

In conclusion, data obtained in this study strongly support intervention specifically focused on grammatical competence in order to improve text comprehension. Such intervention should include those types of structures that have a statistically demonstrated relationship to text comprehension, namely sentences that are reversible, that do not follow a canonical order, that include a pronominal object (a pronoun that performs the function of an object) and disjunctive sentences.

The need for specific intervention is supported by data from Domínguez et al. (2014) who found that, in a sample of deaf readers who read frequently, the mere act of reading, while it improved vocabulary development, did not have the same effect at a grammatical level. The authors noted that these deaf readers did not make the transition from simple syntax to sophisticated syntax, and continued to use the keyword strategy when interpreting texts. The results of the present study reinforce the necessity of deaf students to receive pedagogical intervention in literacy and grammar skills provided by specialized teachers.

Like Domínguez et al. (2014), we believe that it would be desirable to develop a series of longitudinal studies to demonstrate whether grammatical training produces the desired effect in text comprehension.

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Appendix 1: Sets of grammatical structures from the CEG

Set A:	Non-reversible predicate SVO (subject-verb-object) sentences
Set B:	Sentences with attributive verbs
Set C:	Negative predicate sentences
Set D:	Pronoun predicate sentences (reflexive and non-reflexive)
Set E:	Reversible predicate SVO sentences
Set F:	Predicate SVO sentences with subject in plural (reversible and non-reversible)
Set G:	Compound disjunctive clauses (compound object or subject)
Set H:	Predicate SVCC (subject-verb-adverbial of place) sentences with adverbial of place (above, under, in front, and behind)
Set I:	Compound sentences with adversative conjunctions (compound object or subject)
Set J:	Relative SO (subject-object)-type sentences
Set K:	SVO sentences with split subject
Set L:	Absolute comparative sentences
Set M:	OVS (object-verb-subject) sentences with focalized object
Set N:	Sentences with object pronouns (gender contrasts)
Set O:	SS (subject-subject)-type relative sentences
Set P:	Compound sentences with adversative conjunctions (compound object or subject)
Set Q:	Sentences with object pronouns (gender and number contrasts)
Set R:	Reversible passive OVS sentences
Set S:	OVS sentences with split object
Set T:	Relative OS (object-subject)-type sentences

Appendix 2: CEG sentences used to evaluate each type of grammatical structure correlated with text comprehension

Structures	Sentences
Set R: Reversible passive OVS sentences	La niña es empujada por el niño [The girl is pushed by the boy] El gato es perseguido por el ratón [The cat is chased by the mouse] El niño es abrazado por la mujer [The boy is embraced by the woman] La bici es perseguida por el coche [The bike is pursued/chased by the car]
Set G: Compound disjunctive clauses (compound object or subject)	Ni el gato ni el perro son negros [Neither the cat nor the dog are black] La niña no es rubia ni delgada [The girl is neither blond nor thin] Ni el niño ni la niña tienen gafas [Neither boy nor girl have glasses] La pelota no es roja ni pequeña [The ball is neither red nor small]
Set D: Pronoun predicate sentences (reflexive and non-reflexive)	La niña se lava las manos [The girl washes her (own) hands] La mujer le pone los zapatos [The woman puts her shoes (on him/her)] El hombre se corta el pelo [The man cuts his (own) hair] La niña le pinta la cara [The girl paints her (someone else's) face]
Set E: Reversible predicate SVO sentences	El ratón persigue al gato [The mouse chases the cat] El hombre besa a la mujer [The man kisses the woman] La niña empuja al niño [The girl pushes the boy] La bici persigue al coche [The bicycle chases the car]
Set H: Predicate SVCC sentences with adverbial of place (above, under, in front, and behind)	El perro está delante del gato [The dog is in front of the cat] El círculo está encima del cuadrado [The circle is on top of the square] El niño está detrás de la niña [The boy is behind the girl] El lápiz está debajo del libro [The pencil is under the book]

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