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Research Article

Why Are Causal and Temporal Connectives Difficult to Understand? A Comparison Between Italian Hearing Good and Poor Comprehenders and Deaf Poor Comprehenders

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ABSTRACT

Purpose: Both hearing poor comprehenders (PCs) and deaf or hard-of-hearing (DHH) PCs have problems in understanding causal and temporal coherence relations signaled by connectives. The study examined whether hearing and DHH PCs' problems with connective understanding are similar and mainly related to their limited vocabulary, including knowledge of connective words, or to their poor reading comprehension abilities more generally.

Method: Three groups of 7- to 10-year-old readers, matched on grade level (hearing PCs, DHH PCs, and hearing good comprehenders [GCs]) performed a reading comprehension task, a vocabulary task, and causal and temporal connective understanding tasks. Hearing and DHH PCs were also matched on reading comprehension and decoding abilities.

Results: The DHH PCs performed significantly worse than both the hearing GCs and PCs in temporal and causal connective understanding. Significant differences between hearing PCs and GCs were found only in causal connective understanding. DHH readers' difficulties in causal connective understanding were significantly associated with poorer vocabulary knowledge. In contrast, vocabulary knowledge did not uniquely contribute to hearing PCs' difficulties with causal connective understanding, once their reading comprehension skills were controlled for.

Conclusions: The results suggest that despite a similar reading profile, DHH PCs' difficulties with causal connective understanding are more closely related to their vocabulary delay, whereas hearing PCs' difficulties are more strongly influenced by their poor text integration processes (as indexed by their reading comprehension skills). Neither vocabulary knowledge nor reading comprehension skills contributed to the explanation of DHH readers and hearing PCs' temporal connective understanding.

Causal and temporal coherence relations in text are often signaled by logical connectives, such as *because*, *so*, *before*, *after*, or *while*, which can facilitate comprehension by making explicit the semantic relations between clauses (Crosson & Lesaux, 2013; Fajardo et al., 2013; McNamara et al., 1996). For example, in the sentence, "Robin was back home late *because* she had to buy something for dinner," the causal connective signals to readers that "having to buy her dinner" caused Robin's delay. Readers with reading comprehension problems often fail to use these connectives to guide their reading (Boureux et al., 2012; Cain et al., 2005; Fajardo et al., 2013). However, few research studies have focused on their difficulties with connectives, and thus, the nature of their poor connective understanding remains largely unknown.

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This study explores the understanding of causal (*so*, *because*, *therefore*) and temporal (*before*, *after*, *while*) connectives in three groups of readers: hearing good comprehenders (GCs), hearing poor comprehenders (PCs), and deaf or hard-of-hearing (DHH) PCs, and examines two factors associated with hearing and DHH PCs' poor understanding of these causal and temporal connectives: poor reading comprehension skills, which influence their ability to integrate information across clauses and across a text more generally, and poor receptive vocabulary.

Factors Affecting Poor Causal and Temporal Connective Understanding

There are three main reasons as to why some readers might have difficulties in using connectives to support their understanding. First, they might not give sufficient attention to the words (i.e., connectives) that signal the need to infer a connection. Second, they may have poor vocabulary knowledge, including a limited understanding of connective words (see, e.g., Sullivan et al., 2014, 2020). Although connectives represent a special category of words, with a logical and syntactic role (Crosson & Lesaux, 2013), a poorer vocabulary may also involve weaker knowledge of connective words. Third, readers may have difficulty in conceptualizing and representing the logical relation (e.g., causal or temporal) signaled by the connective (see, e.g., Crosson & Lesaux, 2013; Evers-Vermeul & Sanders, 2009; Spooren & Sanders, 2008). For example, in the sentence, "He did not get home (A) *because* he fell asleep in his office (B)," readers not only need knowledge of the meaning of *because* but also need to infer and represent the causal relation implied between events A and B, where B logically precedes and causes A (Evers-Vermeul & Sanders, 2009; Spooren & Sanders, 2008). This ability to connect up the events in a meaningful way is more closely related to reading comprehension skills than to vocabulary knowledge per se and specifically is related to the ability to integrate information both within the text and with prior knowledge.

Connective understanding can be seen as an instance of the construction–integration process. According to Kintsch's construction–integration model (1988; Kintsch & Welsh, 1991), text comprehension involves both the ability to use the linguistic cues in the text to (re)construct the semantic relations specified, and the ability to make inferences through which readers integrate textual information with their background knowledge to build a mental model of the situation described. Understanding coherence relations expressed by connectives in text may involve both these processes: the ability to recognize and use the linguistic cues in the text, which is based on readers' knowledge of connective words and of the syntactic function of connectives, and the ability to build a mental representation of the logical relation implied, based on the reader's background knowledge. Thus, the connective task can be considered a microcosm of reading comprehension ability.

Hearing and DHH PCs' Understanding of Causal and Temporal Connectives

From the age of 7–11 years, as children develop as autonomous readers, their abilities to understand causal and temporal connectives also develop significantly (Cain & Nash, 2011). Prior studies have shown that PCs and less skilled readers have particular difficulties with the comprehension of clauses linked by temporal conjunctions, such as *before* and *after* (Boureux et al., 2012; Cain & Nash, 2011; Crain et al., 1990). As noted above, these difficulties might be related to their poorer vocabulary knowledge of temporal as opposed to causal connectives or to the greater effort necessary to infer the type of relation between clauses (temporal) that is implied by the connective. Current reading research (e.g., Cain & Nash, 2011) has not yet shed light on this issue. Cain et al. (2005) compared 8- and 9-year-old good and poor hearing comprehenders, matched on word reading ability, receptive vocabulary, and receptive syntax, on performance in cloze tasks that required them to select the appropriate additive, temporal, causal, or adversative connective to complete each sentence. Their results showed that the PCs were generally less able to select the appropriate connective and that the temporal and causal items were the most difficult for both groups of readers. As the readers were matched on vocabulary and word reading skills, the authors attributed the findings to PCs' lower comprehension skills and did not assess the association between children's performance on the connective tasks and their vocabulary knowledge.

DHH readers also seem to show difficulties in the understanding of temporal and causal connectives (Passig & Eden, 2010; Sullivan et al., 2014). However, to date, there is no evidence of greater difficulty with understanding of temporal conjunctions in these readers, as direct comparisons of the comprehension of causal and temporal connectives are lacking for this group. Yet, DHH readers' problems with causal and temporal relations are apparent only when the causal and temporal relations are expressed in a linguistic form, in sentences (Sullivan et al., 2014). They do not seem related to a general difficulty in conceptualizing or mentally representing causal or temporal relations because these children do not have difficulty organizing narrations according to a conceptual causal and temporal structure (Arfé & Boscolo, 2006). Moreover, they demonstrate appropriate causal and temporal reasoning in nonverbal tasks, such as reordering a series of pictures based on causal or temporal relations (Sullivan et al., 2014).

In two experiments, Sullivan et al. (2014) compared deaf (mostly orally educated) and hearing young readers (aged 7–11 years) across verbal and nonverbal tasks tapping temporal and causal reasoning skills and found that deaf readers had difficulties only when causal and temporal reasoning was text based, that is, when they had to infer the causal or temporal relation expressed by connectives in written sentences. Performance on the text-based tasks correlated significantly with children's receptive vocabulary in the hearing, but not in the deaf group. However, vocabulary scores were available only for a subgroup of deaf children, and thus, the statistical power was reduced for this group (correlations ranged between .40 and .47).

These preliminary studies point, on the one hand, to the complexity of temporal and causal connective understanding; on the other hand, they suggest that both comprehension skills and vocabulary knowledge can play a role in connective understanding, but their precise contribution remains unclear and could be different in DHH PCs and hearing PCs. A direct comparison between hearing PCs and DHH PCs using the same tasks could help clarify the specific underpinnings of poor causal and temporal connective understanding in these two groups of readers and shed light on the nature of the problems underlying poor understanding of these connectives more generally (Kyle & Cain, 2015; Steele et al., 2013). Connective understanding, especially when temporal and causal connective are considered, is indeed not an easy task even for typically developing readers (Cain et al., 2005). Causal and temporal coherence relations permeate narratives, the first text genre that children experience in their everyday life and at school (e.g., van den Broek, 1989), and thus, an examination of children's difficulties with these connectives is also relevant to inform early intervention.

The Reading Comprehension Profile of Hearing and DHH PCs

The core problem in hearing PCs' reading difficulties is a deficit with language comprehension processes (Rapp et al., 2007). These typically include poor inference-making skills and construction–integration processes (e.g., Cain & Oakhill, 2006; Elbro & Buch-Iversen, 2013), but also deficits in word understanding, as evidenced in tasks of receptive vocabulary and semantic processing: synonym judgments or picture naming (e.g., Cain & Oakhill, 2006; Catts et al., 2006; Nation et al., 2001, 2004; Nation & Snowling, 1998). Thus, although their poor reading comprehension skills have been mainly explained in terms of poor construction–integration, coherence-making, processes (Cain & Oakhill, 2006; Cain et al., 2005), it is difficult to rule out a role of vocabulary knowledge (Cain & Oakhill, 2006; Catts et al., 2006; Oslund et al., 2018). Indeed, a vocabulary deficit is often associated with PCs' reading comprehension problems (Cain & Oakhill, 2011; Catts et al., 2006; Potocki et al., 2017), although the specific role of oral receptive vocabulary in the reading comprehension problems of PCs is not clear (e.g., Oakhill & Cain, 2012).

On the one hand, there is evidence of a strong association between oral vocabulary skills and reading comprehension in hearing readers (Ouellette & Shaw, 2014) as well as evidence suggesting that poorer vocabulary knowledge can play a direct and indirect role in reading comprehension difficulties (Cain & Oakhill, 2014; Catts et al., 2006; Daugaard et al., 2017; Oslund et al., 2018; Potocki et al., 2017; Spencer et al., 2019). On the other hand, when compared with typically developing readers, hearing PCs' deficits in oral language, including vocabulary, are not commensurate with their reading comprehension deficits (Spencer & Wagner, 2018; Spencer et al., 2019). In addition, the association between poor vocabulary knowledge and poor comprehension skills could be also explained by the long-term consequences of poor reading comprehension, which could limit readers' vocabulary growth (Cain & Oakhill, 2011; Chrysochoou et al., 2018). Past research also suggests a limited role of vocabulary knowledge in hearing readers' local coherence inferences (Cain & Oakhill, 2014). However, in tasks such as causal and temporal connective understanding, vocabulary knowledge could play a greater role, as the comprehension of the semantic relation between two clauses or sentences is only possible if the reader knows the meaning of the connective (i.e., understands the specific causal or temporal relation intended).

Several DHH readers, like hearing PCs, also have significant difficulties in making inferences to integrate information during reading (Dyer et al., 2003; Kyle & Cain, 2015) and seem to show specific problems in understanding coherence relations that are signaled by causal and temporal connectives in text (Sullivan et al., 2014). However, their problems might be more straightforwardly attributed to their delayed access to spoken language and their consequent poor receptive vocabulary (Daza et al., 2014; Harris et al., 2017; Sullivan et al., 2014; Worsfold et al., 2018). Indeed, although the linguistic and literacy abilities of DHH readers have consistently improved in the last years (Caselli et al., 2012; Geers et al., 2008; Hayes et al., 2009; Mayer et al., 2016; Tomblin et al., 2005; Yoshinaga-Itano et al., 2018), DHH readers often experience a delay in accessing spoken language, with effects on their vocabulary growth (Lund, 2016; Walker et al., 2019; Worsfold et al., 2018) and in turn on their reading comprehension (Daza et al., 2014; Harris, 2015; Harris et al., 2017; Kyle et al., 2016). Thus, for this group, vocabulary knowledge is considered to be one of the most consistent predictors of reading comprehension (Daza et al., 2014; Harris et al., 2017; Kyle et al., 2016; Kyle & Harris, 2006).

Comparing Hearing and DHH PCs

Although some researchers (e.g., Kyle & Cain, 2015) have highlighted the similarities between hearing PCs and DHH PCs' text comprehension problems, to date, direct comparisons between these two groups have been limited. One reason is that most reading research has been conducted in deep orthographies, like English, in which DHH readers' decoding problems are a confounding variable in the interpretation of research findings (see Kyle & Cain, 2015). In shallow orthographies, like Italian or Spanish, however, decoding is less challenging (Florit & Cain, 2011). In these orthographies, DHH children can develop normal or near-normal decoding abilities and so show a reading comprehension profile closer to that of hearing PCs, except that they typically have a more severe vocabulary delay than their hearing peers (see Arfé et al., 2015; Daza et al., 2014; Gomez-Merino et al., 2020). Gomez-Merino et al. (2020) tested a group of young, orally educated, deaf readers who were cochlear implant users in a sentence reading task and found no significant differences between deaf and hearing Spanish-speaking children in decoding skills but statistically significant differences between the two groups in their ability to detect grammatical violations in sentences and in their receptive vocabulary. Daza et al. (2014) explored the association between language skills (vocabulary knowledge and phonological awareness) and the reading comprehension skills of 30 prelingually deaf children (aged between 8 and 16 years, most of whom were orally educated) and found significant positive correlations between children's receptive vocabulary and reading comprehension, but not between their rhyme awareness (a precursor of decoding skills) and reading comprehension skills. In Italian, Arfé et al. (2015) compared the performance of 7- to 12-year-old orally educated DHH and hearing PCs to that of GCs on a range of tasks, including phoneme awareness, productive vocabulary, and verbal working memory, and found that both the hearing and DHH PCs performed more poorly than the GCs on the productive vocabulary and verbal working memory tasks. All these studies suggest that a poorer vocabulary can contribute to the explanation of DHH PCs' reading comprehension difficulties. In contrast, as noted earlier, the role played by receptive vocabulary in hearing PCs' reading difficulties is less clear. In conclusion, this study aims to determine whether causal and temporal connective understanding is explained by vocabulary or comprehension (or both) and whether this varies as a function of the readers' profile.

This Study

This study compared the understanding of causal and temporal coherence relations signaled by connectives in 7- to 10-year-old Italian hearing and DHH PCs, matched on grade level, reading comprehension, and decoding skills. We had two goals: (a) to explore whether these two groups of PCs showed similar problems in the understanding of causal and temporal connectives in comparison with GCs of the same age and (b) to investigate whether and to what extent their problems were related to poorer vocabulary knowledge or to their poorer reading comprehension skills. This second research question addresses whether vocabulary knowledge contributes to causal and temporal connective understanding above and beyond children's reading comprehension skills.

Since Italian is a very shallow orthography, children around the age of 7 years, at the end of their second year of school, are already relatively fluent readers, and their language comprehension skills become more critical than their decoding abilities to their reading success (Florit & Cain, 2011). An exploration of the reading comprehension difficulties that emerge at this stage is important to inform early intervention programs designed for PCs and struggling readers more generally.

There were two research questions, as follows.

(1) Do Italian hearing and DHH PCs show the same level of difficulty in comparison with GCs in understanding causal and temporal connectives in text? And is the pattern of their performance similar across types of coherence relation (causal and temporal)?

(2) Does receptive vocabulary play a role in the comprehension of causal and temporal connectives? And what is the unique contribution of receptive vocabulary in hearing and DHH PCs' causal and temporal connective understanding?

Based on prior research (Cain et al., 2005; Cain & Oakhill, 2014; Sullivan et al., 2014), we anticipated that both hearing PCs and DHH readers would show difficulties in causal and temporal connective understanding compared to hearing GCs, although the pattern of their performance across the two connective types (causal and temporal) could differ. Specifically, based on previous findings, we would expect hearing PCs to find temporal connectives more difficult than causal ones (Cain & Nash, 2011; Crain et al., 1990), whereas we did not have specific predictions about differences in performance for the group of DHH readers. We also predicted that both vocabulary knowledge and reading comprehension abilities (as a measure of children's construction–integration processes) would contribute to the explanation of performance in causal and temporal connective understanding, but their role would be different in the two groups of PCs: hearing and DHH PCs. More precisely, we hypothesized that DHH readers' comprehension of causal and temporal connectives would be uniquely explained by their vocabulary knowledge. In contrast, we hypothesized that vocabulary would not account for unique variance in hearing PCs' causal and temporal connective understanding, which would be explained mainly by their reading comprehension skill (see Cain et al., 2005).

Method

Participants

Participants were selected from an initial sample of 228 children from Grades 2 to 5, recruited from special and mainstream schools and rehabilitation units. Criteria for inclusion in the study were: (a) being native speakers of Italian; (b) showing decoding skills and nonverbal intelligence within the normal range; and (c) not presenting any certified motor or sensory disabilities, except hearing loss. Reading comprehension scores on a standardized test (Prove di Lettura MT: Cornoldi et al., 2016) were used to identify GCs and PCs, with cutoff scores of 75th percentile and 25th percentile, respectively (see Catts et al., 2006). From this sample, three groups of young readers were identified: 27 hearing PCs; 27 DHH readers, matched for grade level, reading comprehension, and decoding skills to the hearing PCs; and 27 hearing GCs, matched with the hearing PCs for grade level, nonverbal IQ, and decoding skills. The matching between the DHH and hearing PCs by grade level and reading comprehension skills was one by one within the younger (Grades 2/3) and older (Grades 4/5) age groups. The reading comprehension scores of the DHH readers were within ± 2 points of the hearing PCs' reading comprehension raw scores. Decoding skills, assessed by a lexical decision task, in which children had to identify pseudowords among words in a list, were matched at group level, and decoding was within the normal range for all participants.

As shown in Table 1, there were no significant differences between the three groups in sex, $\chi^2 = 2.70$, $p = .26$; grade level, $\chi^2 = .11$, $p = .95$; or lexical decision (decoding) skill, $F(2, 78) = 1.80$, $p = .17$. The DHH readers' IQ scores, reported in their clinical files, were within the normal range (at or above a standard score of 85). The two groups of hearing GCs and PCs were also matched on nonverbal ability, as estimated by the Primary Mental Ability (PMA; Thurstone & Thurstone, 1963) Spatial relations subtest, $F(1, 45) = 2.33$ $p = .13$.

A power analysis indicated that a sample size of 66 participants was required to detect small effects from a within-between group comparison with power set at .95 (Faul et al., 2007). Thus, a sample of 81 participants was considered appropriate for testing the study's hypotheses. Informed consent was obtained prior the data collection in written form from parents and orally from children. Participants' characteristics are displayed in Table 1 and described below.

DHH PCs. All children in this group (n = 27; 18 girls and nine boys, M_{age} = 9.6 years, age range: 7–11) presented congenital and binaural sensorineural hearing loss and scored at or below the 25th percentile on a standardized reading comprehension test appropriate for their grade level (Cornoldi et al., 2016; M = 5.4, range: 2–9). They were selected from an original sample of 40 DHH readers assessed for the study. Inclusion criteria were having normal intelligence, not having received a diagnosis of syndromic hearing loss, and showing an

Table 1. Study 1: participants' characteristics; DHH readers (n = 27), hearing PCs (n = 27), and hearing GCs (n = 27).

Characteristic	DHH	PCs	GCs	p	Post hoc
Girls: n (%)	18 (66%)	12 (44%)	15 (55%)	.26	
Nonverbal IQ: M (SD)	≥ 85	112 (16.5)	107 (12.2)		
Visuospatial PMA scores: M (SD)		13.27 (4.64)	11.4 (3.57)	.15	
Severe to profound HL: n (%)	23 (85%)	-	—		
CI: n (%)	11 (41%)	-	—		
Age: M (SD)	9.6 (1.28)	8.9 (1.09)	8.7 (1.11)	.01	DHH > GCs
Grade level: M (SD)	4.0 (1.13)	3.9 (1.09)	3.67 (1.11)	.95	
Lexical decision: M (SD)	32.3 (11.5)	27.3 (8.86)	30.4 (8.65)	.17	
Reading compreh: M (SD)	5.4 (2.02)	6.0 (2.2)	12.1 (0.99)	.001	DHH = PCs < GCs
Receptive vocab: M (SD)	23.0 (4.46)	25.4 (5.14)	26.2 (2.97)	.02	DHH < GCs

Note. Raw scores are reported for the lexical decision, reading comprehension, vocabulary, and spatial relations (visuospatial) tests. DHH = deaf-or-hard-of-hearing; PCs = hearing poor comprehenders; GCs = hearing good comprehenders; PMA = Primary Mental Ability; Severe to profound HL = severe or profound hearing loss; CI = cochlear implant; Reading compreh = reading comprehension; Receptive vocab = receptive vocabulary.

aided hearing threshold ≤ 40 dB. The DHH children were recruited through two speech therapy units and special schools in northern and southern Italy. Their nonverbal IQ, as reported in their clinical files (most recent assessment, not older than 2 years), was in the normal range (i.e., a standard score equal or greater than 85). Their decoding skills, assessed by a lexical decision task (Caldarola et al., 2012), were average for their age. All children used only oral language to communicate and received regular speech therapy. Of the 27 children selected for the study, four had a mild-to-moderate hearing loss (hearing threshold greater than 30 dB), 10 had a severe hearing loss (hearing threshold greater than 60 dB), and 13 had profound hearing loss (hearing threshold greater than 80 dB). Mean age at diagnosis and first fitting was 3.8 years (SD = 2.8). Thus, all DHH participants had delayed access to verbal language, although their hearing loss was relatively well compensated with hearing aids or cochlear implants (aided hearing threshold ≤ 40 dB). At the time of the study, all children were fitted with digital hearing aids (n = 16) or cochlear implants (n = 11).

Hearing PCs. This group consisted of 27 PCs (12 girls and 15 boys, M_{age} = 8.9 years, age range: 7–10), who scored at or below the 25th percentile on a reading comprehension task (Cornoldi et al., 2016) appropriate for their grade (M = 6.0, range: 1–9). Their decoding skills (lexical decision; Caldarola et al., 2012) were adequate to their age, and their nonverbal intelligence, estimated by the PMA visuospatial task (Thurstone & Thurstone, 1963), was within the normal range.

Hearing GCs. All children in this group (n = 27; 15 girls and 12 boys, M_{age} = 8.7 years, age range: 7–10) scored at or above the 75th percentile in a reading comprehension task (Cornoldi et al., 2016) appropriate for their age (M = 12.15, range: 11–14). All were native speakers of Italian and had decoding skills (Caldarola et al., 2012) and nonverbal intelligence (PMA visuospatial task; Thurstone & Thurstone, 1963) within the normal range.

Procedure

All children were administered the following tasks in two separate testing sessions of about 40 min each:

Lexical decision task. A standardized lexical decision task (Caldarola et al., 2012) was used to assess children's decoding abilities (see also Wauters et al., 2006). Children were presented a list of 60 words and 60 pseudowords, that is, permissible and pronounceable letter strings that are not words, on a sheet of paper, and were asked to identify as many pseudowords as possible by marking them with a pencil, within 2 min. To decide whether a letter string was a word or a pseudoword, children had to rely on their decoding skills. The score was the number of pseudowords correctly identified within the time limit. Concurrent validity calculated by correlations with a standardized text reading test (Cornoldi et al., 2016) is .75 for reading speed (measured in syllables per second) and −.52 for reading accuracy (word reading errors). In Italian, reading speed is more predictive of word reading than accuracy (Carioti et al., 2021). The low concurrent validity on the accuracy measure depends on the type of concurrent measure: Text reading tasks involve not only decoding but also reading comprehension skills (Carretti et al., 2020; Gellert, 2014). Reliability was not reported.

PMA Vocabulary Subscale. This task assesses children's receptive vocabulary and is widely used as an alternative to the Peabody Picture Vocabulary Test since it can be group administered (Thurstone & Thurstone, 1963). Children were given a sheet of paper containing a list of target words and, for each target word, a list of four pictures put in a row. All target words were concrete nouns. The experimenter read each word aloud, letting the children make their choice by crossing out the picture corresponding to the word with a pencil. Each item had four alternatives, with only one correct answer. To ensure recognition of the target word by the DHH participants, words were both read aloud by the experimenter and also presented in written form. The total score is the number of items correctly identified within 6 min. Split-half reliability, as reported in the manual, is .86.

Reading comprehension (MT tests of reading for primary school). A standardized reading comprehension test was used to assess text comprehension (Cornoldi et al., 2016). The test consists of reading a passage and answering multiple-choice comprehension questions, which assess both literal comprehension and inferential skills. Parallel-form reliability coefficients reported by the manual range from .57 to .70, depending on the children's grade level.

PMA Spatial Relations Subscale. This test was used to estimate nonverbal (visuospatial) abilities in the hearing controls (PCs and GCs ; Thurstone & Thurstone, 1963). The task requires the child to choose, from among four options, the one that best completes a geometric figure. The split-half reliability of the subscale is .94.

Causal and temporal connectives task. Children's comprehension of temporal and causal coherence relations was assessed in an experimental multiple-choice judgment task. Twenty-four items were presented to each child. Each item included a black-and-white picture that illustrated a situation or an event, followed by a choice of three sentences that differed only in their connectives (see Figure 1; further examples are reported in the Appendix).

The picture was consistent with only one of the three sentences/connectives (target). The task thus required the participants to compare the meaning of the three sentences and infer which causal or temporal relation (sentence) was most appropriate to express the contextual information given by the picture. In summary, to succeed in the task, participants required both knowledge of the specific connectives used and inference-making abilities.

For 12 items, the correct response was a temporal connective (*prima/before*, *dopo/after*, or *mentre/while*; four items per connective); for the remaining 12 items, it was a causal connective (*perchè/because*, *così/so*, *perciò/therefore*; four items per connective). Causal and temporal connectives were chosen based on prior studies (e.g., Cain & Nash, 2011). The task was developed by the authors. The items were first selected from a larger item set based on an agreement of 90% between the researchers on targets, and subsequently they were tested with children, skilled and less skilled readers between 7 and 11 years old (Boureux et al., 2012). The items that did not discriminate well between skilled and less skilled readers or that were ambiguous (i.e., with less than 70% accuracy and no clear target choice) were reformulated or replaced by new items.

The final test comprised sentences that varied in length from seven to 13 words ($M = 9.46$). Temporal and causal sentences had the same syntactic structure—a main clause followed by a subordinate clause introduced by a causal or temporal connective—and did not differ in number of words, $t = 1.75$, $p = .09$ ($M = 10.2$, $SD = 1.99$ for causal items and $M = 8.9$, $SD = 1.6$ for temporal items), or number of letters, $t = 1.67$, $p = .11$ ($M = 60$, $SD = 9.5$ for causal items and $M = 54$, $SD = 6.7$ for temporal items). Cronbach's α computed in this study was .72. Interrater agreement on correct responses between independent scorers, computed on 30% of the connective tasks was 99%.

The causal and temporal items were presented in two separate booklets, of 12 items each. The order in which each booklet was presented was counterbalanced between participants. Within each booklet, four different orders were generated for the items, which were also counterbalanced across the participants.

The two testing sessions were carried out the same day and were divided by a break. All tasks were administered to the DHH participants either by children's speech-language pathologist (the fourth author), during speech therapy sessions, or by a research assistant, at school. Hearing participants were tested at school by the research assistant. Thus, in the case of hearing participants, the PMA vocabulary and other tasks (i.e., the lexical decision task, the reading comprehension task, and the spatial relations task) were administered collectively to the class the children belonged to. Children performed the reading comprehension task, lexical decision task, and PMA Spatial Relations subscale during the first testing session and the connective task and PMA Vocabulary subscale in the second session.

Results

Differences between the GCs and hearing and DHH PCs in reading comprehension, age, and receptive vocabulary were explored by analyses of variance (ANOVAs). The ANOVAs showed significant differences between the groups in reading comprehension, $F(2, 78) = 112.01$, $p < .001$, $\eta_p^2 = .74$, with hearing GCs showing higher comprehension scores than both hearing PCs, $t(52) = -13.07$, $p <$

Figure 1. Connective task: sample items of causal and temporal connectives; answer choices with correct answer in bold. Policeman image: Reprinted with permission from Clipart.com, Authentic Creatives, LLC, https://clipart.com/download.php?iid=177918&tl=clipart. Old lady image: Reprinted from Clipartmag.com under the CC BY-NC 4.0 License (non-commercial use) from https://clipartmag.com/helping-others-drawing.

- The policeman fell asleep after leaving the office
- **The policeman fell asleep before leaving the office**
- The policeman fell asleep while leaving the office

- Jack helped the old lady with the shopping bags, therefore she was tired
- Jack helped the old lady with the shopping bags after she was tired
- **Jack helped the old lady with the shopping bags because she was tired**

.001, $d = -3.56$, and DHH PCs, $t(52) = -15.55$, $p < .001$, $d = -4.23$, who did not differ from each other.

Differences between the groups were also found in age, $F(2, 78) = 4.44$, $p = .01$, $\eta_p^2 = .10$, and in receptive vocabulary, $F(2, 78) = 3.85$, $p = .02$, $\eta_p^2 = .09$. In both cases, the effect size was medium. The DHH readers were significantly older than the hearing GCs ($p = .02$). However, they had significantly lower vocabulary scores than the GCs ($p = .03$). Although DHH readers' vocabulary scores were on average lower than those of hearing PCs, no significant differences in vocabulary were found between these two groups (see Table 1). In the next sections, the analysis plan is presented in relation to the two research questions of the study.

Research Question 1: Do Hearing and DHH PCs Show the Same Level of Difficulty in Comparison With GCs in Understanding Causal and Temporal Connectives? Is the Pattern of Their Performance Similar Across Types of Coherence Relation (Causal and Temporal)?

Group differences in connective understanding were tested using a mixed 3 (Group: DHH, hearing PCs, hearing GCs) × 2 (Connective Type: causal, temporal) analysis of covariance (ANCOVA). As age varied between groups, it was used as a covariate. Proportion of correct responses was the dependent variable, and arcsine transformations of proportions were used to improve the normality of the distribution (Howell, 2007). Nontransformed means are reported in Table 2 for ease of interpretation. Main effects were explored by pairwise comparisons, and interaction effects between the two factors (Connective Type and Group) were explored by running separate between-groups ANCOVAs for each connective type (causal and temporal) and separate within-group ANOVAs for each group (DHH, PCs, or GCs). To control for multiple comparisons, the level of statistical significance was adjusted to .02 for the repeated-measures ANCOVAs and to .02 for the between-groups ANCOVAs (Bonferroni corrections).

A significant main and large effect of group, $F(2, 77) = 16.23$, $p < .001$, $\eta_p^2 = .30$, and a significant and moderate interaction between Group and Connective Type were found, $F(2, 77) = 3.21$, $p = .046$, $\eta_p^2 = .08$ (see Figure 2). The interaction between Age and Connective Type was also significant, with a medium effect size, $F(1, 77) = 5.72$, $p = .019$, $\eta_p^2 = .07$. Inspection of the unstandardized beta (b) coefficients showed that age was significant for causal, $b = 0.16$, $t = 2.60$, $p = .01$, but not temporal, $b = 0.01$, $t = 0.09$, $p = .93$, relations. The main effect of group was explored by pairwise comparisons, which showed that, overall, DHH readers performed more poorly than either group of hearing readers: hearing PCs ($p < .001$) and hearing GCs ($p < .001$), who did not differ significantly from each other. The main effect of coherence relation was not significant, $p = .11$ (means are reported in Table 2).

The follow-up between-group ANCOVAs that explored group differences in the understanding of causal and temporal connectives separately showed significant differences between the three groups in both causal connective understanding, $F(2, 77) = 15.73$, $p < .001$, $\eta_p^2 = .29$, and temporal connective understanding, $F(2, 77) = 7.24$, $p = .001$, $\eta_p^2 = .16$. In both cases, the effect size was large. Age was significant only for causal connective understanding, $F(1, 77) = 6.74$, $p = .01$, $\eta_p^2 = .08$ (for temporal connectives, the p value was .93). Pairwise comparisons, with Bonferroni corrections, showed significant differences in causal connective understanding between the DHH PCs and both the hearing PCs, $p = .006$, Cohen's $d = -0.80$, and GCs, $p < .001$, Cohen's $d = -1.60$, and between hearing PCs and hearing GCs, $p = .035$, Cohen's $d = -0.72$. All effect sizes ranged from medium–large to large. A statistically significant difference between DHH readers and the two hearing groups was also found for temporal connective understanding, with medium–large and large effects (PCs: $p = .01$, Cohen's $d = -0.74$; GCs: $p = .002$, Cohen's $d = -0.96$), whereas PCs and GCs did not differ significantly from one another.

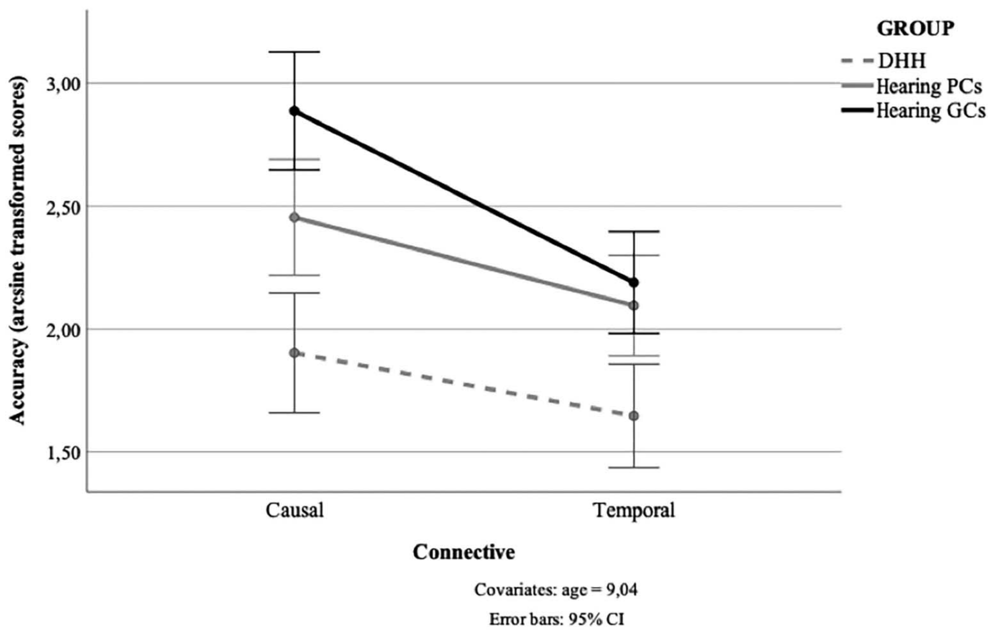
Inspection of Figure 2 shows that all three groups performed better on the causal than on the temporal connective task. However, follow-up within-group ANCOVAs did not show any significant effect of connective type (causal or temporal): $F(1, 25) = 0.86$, $p = .36$, for DHH readers; $F(1, 25) = 4.79$, $p = .038$, $\eta_p^2 = .16$, for PCs (α was set at .02 after Bonferroni corrections); and $F(1, 25) = 0.74$, $p = .40$, for GCs. For the hearing PCs, the effect approached statistical significance ($p = .038$ with α .02). The effect of the covariate age and the interaction between connective type and the covariate were significant

Table 2. Proportion of correct responses to the causal and temporal items of the DHH PCs ($n = 27$), hearing PCs ($n = 27$), and hearing GCs ($n = 27$): $N = 81$.

Item	DHH PCs *M* (*SD*)	PCs *M* (*SD*)	GCs *M* (*SD*)	*F*	*p*	η_p^2	Pairwise
Causal	0.64 (0.25)	0.85 (0.18)	0.93 (0.16)	15.73	< .001	.29	GC > PC > DHH
Temporal	0.53 (0.28)	0.70 (0.15)	0.78 (0.14)	7.24	.001	.16	GC = PC > DHH

Note. DHH PCs = deaf-or-hard-of-hearing poor comprehenders; PCs = hearing poor comprehenders; GCs = hearing good comprehenders.

Figure 2. Performance of the DHH readers, hearing PCs, and hearing GCs on the causal and temporal connective task. CI = confidence interval; DHH = deaf or hard-of-hearing; GCs = good comprehenders; PCs = poor comprehenders; CI = confidence interval.



only for the hearing PC group: $F(1, 25) = 8.04$, $p = .009$, $\eta_p^2 = .24$, and $F(1, 25) = 6.28$, $p = .019$, $\eta_p^2 = .20$, respectively. Effect sizes were large in both cases. Inspection of the unstandardized beta (*b*) coefficients showed that age was significant in the case of causal connectives, $b = 0.35$, $t = 3.39$, $p = .002$, but not for understanding of temporal connectives, $b = 0.04$, $t = 0.47$, $p = .64$: The older children performed better than the younger children on the causal items.

In summary, both DHH readers and hearing PCs showed poorer comprehension of causal connectives than GCs. DHH readers showed significantly lower performance in temporal connective understanding in comparison to both hearing GCs and PCs, who did not differ significantly from each other. Although inspection of Figure 2 shows that all three groups performed generally better on causal than temporal connectives, once age effects were controlled, the effect of connective type (causal or temporal) did not reach statistical significance.

Research Question 2: Does Receptive Vocabulary Play a Role in the Comprehension of Causal and Temporal Connectives of Hearing and DHH PCs? What Is the Unique Contribution of Vocabulary in Hearing and DHH PCs' Causal and Temporal Connective Understanding?

To explore further the difficulties of DHH and hearing PCs, we first ran a second ANCOVA with Group (DHH PCs, hearing PCs, hearing GCs) and Connective Type (causal, temporal) as factors, and Vocabulary as an additional covariate (in addition to Age). This analysis tested the main effects of group, age, and vocabulary; the two-way interaction between Group and Vocabulary; and the three-way interaction between Group, Vocabulary, and Connective Type. Main effects were explored by pairwise comparisons, and interaction effects were explored by running separate within-group ANCOVAs for each group (DHH, PCs, or GCs). To control for multiple comparisons, the level of statistical significance was adjusted to .02 (Bonferroni corrections).

As a second step in our analysis, we ran hierarchical regression models to examine the unique contribution of vocabulary knowledge to causal and temporal connectives separately for each group. There was substantial interindividual variation in reading comprehension scores within the hearing and DHH PC groups (scores ranged from 1 to 9 for the hearing PCs and from 2 to 9 for the DHH PCs). Thus, for each group, the hierarchical regression analyses controlled both for age and reading comprehension. The level of statistical significance was adjusted to .02.

ANCOVAs with vocabulary scores. The effect of group remained significant and large even when controlling for the covariate vocabulary, $F(2, 74) = 5.62$, $p = .005$, $\eta_p^2 = .13$. Pairwise comparisons showed significant differences between the DHH PCs and the hearing GCs ($p < .001$). The difference between DHH and hearing PCs approached statistical significance, $p = .057$. Vocabulary showed a significant effect on readers' connective understanding, with a medium effect size, $F(1, 74) = 5.15$, $p < .05$, $\eta_p^2 = .06$, and the interaction between Group and Vocabulary was also significant, $F(2, 74) = 3.52$, $p < .05$, $\eta_p^2 = .09$. The main effect of connective type and age was not significant. The interaction between Group and Connective Type approached statistical significance once controlling for vocabulary knowledge, $F(2, 74) = 3.05$, $p = .053$, $\eta_p^2 = .08$, and the interaction between Connective Type and Vocabulary was significant, $F(1, 74) = 4.81$, $p < .05$, $\eta_p^2 = .06$. The three-way interaction between Group, Vocabulary, and Connective Type did not reach statistical significance, $F(2, 74) = 2.67$, $p = .08$, $\eta_p^2 = .07$.

The interaction between Group and Vocabulary was explored by follow-up within-group ANCOVAs. These analyses showed a significant main effect of the covariate vocabulary only in the DHH PC group, $F(1, 24) = 10.71$, $p < .005$, $\eta_p^2 = .31$. The interaction between Vocabulary and Connective Type was not statistically significant for this group, $F(1, 24) = 0.39$, $p = .54$. For the hearing PCs, the main effect of vocabulary was nonsignificant, $F(1, 24) = 0.41$, $p = .53$. However, the interaction between Vocabulary and Connective Type was statistically significant, $F(1, 24) = 11.86$, $p < .005$, $\eta_p^2 = .33$. Inspection of the unstandardized beta (*b*) coefficients showed that vocabulary was significantly associated to DHH PCs' causal connective understanding, $b = 0.09$, $t = 3.34$, $p < .005$, $\eta_p^2 = .32$, whereas for temporal connectives, the effect was not significant after Bonferroni corrections (α set at .02), $b = 0.07$, $t = 2.11$, $p = .046$, $\eta_p^2 = .16$. For the hearing PCs, the association between vocabulary and causal connective understanding only approached statistical significance after Bonferroni corrections, $b = 0.06$, $t = 2.35$, $p = .03$, and the association between vocabulary and temporal connective understanding was not significant, $b = 0.04$, $t = 1.75$, $p = .09$. Vocabulary knowledge did not account for significant variance in the GCs' performance.

In summary, both reading comprehension abilities and vocabulary knowledge explained performance on the connective tasks, but the effects of vocabulary were statistically significant only for the DHH PCs and limited to causal connective understanding. For the hearing PCs, the effects of vocabulary approached statistical significance in causal connective understanding. Vocabulary knowledge seemed to contribute less to the readers' performance in the temporal connective task. Figure 3 shows the relationship between vocabulary scores and causal and temporal connective understanding in the three groups.

Hierarchical Regression Analyses by Group

Separate hierarchical regressions for the three groups (DHH readers, hearing PCs, and hearing GCs) clarified these findings. Table 3 summarizes the results of the hierarchical regression analyses. Age was entered at Step 1, as both the ability to make inferences and comprehend connectives varies with age (Cain & Nash, 2011). Reading comprehension scores were entered at Step 2, to account for interindividual variation in reading comprehension within each group. Vocabulary scores were entered last, at Step 3, to test whether vocabulary accounted for additional variance in connective understanding once age and reading comprehension skills were considered.

Causal connective understanding. For the DHH readers, age and reading comprehension scores, at Steps 1 and 2, did not explain significant variance in causal connective understanding. Vocabulary knowledge, at Step 3, accounted for 20% of variance. The standardized beta coefficients reported in Table 3, $\beta = .50$, $t = 2.71$, $p = .01$, indicate that the DHH children with higher vocabulary scores performed better on the causal connective task. The full model (Model 3) accounted for 38% of variance in causal connective understanding, $F(3, 23) = 4.65$, $p = .011$.

For the hearing PCs, age, at Step 1, explained 32% of variance in the comprehension of causal connectives (Model 1). At Step 2, reading comprehension scores accounted for additional 16% of variance (Model 2), and vocabulary did not contribute further variance to the model (Model 3). When vocabulary was added in the full regression model (Model 3), age and reading comprehension skills were no longer significant, suggesting shared variance between the three predictors. The full model was significant and accounted for 49% of variance in causal connective understanding, $F(3, 23) = 7.32$, $p = .001$. For the hearing GCs, none of the factors (age, reading comprehension skills, and vocabulary knowledge) accounted for statistically significant variance in causal connective understanding.

Temporal connective understanding. Age, reading comprehension skills, and vocabulary knowledge did not explain significant variance in temporal connective understanding in any of the three groups.

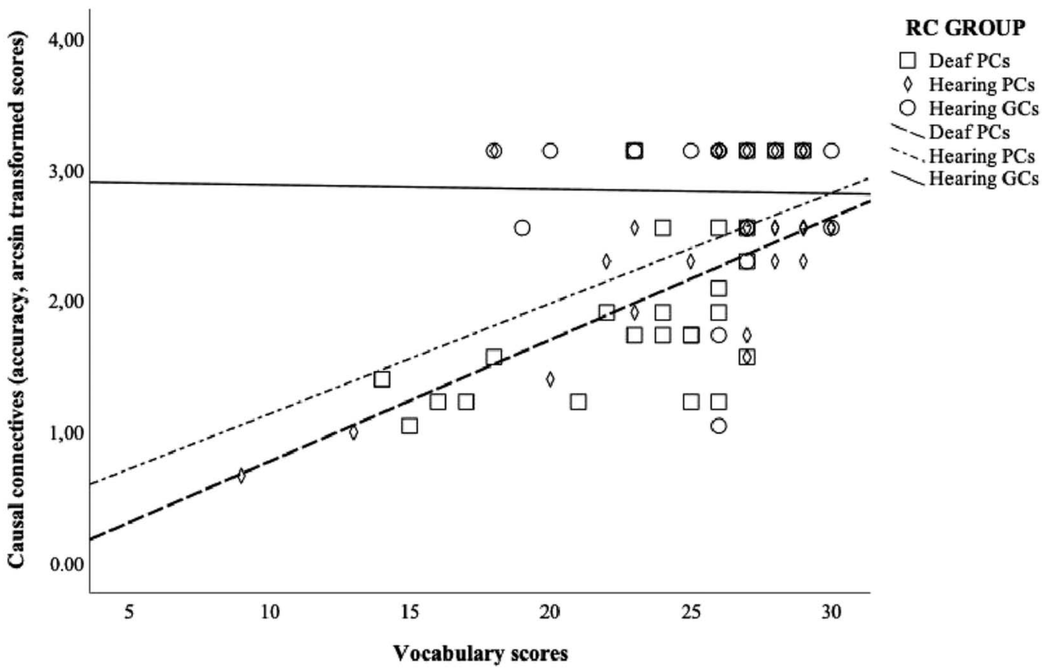
In summary, different factors accounted for the performance of the DHH readers and hearing PCs on the causal connective understanding task. Vocabulary was the only significant predictor of DHH readers' poor causal connective understanding, whereas age and reading comprehension skills explained hearing PCs' performance. In contrast, the analyses did not reveal significant contributions of age, reading comprehension, or vocabulary to the comprehension of temporal connectives for any of the three groups.

Discussion

This study compared hearing GCs and DHH and hearing PCs' comprehension of coherence relations expressed

Figure 3. Regression slopes displaying the relationship between vocabulary and causal (a) and temporal (b) connective understanding in the three reading comprehension (RC) groups (hearing GCs, DHH and hearing PCs). Deaf PCs = deaf poor comprehenders; GCs = good comprehenders; PCs = poor comprehenders.

(a)



(b)

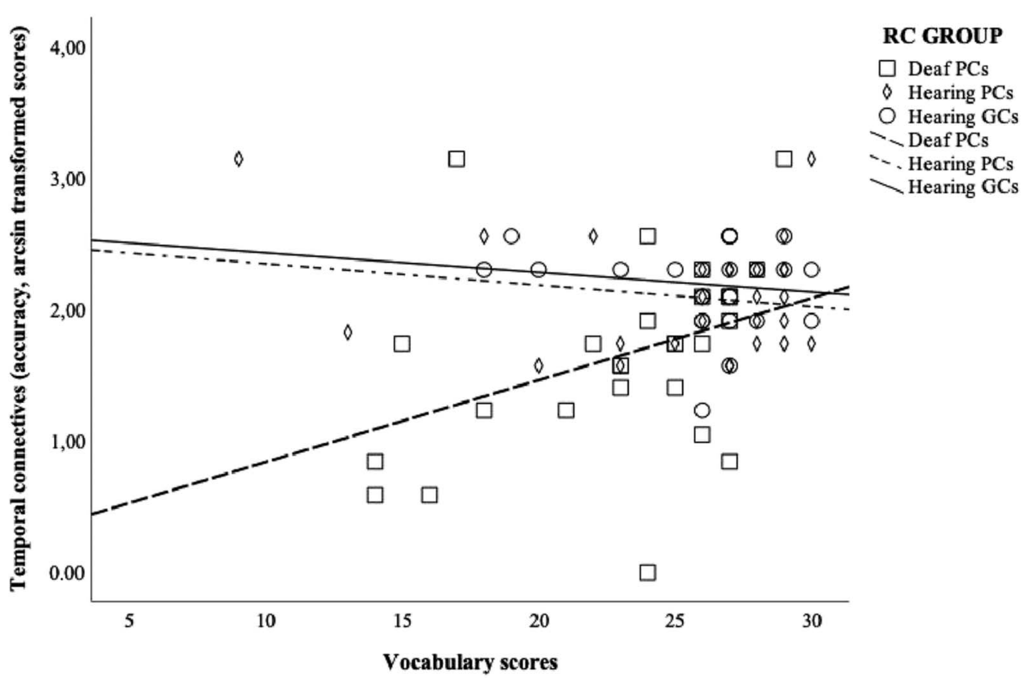


Table 3. Hierarchical regressions by group: contribution of age, reading comprehension, and receptive vocabulary to causal and temporal connectives understanding.

DHH PCs										
	Causal connectives					**Temporal connectives**				
Variables	**β**	***t***	***F***	R^2	ΔR^2	**β**	***t***	***F***	R^2	ΔR^2
Model 1.	.24	1.26	1.59	.06	.06			0.01	.00	.00
1. Age						−.01	−0.07			
Model 2.			2.60	.18	.12			1.76	.13	.13
1. Age	.17	0.91				−.09	−0.46			
2. RC	.35	1.86				.37	1.88			
Model 3.			4.65**	.38	.20**			1.97	.20	.08
1. Age	.08	0.49				−.14	−0.75			
2. RC	.16	0.85				.24	1.18			
3. Vocab	.50	2.71**				.31	1.49			
Hearing PCs										
	Causal connectives					**Temporal connectives**				
Variables	**β**	***t***	***F***	R^2	ΔR^2	**β**	***t***	***F***	R^2	ΔR^2
Model 1.			11.48**	.32	.32**			0.22	.01	.01
1. Age	.56	3.39**				.09	0.47			
Model 2.			10.81***	.47	.16**			0.29	.02	.01
1. Age	.36	2.20*				.15	0.68			
2. RC	.44	2.69**				−.13	−0.60			
Model 3.			7.32***	.49	.01			1.25	.14	.12
1. Age	.28	1.40				.40	1.56			
2. RC	.32	1.44				.21	0.73			
3. Vocab	.22	0.81				−.61	−1.77			
Hearing GCs										
	Causal connectives					**Temporal connectives**				
Variables	**β**	***t***	***F***	R^2	ΔR^2	**β**	***t***	***F***	R^2	ΔR^2
Model 1.			0.00	.00	.00			0.03	.00	.00
1. Age	−.01	−0.03				−.03	−0.16			
Model 2.			0.23	.02	.02			0.24	.02	.02
1. Age	.09	0.37				−.13	−0.52			
2. RC	−.17	−0.68				.17	0.68			
Model 3.			0.17	.02	.00			0.24	.03	.01
1. Age	.12	0.43				−.08	−0.29			
2. RC	−.19	−0.71				.13	0.52			
3. Vocab	−.06	−0.26				−.11	−0.51			

Note. DHH PCs = deaf-or-hard-of-hearing poor comprehenders; PCs = hearing poor comprehenders; RC = Reading Comprehension scores; Vocab = Vocabulary scores; GCs = hearing good comprehenders.

*$p \le .05$. **$p \le .01$. ***$p \le .001$.

in text by causal and temporal connectives. Children's comprehension of connectives was assessed through multiple-choice tasks, in which children selected among three sentences that varied only in the connective used, the sentence that best matched the (causal or temporal) relation represented in a picture. The task thus involved knowledge of the meanings of connective words but also comprehension processes including inference-making skills, as children had to construct a mental model of the coherence relation implied in the sentences and infer the specific causal or temporal relation indicated in the picture.

DHH and Hearing PCs' Understanding of Temporal and Causal Connectives

The two groups of PCs in this study, DHH and hearing PCs, were matched on reading comprehension abilities and decoding skills and also showed similar levels of vocabulary knowledge. Despite these similarities, they performed rather differently on the connective understanding tasks. The DHH readers showed poorer understanding of both causal and temporal connectives in comparison to the hearing GCs and also performed more poorly than the hearing PCs on both connective tasks (causal and temporal). In contrast, the hearing PCs had specific difficulties with causal connective understanding: Their performance, although relatively good (85% correct responses), was not at the level of that of the GCs (93% correct responses). The near-ceiling performance of GCs in the two connective tasks may explain why, for these students, reading comprehension skill and vocabulary knowledge did not predict variance in connective understanding.

The magnitude of the between-groups differences in causal connective understanding and temporal connective understanding is medium–large or large, as shown by the effect sizes. This suggests that deepening the ability to comprehend connectives may be clinically relevant. Despite these group differences, the general pattern of performance on the connective tasks was similar across the three groups of readers (DHH, hearing PCs, and hearing GCs): Temporal coherence relations were relatively more difficult for all readers. This result is in line with what has been found in English children (Cain & Nash, 2011) and suggests that difficulties with temporal coherence relations are language independent.

It is unlikely that the greater difficulty of temporal connectives (*before*, *after*, *while*) was due to the participants' poorer vocabulary knowledge of these terms because temporal connectives are typically acquired earlier than causal connectives (Bloom et al., 1980) and children start using them from around 3 years of age (Diessel, 2004), although full understanding of temporal relations may require some years (Blything & Cain, 2016; Blything et al., 2015). The finding in this study that children's understanding of temporal connectives was not significantly associated with vocabulary knowledge seems consistent with this interpretation. Thus, it would seem that more general cognitive factors are playing a part in temporal connective understanding. Reasoning about the temporal sequence of events can be a complex cognitive task (McCormack & Hoerl, 2007), and children may struggle even further with temporal reasoning when the task is abstract and metalinguistic, like in the sentence comprehension task of this study. Prior studies have shown that the ability to understand the temporal relations expressed by connectives like *before* and *after* continues to develop until at least the age of 7 years (Blything & Cain, 2016; Blything et al., 2015; Zhang & Hudson, 2018). Together with other studies (Boureux et al., 2012; Cain & Nash, 2011), this study suggests that its full development (at least in reading) may extend even further, after the first years of primary school.

In the sentences of our connective tasks, as is often the case in narratives, causal relations are typically more intuitive than temporal relations because they are more closely related to children's everyday experience. Consider, for example, the following sentences: "George got stuck in a traffic jam, and *so* got back home late" or "The waiter was busy *because* it was lunchtime." In contrast, temporal relations can be more arbitrary: "The policemen felt asleep *before* leaving his office" or "*Before* going to school, Jeff went to the swimming pool." In synthesis, children's world knowledge may support their understanding of causal relations more than their understanding of temporal relations. It entails that the understanding of causal coherence relations is probably more closely related to children's inference-making skills, which fits with the finding that the hearing PCs in this study showed a selective deficit in the causal connective task. DHH readers also showed poor comprehension of the relations expressed by causal connectives. However, they seemed to have more profound problems, related to the understanding of the connective words, which was more strongly associated with their vocabulary knowledge.

The Role of Receptive Vocabulary in Causal and Temporal Connective Understanding

Several studies suggest that hearing PCs and DHH readers' reading difficulties may be associated with their limited vocabulary knowledge (Cain & Oakhill, 2014; Catts et al., 2006; Daza et al., 2014; Harris et al., 2017; Nation et al., 2010; Oslund et al., 2018; Spencer et al., 2019). The results of this study are only partially consistent with these findings. The general vocabulary delay of DHH children reported in previous studies (Lund, 2016; Walker et al., 2019) was confirmed in this study, but the hearing PCs did not show a clear vocabulary delay in comparison to the GCs. Their vocabulary scores were between those of the DHH readers and the GCs but did not differ significantly from either of those two groups. The fact that they did not differ from the GCs' scores is consistent with research that shows that PCs' vocabulary problems are not commensurate with, or as severe as, their reading comprehension difficulties (Spencer & Wagner, 2018; Spencer et al., 2019). The results of the analyses of covariance help clarify these findings. These analyses revealed, on one hand, that vocabulary accounted for significant variance in the children's causal and temporal connective understanding. On the other hand, they revealed that the effects of vocabulary differed in the three groups and between the two connective types. Indeed, vocabulary knowledge accounted for significant variance in the DHH PCs' understanding of causal connectives, but its effect only approached statistical significance in hearing PCs' causal connective understanding and in DHH PCs' temporal connective understanding and was not significant in hearing PCs' temporal connective understanding. The hierarchical regression analyses clarified the role played by vocabulary knowledge in the three groups. In the DHH PCs, vocabulary knowledge contributed uniquely, that is, independently of DHH children's age and reading comprehension skills, to the comprehension of causal connectives (it accounted for 20% of variance) and was the only significant predictor of performance. For the hearing PCs, vocabulary did not contribute unique variance to poor causal connective understanding, once children's reading comprehension skills and age were controlled (age accounted for 32% of variance in causal connective understanding in this group). In summary, in these readers, variance in causal connective understanding seemed to be more strongly associated to their poor reading comprehension skills, a measure of their construction–integration processes. As discussed earlier, construction–integration processes during reading comprehension involve also vocabulary knowledge, and vocabulary could be especially important for logical connective understanding, as knowledge of the causal or temporal meaning of a connective is essential to represent the causal or temporal relation implied by a sentence. However, this seems a more critical factor in the performance of the DHH readers than in that of hearing PCs.

It should be considered that in all regression models run in this study, a large amount of variance was not explained, so other factors could contribute to the understanding of causal and temporal connectives, such as working memory in view of its role in individual differences in reading comprehension (e.g., Cain & Oakhill, 2006; Carretti et al., 2009). Another potential factor in causal and temporal connective understanding is grammatical and syntactic ability. The meaning of connectives is more abstract and relational than that of concrete nouns, adjectives, or verbs, which are typically assessed in vocabulary tests (Crosson & Lesaux, 2013). As connectives signal syntactic relations between clauses, connective understanding may also require grammatical and syntactic knowledge as will be discussed below. These aspects can be further explored in future research.

Also, reading comprehension skills seemed to play a greater role in causal than in temporal connective understanding. Differences between hearing PCs and GCs emerged only for causal connective understanding, and the regression analyses by group revealed that for temporal connective understanding, reading comprehension skills were not significant for either the hearing PCs or the DHH readers. This finding is consistent with the hypothesis discussed earlier: that children's world knowledge and inference making skills might support their understanding of causal relations more than their understanding of temporal relations.

Temporal connectives were, in general, more difficult to understand for all groups. Syntactic skills could have played a role especially in the understanding of these temporal items. Oakhill and Cain (2012) have found that sentence-level comprehension is not highly predictive of text-level comprehension. In addition, Cain et al. (2005) not only found no significant differences between GCs and PCs on a test of receptive syntax, but they also found no significant relation between PCs' understanding of connectives and their sentence-level comprehension skills. However, other findings suggest a relationship between syntactic abilities and reading comprehension skills (see Ecalle et al., 2013), and syntactic ability has been shown to be a factor in the sentence-level comprehension skills of DHH readers (Gomez-Merino et al., 2020). This could explain why these readers showed a deficit in both connective tasks in comparison with the other two groups. An alternative explanation is that the DHH comprehenders' difficulties in understanding connectives were related to their poorer verbal working memory. Deaf readers are known to have deficits in verbal working memory in comparison to hearing children (Arfé, 2015), and this could have also an impact on the comprehension processes involved in connective understanding.[1]

In general, the hearing PCs in this study seemed to show a relatively good understanding of the sentences used in the causal and temporal connective tasks: Mean response accuracy was 85% for causal and 70% for temporal sentences, respectively. This leads to a further consideration: The PCs in this study showed better connective understanding skills than the PCs in prior studies (e.g., Cain et al., 2005). In Cain et al.'s (2005) study, PCs achieved an accuracy of only about 55% for sentences with temporal or causal connectives. Differences in the experimental tasks used in our study and in Cain et al.'s study could explain these seemingly contrasting findings. Indeed, Cain et al. asked children to perform a cloze task, by completing gaps in a text with the appropriate connectives. To succeed in the task, their participants had to evaluate the linguistic context in which the gap occurred, that is, the preceding and following text. This could have been more demanding for PCs than the task used in this study, in which participants were simply asked to read and understand single sentences, with the aid of a visual prompt (a picture).

General Conclusions

The examination of differences between groups with atypical development can shed light not only on the specific factors underlying different developmental profiles but also on the nature of problems underlying typical development (Kyle & Cain, 2015; Steele et al., 2013). In

[1]We collected the digit span scores from some of the DHH participants in this study (n = 19) and computed the correlations with their causal and temporal connective understanding. In both cases, the correlations were low and not significant (r = .299 for causal and r = .007 for temporal relations).

this study, the selective difficulties of hearing PCs with causal connectives and the more general and greater difficulties of the DHH readers in understanding both causal and temporal connectives suggest that causal and temporal connective understanding could rely on partially different skills. Both vocabulary knowledge and comprehension skills seem to support the comprehension of causal connectives. In contrast, temporal connective understanding seems less strongly related to children's reading comprehension skills and only weakly related to vocabulary knowledge.

The different involvement of vocabulary knowledge in the connective understanding of the two groups of readers with poorer comprehension abilities suggests that, although they had ostensibly similar reading profiles, the nature of their reading comprehension problems differ. In this respect, it is interesting that these hearing PCs and DHH readers did not differ significantly on vocabulary scores. Rather than being explained by differences in vocabulary knowledge, the differences in connective understanding between the two groups could be explained by the different roles of vocabulary and reading comprehension processes in the task. Consistent with prior studies (Daza et al., 2014; Sullivan et al., 2014), DHH readers' problems with connective understanding were more closely related to their weaker vocabulary knowledge, the only factor that was associated to their performance in the causal connective task. Other studies have shown that deaf readers have problems with verbal causal and temporal reasoning in text (Sullivan et al., 2014). However, these findings clearly suggest that part of their problems could be specifically accounted for by their poorer vocabulary knowledge, which could be also associated with their difficulties in understanding connective words.

In contrast, for the PCs, who showed selective problems in the understanding of causal connectives, the role of vocabulary knowledge was less significant. The different pattern of difficulties shown by this group in comparison to the DHH readers suggests that PCs' difficulties were mainly related to their poorer comprehension processes. The differences between the hearing PCs and GCs in causal connective understanding could be better explained by the PCs' lower ability in activating and using relevant world knowledge to make inferences during reading and form a mental model of the coherence relation expressed by the connective. As shown by other studies (Kyle & Cain, 2015), DHH readers also show problems in inference making, and we cannot thus exclude that the DHH readers in this study also experienced difficulties at this level. However, the poorer vocabulary knowledge of the DHH readers may have overridden their inference-making difficulties in the connective understanding tasks of this study.

Overall, these findings also shed light on readers' causal and temporal connective understanding more generally. Although connectives are normally considered as an aid to reading comprehension (McNamara et al., 1996), this study suggests that connective understanding can be a complex linguistic and cognitive task for struggling readers. Moreover, the relative contribution of readers' vocabulary knowledge and reading comprehension skills could vary with the kind of coherence relation, making some coherence relations more difficult for readers with comprehension difficulties than others. This hypothesis needs to be further tested in future studies.

Practical Implications

These results have important practical implications for text simplification as well as for the design of reading interventions targeting hearing PCs' and deaf readers' needs. Text simplification consists of adapting texts to the linguistic and reading abilities of struggling readers, thus facilitating access to texts that could be otherwise difficult to understand for them (Arfé et al., 2018). Linguistic simplification of texts is often used as a method to address this goal (see Arfé et al., 2018; Fajardo et al., 2013). However, little is known about the linguistic characteristics that make texts more comprehensible for such readers. Making explicit the link between the information in the text, connectives can be used to improve its understandability (Arfé et al., 2018; Fajardo et al., 2013), but this study suggests that the use of explicit causal or temporal connectives in text may not necessarily facilitate readers' comprehension and that greater focus on these connectives is probably necessary in instructional interventions, particularly for readers who show a language delay like DHH readers.

Understanding discourse signals, such as connectives, is indeed an important reading comprehension skill. This study suggests that activities to develop vocabulary knowledge of connective words could be important to support reading comprehension in some poor readers, like DHH readers. For hearing PCs with sufficient vocabulary skills, work on connective understanding may be important at the text level and with greater focus on causal coherence relations. In particular, for these readers, reading interventions could target the inference-making skills required to construct the coherence relations expressed by the connective, in order to understand how the information in the two clauses should be integrated.

Limitations

An important limitation of this study is the experimental task used to explore connective understanding. The use of sentences associated with pictures resulted in a task that was relatively easy for hearing participants, even for PCs. This might have reduced differences between the hearing readers. However, the choice of task was motivated to include readers who were DHH.

A second limitation of this study is that we assessed children's comprehension of connectives by using offline (accuracy) measures only. Online reading measures, such as reading times or eye movements, could be more sensitive to children's difficulties in processing coherence relations and connectives (Gomez-Merino et al., 2020). Such measures can provide more detailed information about the processing costs of understanding temporal, as opposed to causal, coherence relations, or understanding sentences with or without explicit causal and temporal connectives. Future studies might also explore whether DHH readers' understanding of causal and temporal coherence relations varies according with the specific causal or temporal connectives used (e.g., *because* or *therefore*, *before* or *after*) and thus whether DHH children show more problems in understanding specific causal and temporal connective words. Unfortunately, in this study, it was not possible to conduct such analyses, due to the limited number of exemplars of each type of connective.

Data Availability Statement

All data are available on request from the authors.

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Appendix (p. 1 of 3)

Examples of Causal and Temporal Connective Items

Temporal connectives: *Before, After, While*. The target response is in bold.
Before

- ○ Jake switched off the television because the scary movie finished
- ○ Jack switched-off the television after the scary movie finished
- ○ **Jack switched-off the television before the scary movie finished**

After

- ○ **It started to rain after the chef finished cooking the meat**
- ○ It started to rain before the chef finished cooking the meat
- ○ It started to rain while the chef was cooking the meat

Examples of Causal and Temporal Connective Items

While

- ○ **Susan was finishing sewing while Jane was painting a picture**
- ○ Susan was finishing sewing before Jane was painting a picture
- ○ Susan was finishing sewing because Jane was painting a picture

Causal connectives: *Because, Therefore, So*. The target response is in bold.

Because

- ○ **Jack was bored because the book was not interesting**
- ○ Jack was bored, so the book was not interesting
- ○ Jack was bored while the book was not interesting

Appendix (p. 3 of 3)

Examples of Causal and Temporal Connective Items

Therefore

- ○ Luke worked hard all day because he was really tired
- ○ **Luke worked hard all day, therefore he was really tired**
- ○ Luke worked hard all day after he was really tired

So

- ○ Karl wasn't able to do his own homework after he copied it from Michael
- ○ **Karl wasn't able to do his own homework, so he copied it from Michael**
- ○ Karl wasn't able to do his own homework because he copied it from Michael

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