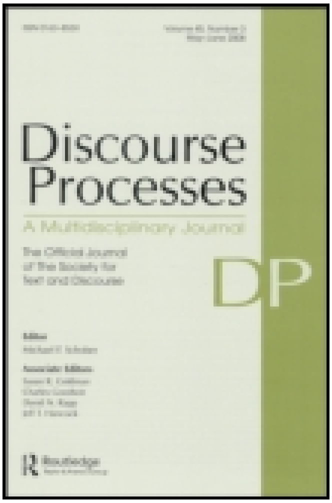

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Temporal and Causal Reasoning in Deaf and Hearing Novice Readers

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Temporal and causal information in text are crucial in helping the reader form a coherent representation of a narrative. Deaf novice readers are generally poor at processing linguistic markers of causal/temporal information (i.e., connectives), but what is unclear is whether this is indicative of a more general deficit in reasoning about temporal/causal information. In Study 1, 10 deaf and 63 hearing children, matched for comprehension ability and age, were compared on a range of tasks tapping temporal/causal reasoning skills. In Study 2, 20 deaf and 32 hearing children, matched for age but not reading comprehension ability, were compared on revised versions of the tasks. The pattern of performance of the deaf was different from that of the hearing; they had difficulties when temporal and causal reasoning was text-based, but not when it was nonverbal, indicating that their global temporal/causal reasoning skills are comparable with those of their hearing counterparts.

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INTRODUCTION

The motivation to read, and indeed the essence of reading, is in being able to comprehend the text (Durkin, 1993). Because deaf students do not generally achieve reading levels above that of a typical 9-year-old hearing child (Traxler, 2000), it is not surprising that research has found that deaf children typically lack the motivation to read and have difficulties comprehending the texts with which they engage. A number of studies indicate that deaf children are significantly delayed in reading attainment (e.g., Allen, 1986; Banks, Gray, & Fyfe, 1990; Harris & Moreno, 2004; Kyle & Harris, 2006), and a number of researchers note that despite several decades of research there has been little improvement in deaf children's reading achievements (Marschark & Harris, 1996; Musselman, 2000; Luckner & Handley, 2008).

Word reading and reading comprehension difficulties are related in deaf children, but this relation does not entirely explain their delays in reading attainment and indicates that other factors need to be taken into consideration to account for their well-established difficulties with text comprehension (Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007; Wauters, van Bon, & Tellings, 2006). For instance, in the case of narrative texts, comprehension depends primarily on relating the narrated events to form a mental representation of their temporal and causal sequence. Readers use their knowledge of language, and of the world, to construct this mental model of the text (e.g., Kintsch & Rawson, 2005). Explicit connectives such as *before*, *after*, *because*, and *so* help readers recognize causal and temporal relations in texts, and their effective processing has been shown to be crucial to good text comprehension (e.g., Cain & Nash, 2011; Ge & Xuehong, 2002; McColgan & McCormack, 2008; Trabasso & Van den Broek, 1985; Winskel, 2004).

The studies reported in this article add to our knowledge of text comprehension processes in deaf readers by examining their ability to recognize temporal and causal relations when these are expressed by linguistic connectives and in nonverbal tasks. Very few studies have investigated these sorts of text-level processes in deaf students; most research into the reading abilities of deaf children has focused on lower level component skills involved in text comprehension (e.g., vocabulary or phonology) (e.g., Kyle & Harris, 2006; Leutke-Stahlman & Nielsen, 2003).

Although some research demonstrates that causal understanding may be relatively unimpaired in deaf readers and that deaf students can use causal information when producing narratives (e.g., Arfé & Boscolo, 2006; Marschark, Mouradian, & Halas, 1994), other findings suggest that deaf readers have difficulty in this domain (e.g., Eden, 2008; Banks et al., 1990). For instance, they are known to have problems when using and comprehending connectives in narratives (e.g., Yoshinaga-Itano & Downey, 1996) and in organizing and relating ideas in a text according to temporal and other logical relations (Banks et al., 1990; Weiss & Johnson, 1993; Yoshinaga-Itano & Downey, 1996). These problems likely affect their reading comprehension and ability to identify and understand the global organization of meaning within a text (Wilbur, 2000). However, what is unclear in the literature is whether deaf children's difficulties are specific to understanding linguistic markers of temporal and causal information or whether they arise from a general global deficit in being able to process temporal and causal information.

For instance, children with hearing loss have been found to have difficulty arranging pictures in a temporal order to produce a story (Eden, 2008), and Marschark, Lang, and Albertini (2002) postulate that even on nonverbal IQ tests (designed for deaf children), hearing children outperform them on tasks tapping sequential/temporal ordering. Such findings suggest that deaf readers may have a global deficit in reasoning about temporal and causal information, because their sequential ordering skills are impaired even when the tasks do not involve the processing of textual information or connective understanding. However, Ingber and Eden's (2011) successful intervention with deaf readers made use of picture arrangement tasks to train story-telling skills, and their deaf readers performed well in sequencing events when using nonverbal tasks. Banks et al. (1990) also found that deaf students perform well when asked to pictorially represent a written story.

The motivation for the current studies was to examine whether deaf children's difficulties in processing temporal and causal information are limited to text-based tasks and are related to their poor understanding of linguistic connectives that signal these relations, or whether their difficulties reflect a more general deficit in reasoning about temporal/causal information, independently of the nature of the task (text-based or not). With this aim in mind, we used tasks that differed in the degree to which they required the child to make use of textual versus pictorial information to recognize temporal or causal relations between events.

Given the typical verbal language delay of deaf children, we expected that deaf children would perform significantly worse than their hearing matched counterparts on tasks that required them to understand temporal and causal linguistic markers (i.e., connectives) in text (e.g., Yoshinaga-Itano & Downey, 1996). We were particularly interested in how deaf children would perform compared with their hearing counterparts on the tasks that did not involve textual information but still required the child to reason about temporal and causal relations.

STUDY 1

Participants

Seventy-three children participated in the first study: 10 deaf children (3 boys, 7 girls) aged between 8 and 11 years (mean = 9.40, $SD = 1.17$) and 63 hearing control subjects (31 boys, 32 girls) aged between 7 and 11 years (mean = 9.03, *SD* = 1.22) who were matched for comprehension ability and age with the deaf children. The hearing children were selected from three schools in East Sussex, United Kingdom, in predominantly White middle-class areas. All had English as their first language.

Table 1 shows the characteristics of the deaf participants. All participants were congenitally deaf. Six children wore hearing aids, and four children were fitted with cochlear implants. They attended two schools in East Sussex: three participants attended a school solely for the deaf, where the main form of communication is British Sign Language (BSL), combined with oral language, and seven attended a mainstream school in which the main form of communication is oral language combined with sign-supported English (which uses the same signs as BSL but follows the same word order as spoken English). Nine children had hearing parents and the main form of communication at home was oral, and one child had deaf parents but was fully bilingual and used both oral language and BSL.

Materials

Children were administered a standardized assessment of reading comprehension and three experimental tasks designed to assess their understanding of temporal and causal coherence relations specifically.

Standard comprehension measures. Most children attending junior school in the United Kingdom are required to take national exams, known as Statutory Assessment Tests (SATs), in reading comprehension; the child is given 15 minutes to read a booklet and 45 minutes to answer questions about the text. In the current study, SATs results (from 2012) were obtained for all hearing participants and for seven of the deaf participants. The remaining three deaf participants were described as "average text comprehenders" by their teacher.

Reading comprehension: Picture ordering. Children were asked to read one written sentence and sequence three pictures to correctly represent the temporal or causal sequence of events it described. The task consisted of 16 items describing causal or temporal sequences of events. The following connectives were used: *after, before, because*, and *while*. Sentences varied in length from between 9 and 13 words. Two sets of eight sentences were presented to the participant at two different time points within the same test session in counterbalanced order. The internal consistency of this task, as assessed by Cronbach's alpha, was .75.

Reading comprehension: Sentence choice. Children were presented with a picture and three sentences, differing only in the (causal or temporal)

TABLE 1
Characteristics of Participants in Study 1

	Mean Age[a]	*Proportion of Boys*	*Deaf < 2 Years*	*Parents Deaf*	*Degree of Hearing Loss*	*Compensation*	*Additional Diagnosed Difficulties*
Deaf ($n = 10$)	9.40 (1.17)	.49	10	1	8 profoundly deaf 2 severely deaf	6 hearing aids 4 cochlear implants	1 specific language delay
Hearing ($n = 63$)	9.03 (1.22)	.30					

[a] *SD* in parentheses.

connective used, and were asked to decide which of the three sentences best matched the picture. There were 21 items in total. For 12 items the correct response was a temporal connective (i.e., *while*, *before*, *after*), and for 9 items a causal connective was the correct response (i.e., *so*, *therefore*, *because*). Sentences varied in length from 8 to 15 words and, as in the picture ordering task of reading comprehension, they were all affirmative sentences. The items were divided in two sets and were presented to participants at two different time points within the same test session, in counterbalanced order. The internal consistency of this task, as assessed by Cronbach's alpha, was .82. Example items from both the reading comprehension tasks are provided in the Appendix.

Sequence understanding (nonverbal). Children were given two sets of pictures drawn from Vianello (2000), one set at a time. Each set varied between five and six pictures. Children were required to place the pictures into a logical sequence that reflected a coherent story. They then placed the pictures into a booklet in the order they deemed correct. The two sets of pictures were counterbalanced across participant groups. There were too few items to assess the internal consistency of this task.

Procedure

All children completed all tasks, with the order of presentation of the tasks counterbalanced across participants within the deaf and hearing groups. For each task the child was presented with written instructions and a practice item. The researcher clarified the procedure with each child individually before the child commenced each task. The children were instructed to complete the tasks independently.

Results

There were no significant differences in comprehension scores between the hearing and deaf children: $t(67) = .14$, *n.s.*, and no significant differences between the groups in chronological age: $t(71) = .89$, *n.s.*

Scores on the three tasks were converted to proportional scores to allow for comparisons across tasks. Figure 1 shows the scores for hearing and deaf participants on the three tasks.

We first explored the relation between comprehension ability (as measured by SATs scores) and performance on the three experimental tasks. Hearing children showed strong significant correlations between performance on each of the tasks and comprehension ability; picture ordering: $r(62) = .27$, $p = .031$, sentence choice: $r(62) = .66$, $p < .0001$, and sequence understanding (nonverbal):

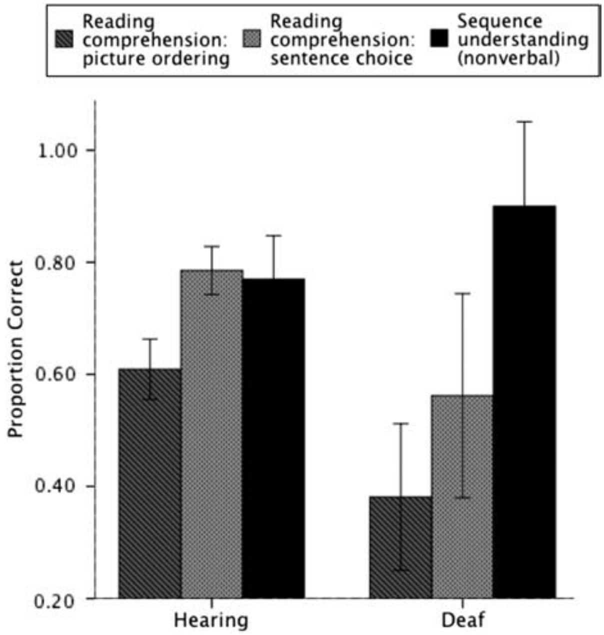

FIGURE 1 Mean proportion of correct scores on the three tasks in Study 1 as a function of hearing status (hearing vs. deaf).

$r(62) = .51$, $p < .0001$. Comprehension ability for deaf participants was highly correlated with performance on the picture ordering task: $r(7) = .83$, $p = .022$, and the sentence choice task: $r(7) = .88$, $p = .010$, but not on the sequence understanding task: $r(7) = .44$, $p = .33$.

Second, to examine differences in performance between deaf and hearing children on the tasks, a 2 (hearing status: hearing vs. deaf) × 3 (task) ANOVA was carried out, with scores on each task (as a proportion) as the dependent variable. The main effect of hearing status was only marginally significant: $F(1,71) = 3.16$, $p = .08$. There was a main effect of task: $F(2,142) = 27.44$, $p < .0001$, $\eta_p^2 = .28$, and a significant interaction between hearing status and task: $F(2,142) = 10.03$, $p < .0001$, $\eta_p^2 = .12$.[1] The interaction was explored with t-tests, which revealed that whereas hearing children significantly outperformed deaf children on the two reading comprehension tasks: picture ordering:

[1]Because of differences in group size between hearing and deaf participants, we also conducted the same analyses using mixed effects modeling. The interaction remained significant ($p = .001$).

$t(71) = 3.19$, $p = .002$, and sentence choice: $t(71) = 3.59$, $p = .001$, the same was not true for performance on the nonverbal sequence understanding task, where there was no significant difference in performance between the hearing and deaf participants: $t(71) = 1.28$, $p = .20$

We then examined the children's pattern of performance across the three tasks. The deaf children scored significantly higher on the nonverbal sequence understanding task than on the reading comprehension tasks: picture ordering: $t(9) = 6.22$, $p < .0001$, and sentence choice: $t(9) = 3.36$, $p = .008$, and there was a significant difference in performance on the two reading comprehension tasks, with better performance on the sentence choice task: $t(9) = 3.79$, $p = .004$. The pattern of performance was similar for the hearing children, with superior performance on the sentence choice task compared with the picture ordering task: $t(62) = 7.26$, $p < .0001$. However, the hearing children's highest score was on the sentence choice task (mean score as a proportion: .79), although their score on this task was not significantly different from their score on the nonverbal sequence understanding task: $t(62) = .42$, *n.s*. In comparison, the deaf children's highest score was on the nonverbal sequence understanding task (mean score as a proportion: .90), and this was significantly better than their performance on the two reading comprehension tasks.

Discussion

The findings from Study 1 were in keeping with our prediction that hearing children would significantly outperform deaf children (matched for comprehension ability) on tasks tapping text processing and understanding of temporal and causal connectives. Previous research was unclear as to whether deaf readers' difficulties in processing temporal/causal information were restricted to problems in processing linguistic markers of these events or indicative of a more general difficulty in processing temporal and causal information per se. The findings from Study 1 indicate that when the task used to examine understanding of these relations is entirely nonverbal, then deaf children's performance is not significantly different from that of their hearing counterparts and is considerably better than their performance on either of the tasks that require reading comprehension.

It is not simply the case that the nonverbal sequence understanding task is easier than the reading comprehension tasks, becasue the highest scores for hearing children were on one of the reading comprehension tasks. Hence, the main finding from this study is that deaf readers not only found the nonverbal task substantially easier than either of the tasks requiring reading comprehension (unlike the hearing children), they also performed somewhat better than the hearing children on that task (although not significantly so). This pattern of performance indicates that deaf children have problems with temporal and causal markers in written text (as predicted), but their difficulty is specific to these linguistic markers, because they do not have problems with temporal/causal reasoning when using nonverbal tasks. This would support the hypothesis of a specific linguistic deficit in the understanding of temporal causal relations.

This pattern of results also indicates that the deaf children tested in this study have a specific deficit in reasoning about temporal and causal information in text that would not have been predicted from their overall level of reading comprehension skill. Indeed, these deaf students were fairly advanced as a group in terms of their reading comprehension abilities, with most attending mainstream schools and with reading comprehension scores commensurate with those of the group of hearing children. This finding has implications for deaf students in mainstream schools, where their difficulties in processing connectives may be underestimated when using their general reading comprehension scores as an indicator of their text comprehension skills.

The picture ordering task was the hardest for both hearing and deaf children, and this may be due to the structure of the task. In this task there are no cues for interpreting the meaning of the connective because the pictures represent events but do not allow for inferences about their relations, whereas in the sentence choice task the child can compare sentences on the basis of the picture, which provides a context for inference making (see Boureux et al., 2012). Thus, successful performance on the picture ordering task relies on the processing and understanding of the connective in the sentence to a greater degree than the sentence choice task.

Overall, the results of the study suggest that deaf children's problems with causal and temporal information may be limited to tasks where this information is given in the text. Where the task is nonverbal, they perform at a comparable level with their hearing peers. However, Study 1 included only a small group of deaf children who were relatively able in terms of their comprehension ability, as can be seen from their comprehension scores, which were not significantly different from those of their same-aged hearing counterparts; also, the majority attended a mainstream school. If causal and temporal reasoning is mediated by experience of verbal language, it is possible that deaf children with lower linguistic skills or a different background may exhibit a different pattern of performance, with difficulties on nonverbal sequential reasoning tasks as well.

STUDY 2

In Study 2, we wanted to explore whether the findings from Study 1 could be generalized to deaf children whose verbal language and reading skills were significantly below those of their hearing peers and who may be more representative of the population of deaf young readers. Study 2 also built on the findings from the original study in a number of ways. First, Study 1 included only two items in the nonverbal sequence understanding task, and so in Study 2 the original task was replaced with the picture sequences from Wechsler Intelligence Scale for Children Revised, which included a greater number of items. Second, we also increased the number of items used in the picture ordering task. Third, we revised the sentence choice task so there were an increased, and equal, number of temporal and causal connectives. Fourth, we controlled for language abilities by administering the British Picture Vocabulary Scale (BPVS-II).

Participants

Fifty-two children participated: 20 deaf children (13 boys, 7 girls) aged between 7 and 11 years (mean = 9.97, *SD* = 1.22) who attended a school for the deaf where the main form of communication is BSL (combined with oral) and 32 hearing children (15 boys, 17 girls), matched for age with the deaf children, who attended a mainstream school in East Sussex, United Kingdom, from a predominantly White middle-class area. All used English as their first language. Their age ranged between 7 and 11 years (mean = 8.97, *SD* = 1.27).

Eighteen deaf children had hearing parents, and the main form of communication at home varied between oral language and BSL. All were congenitally deaf. Three children were diagnosed as being on the autistic spectrum, one child had Charge syndrome, two children had medical diabetes, two children had moderate learning disabilities, and one child had microcephaly. It is common for deaf children to have additional difficulties (over and above deafness; see Arfé, 2011; Fortnum, Marshall, & Summerfield, 2002). Twelve children wore hearing aids, and 8 children were fitted with cochlear implants. Not every deaf child was capable of completing every task, and so the number of deaf participants in the analyses varies across tasks. These children attended a school where participants were not entered for national SATs exams because their ability was considered below that needed to sit the exam. Table 2 shows the characteristics of the participants in Study 2.

Materials

Standardized reading comprehension. Different comprehension tests were used to assess reading comprehension ability in hearing and deaf children. In hearing children, reading comprehension level was taken from SATs exams (2012). In deaf children, reading age was derived from the Suffolk Reading Scale (SRS).

Vocabulary. The BPVS-II was administered. Although most deaf participants were administered the BPVS-II, the teachers of two deaf participants

TABLE 2
Characteristics of Participants in Study 2

	Mean Age[a]	*Proportion of Boys*	*Mean BPVS*[a]	*Deaf < 2 Years*	*Parents Deaf*	*Degree of Hearing Loss*	*Compensation*	*Additional Diagnosed Difficulties* (n = 9)
Deaf ($n = 20$)	9.70 (1.28)	.65	39.67 (12.77)	20	2	19 profoundly deaf 1 severely deaf	12 hearing aids 8 cochlear implants	3 autistic spectrum 1 charge syndrome 2 medical diabetes 2 moderate learning disabilities 1 microcephaly
Hearing ($n = 32$)	8.97 (1.27)	.47	93.26 (12.63)					

[a] *SD* in parentheses.

believed that this task would be too difficult for them to complete, so no vocabulary data are available for those participants.

Revised reading comprehension: Picture ordering. The revised version consisted of 32 items compared with the original 16 items. These were randomly allocated to two sets, each set consisting of 16 items in total. The sets were presented to the participant at two different time points within the same test session. The internal consistency of this task over all 32 items, as measured by Cronbach's alpha, was .84.

Revised reading comprehension: Sentence choice. The revised sentence choice had 24 items in total, compared with the original 21. For 12 items the correct response was a temporal connective, and for the remaining 12 items a causal connective was the correct response. The items were assigned to two different sets, and these were presented to participants at two different time points within the same test session. Order of presentation was counterbalanced across participants. The internal consistency of this task over all 24 items, as measured by Cronbach's alpha, was .91.

Sequence understanding (nonverbal). Picture sequences were taken from the Wechsler Intelligence Scale for Children Revised. The child was presented with five envelopes and asked to randomly select one of them. Each envelope contained a set of either five or six pictures. The child had to examine the set of pictures and then place them in a sequence that represented a coherent story. They were instructed to indicate the correct order of the pictures by writing a number on the front of each one (i.e., 1 for the first picture in the sequence, 2 for the second picture in the sequence, etc.). When all pictures had been numbered, the child placed them back in the envelope, randomly selected a different envelope, and repeated the procedure until all five sequence tasks were completed. The internal consistency of this task over the five items, as measured by Cronbach's alpha, was .62.

Procedure

The presentation of the tasks was counterbalanced across all participants. For deaf participants the BPVS-II was administered in a quiet room that had hearing loops installed (thus amplifying sound). The test words were presented orally (with no signing) and in written form simultaneously. In contrast, the hearing participants were administered the BPVS-II in the standard format, whereby the test word is orally spoken to the participant and not provided in written form. Test words were only repeated if the child requested it. There were few requests for repetitions.

Results

Scores on the three tasks were converted to proportional scores. The relation between language (BPVS-II) and comprehension ability (as measured by SATs scores for hearing children and SRS for deaf children) and performance on the three experimental tasks was examined. Hearing children showed strong significant correlations between performance on the reading comprehension tasks and comprehension ability (SATs scores); picture ordering: $r(32) = .55$, $p = .001$, sentence choice: $r(32) = .69$, $p < .0001$, but not for the nonverbal sequence understanding task: $r(32) = .24$, $p = .20$. Performance on both reading comprehension tasks was also significantly correlated with language scores (BPVS-II) for the hearing children: $r(31) = .55$, $p = .001$, and $r(31) = .56$, $p = .001$, respectively. Language (BPVS-II) was not correlated with performance on the sequence understanding task: $r(31) = .23$, *n.s.*

For deaf participants, although comprehension (SRS) and language measures (BPVS-II) were intercorrelated: $r(16) = .59$, $p = .02$, there were no significant correlations between these measures and performance on the three experimental tasks: language (BPVS-II) and performance on the picture ordering task: $r(12) = .47$, *n.s.*; the sentence choice task: $r(9) = .40$, *n.s.*, and the nonverbal sequence understanding task: $r(15) = .44$, *n.s.* Also, there were no significant correlations between reading comprehension ability (SRS) and performance on the picture ordering task: $r(15) = .47$, *n.s.*; the sentence choice task: $r(12) = .49$, *n.s.*, and the nonverbal sequence understanding task: $r(20) = .14$, *n.s.*

To examine differences in performance between deaf and hearing children on the tasks and in keeping with the analyses for Study 1, we conducted a 2 (hearing status: hearing vs. deaf) × 3 (task) ANOVA, with proportional scores on the tasks as the dependent variable. This revealed a significant main effect of hearing status: $F(1,42) = 15.99$, $p < .0001$, $\eta_p^2 = .28$, a significant main effect of task: $F(2,84) = 9.02$, $p < .0001$, $\eta_p^2 = .18$, and a significant interaction between hearing status and task: $F(2,84) = 18.43$, $p < .0001$, $\eta_p^2 = .31$.[2] The interaction was explored with t-tests, which revealed that hearing children outperformed deaf children on the two reading comprehension tasks: picture ordering: $t(45) = 4.99$, $p < .0001$, and sentence choice: $t(42) = 7.02$, $p < .001$, but not on the nonverbal sequence understanding task: $t(50) = .78$, $p = .44$. Figure 2 shows the scores for hearing and deaf participants on the three tasks.

We then examined whether the children's pattern of performance across the three tasks was consistent with that found in Study 1. In keeping with the findings from Study 1, the deaf children scored significantly higher on the nonverbal sequence understanding task than on either of the reading comprehension tasks:

[2]Because of differences in the group size of hearing and deaf participants, we also conducted the same analyses using mixed effects modeling. The interaction remained significant ($p < .001$).

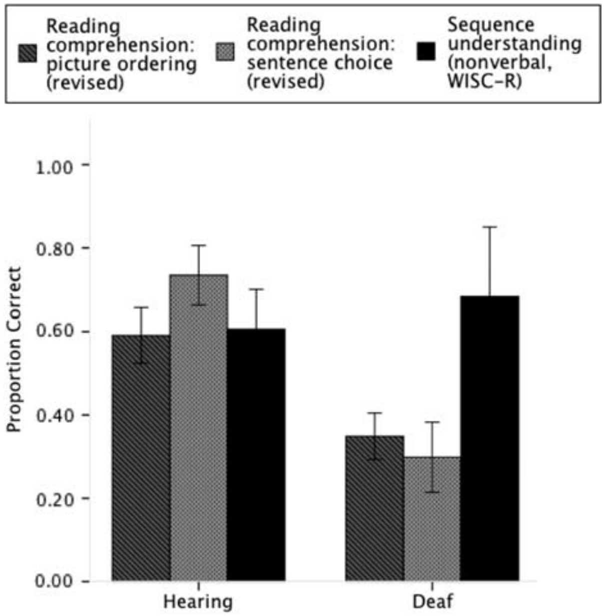

FIGURE 2 Mean proportion of correct scores on the three tasks in Study 2 as a function of hearing status (hearing vs. deaf). WISC-R = Wechsler Intelligence Scale for Children Revised.

picture ordering: $t(14) = 3.02$, $p = .009$, and sentence choice: $t(11) = 3.57$, $p = .004$. However, contrary to the findings from Study 1, there was no significant difference between their performance on the two reading comprehension tasks: $t(11) = 1.39$, $p = .19$. As in Study 1, the hearing children demonstrated superior performance on the sentence choice task than on the picture ordering task: $t(31) = 5.37$, $p < .0001$, and their highest score was, again, on the sentence choice task (compared with the deaf children, whose highest mean score was on the nonverbal sequence understanding task).

We also examined whether the same pattern of performance would be found between the hearing and deaf children once those deaf participants exhibiting a syndromic profile and cognitive impairment were excluded from the analyses ($n = 7$). The relation between language (BPVS-II) and comprehension ability (reading age derived from SRS) and performance on the three experimental tasks was examined for the 13 remaining deaf participants. Once more, comprehension and language measures were intercorrelated: $r(11) = .62$, $p = .041$, and there was a significant correlation between performance on the sentence choice task and reading age: $r(10) = .77$, $p = .01$, but not between the other experimental tasks and measures. We then conducted a 2 (hearing status: hearing vs. deaf) × 3 (task) ANOVA, with proportional scores on the tasks as the dependent variable. In keeping with the previous findings, we found a main effect of hearing status: $F(1,40) = 11.59$, $p = .002$, $\eta_p^2 = .23$, a significant main effect of task: $F(2,80) = 11.27$, $p < .0001$, $\eta_p^2 = .22$, and a significant interaction between hearing status and task: $F(2,80) = 21.81$, $p < .0001$, $\eta_p^2 = .35$ The interaction was explored with t-tests, which revealed, once again, that hearing children outperformed deaf children on the two reading comprehension tasks: picture ordering: $t(42) = 4.20$, $p < .0001$, and sentence choice: $t(40) = 6.80$, $p < .0001$, but not on the nonverbal sequence understanding task: $t(43) = .96$, *n.s.*

Discussion

The deaf participants in Study 2 were at a disadvantage to their hearing counterparts in terms of both comprehension and language skills, and they were also significantly older; however, the results were consistent with those from the original study in which the deaf and hearing students were matched for both comprehension and chronological age. That is, across both studies, hearing children significantly outperformed the deaf children on tasks tapping temporal and causal understanding, but only when the tasks required the understanding of written text. When the tasks were nontextual in nature, and tapping more general aspects of temporal and causal understanding, deaf children's performance was not significantly different from that of their hearing counterparts. This was also true when children with comorbidities were included in the deaf group and across different cohorts of deaf and hearing children.

As in Study 1, it was not simply the case that correct performance on the nonverbal sequence understanding task was easier than on the reading comprehension tasks, because the highest scores for hearing children were, once again, on one of the reading comprehension tasks. Also in keeping with the findings from Study 1, the deaf children's scores were significantly higher on the nonverbal sequence understanding task than either of the reading comprehension tasks, despite the use of a more difficult nonverbal task in the second study (as reflected in the lower scores for both hearing and deaf children in Study 2 vs. Study 1).

In keeping with the findings from Study 1, hearing children once more showed the same advantage on the sentence choice task in comparison with the picture ordering task (although the deaf children did not).

GENERAL DISCUSSION

The primary aim of these studies was to examine whether deaf readers' difficulties in processing temporal and causal information is specific to understanding linguistic markers of these relations or indicative a more general problem in reasoning about such information. Although previous research indicated that deaf readers have difficulty processing connectives (in comparison with hearing children), previous findings were unclear as to whether they have problems processing temporal and causal information when working with nonverbal stimuli. Some researchers suggested intact temporal/causal reasoning skills in deaf children when working with pictorial stimuli (Banks et al., 1990; Gentry, Chinn, & Moulton, 2004), whereas others had indicated difficulties even on such tasks (e.g., Eden, 2008; Marschark et al., 2002).

We found across two studies (including children who varied widely in their language and comprehension abilities) that deaf children's temporal and causal reasoning abilities are comparable with those of their hearing counterparts when using nonverbal tasks, but, as predicted, they were significantly worse than hearing children when processing connectives in text. The pattern of performance of the deaf children across the tasks (a pattern not observed in the hearing children) suggests that deaf readers do not have a general deficit in being able to reason about temporal and causal information but their deficit is specific to reasoning about linguistic markers of these relations.

Most deaf students are primarily visual leaners (Luckner, Bowen, & Carter, 2001; Nover & Andrews, 1998), which may underpin their successful performance on the nonverbal sequence understanding tasks used in the current studies. Because deaf participants in both studies outperformed their hearing counterparts (although not significantly so) on these tasks, future research should explore how this apparent strength in deaf readers profiles could be used for future text intervention strategies. Because of the variability in the population of deaf readers (with regard to primary language and comorbidities) used in the current studies, it would be beneficial to replicate their specific linguistic deficit in reasoning about temporal/causal relations in a more homogenous group of deaf readers.

This pattern of performance (i.e., deaf children's comparable performance with hearing children when using nonverbal tasks but worse performance when processing connectives in text) was apparent even in Study 1, where the hearing and deaf groups were matched for overall text comprehension skill. This pattern might be explained by different processes leading to similar outcomes in a general reading comprehension assessment, where deaf readers might be able to gain a global impression of what a text is about even without precise comprehension of the linguistic markers in that text; such a strategy might result in adequate comprehension scores up to a certain level. This finding also has implications for deaf children attending mainstream schools, because it suggests that difficulties in processing connectives may go unnoticed if a general measure of text comprehension is relied upon when determining text comprehension skills. That is, comprehension of temporal and causal connectives may be a specific kind of linguistic comprehension, which could be delayed even in deaf readers who have good general text comprehension skills.

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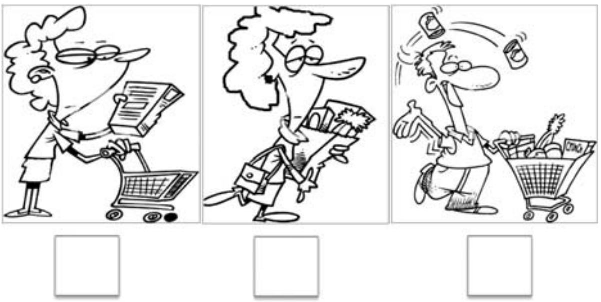
APPENDIX

Example Item From the Reading Comprehension: Picture Ordering Task

Children read the sentence and then sequenced the pictures into the correct order by placing a number (1, 2, 3, etc.) under each picture.

e.g., Because John forgot the sugar and the washing powder, Isabel went back to the shop.



Example Item From the Reading Comprehension: Sentence Choice Task

Children read three sentences and decided which one best matched the picture.

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