SPECIFIC EF RELATED TASKS AND READING IN ADOLESCENTS WITH TYPICAL HEARING OR A COCHLEAR IMPLANT

Abstract

The acquisition of effective reading comprehension for adolescents with cochlear implant (CI) in inclusive settings is crucial for ensuring the benefit of current traditional reading curricula and instructional practices. Executive functions (EF) are recognized as important cognitive processes during reading by students with typical hearing (TH). This study compared the relationship between EF and reading comprehension in adolescents with TH and CI. Three tests sessions were performed on two groups of adolescents between 12 and 16 years old (36 with CI and 54 with TH). Reading comprehension was assessed by a standardized reading battery and EF by computerized tests. The results indicated that adolescents with CI perform EF tasks with a similar efficiency as the TH group, but the performance of CI group on expository texts was lower than in TH students. Reading comprehension of expository texts was related to inhibition and shifting in adolescents with CI.

Keywords: reading, cochlear implants, middle school, deaf.

The current policy of inclusion and the increasing number of schoolchildren with cochlear implants (CI) has promoted more inclusive schools, where the majority of these children and adolescents are educated in regular classrooms (De Raeve et al., 2012). In inclusive schools, adolescents with CI are members of the general education classroom and may receive speech-language services, just like typical hearing (TH) students. This shift in educational placement has brought with it a new set of issues, particularly in middle school[1], that must be addressed with new didactic strategies (Miller, 2014) to enable students with CI to acquire competencies that contribute to improved self-efficacy and self-control (Hintermair, 2013). One of these issues is that adolescents with CI appear to be more delayed both in linguistic competence and in executive functions (EF) than children in earlier stages of development (Marschark & Knoors, 2012). Another is that middle schools are typically large and, consequently, students are not so well known by their teachers as in elementary schools. Students with special needs receive less personal attention in many cases and their needs may not be readily addressed (Hopwood et al., 2017).

In this educational context, efficient EF in adolescents with hearing loss could be crucial to dealing with academic and language challenges. In fact, EF is considered an important domain impacting reading comprehension in TH students (Kieffer & Christodoulou, 2020), but little research has documented the role of EF in the reading comprehension of children and adolescents with CI.

EF are a group of cognitive processes that enable voluntary control of our behaviors, thoughts and emotions (Marschark et al., 2018). They support reading comprehension beyond the linguistic skills that have been demonstrated to be relevant to reading in adolescents with TH (Sesma et al., 2009). Miyake et al. (2000) established a multimodal system for EF, with three different, but related components, namely inhibition, updating, and shifting. In this regard, reading comprehension requires a variety of abilities, such as selecting key information and central ideas to understand a text. In order to avoid overloading working memory during reading, the inhibition process allows the reader to set aside less relevant content (Borella et al., 2010). Once the new content is selected through inhibition, it is incorporated into the memory. Afterwards, updating maintains and processes incoming information, which gives further coherence to the text (Carriedo et al., 2011; Palladino et al., 2001). Lastly, shifting is the ability to flexibly switch attention to a relevant task or strategy, disengaging an irrelevant mental operation in favor of task demands (Altemeier et al., 2008). For example, shifting is required to connect long-term knowledge and reading (García-Madruga et al., 2016) or to decode words (Altemeier et al., 2008; Yeniad et al., 2013).

Individuals with hearing loss have obtained lower scores in previous studies in which EF and memory skills were evaluated. Children, adolescents, and adults with CI showed lower efficiency in performing inhibition and working memory tasks (Beer et al., 2014; Hintermair, 2013; Kronenberger et al., 2014), shifting tasks (Hintermair, 2013; Kronenberger et al., 2014) or in deploying other high-level cognitive skills such as planning, sustained attention and fluency (Beer et al., 2014; Kronenberger et al., 2013). However, these studies were carried out in participants from a variety of educational settings, age ranges and auditory statuses. The executive and linguistic difficulties that adolescents with CI must face in their daily lives can vary greatly in accordance with the neurodevelopmental particularities of this stage (Spear, 2013), so this variability in sample characteristics should be delimited. Indeed, adolescents with hearing loss tend to seek assistance in regular middle school classrooms more frequently than their TH peers and, as a consequence, they do not find their own way to solving their academic, linguistic and social problems (Marschark & Knoors, 2012). This could increase their EF delay and affect their performance in other skills, as EF exhibit particular importance in less conventional tasks, or in tasks that an individual may not possess the skillset to complete automatically, such as reading.

Weaknesses in these EF could have a negative effect on different academic domains such as studying, test-taking, long-term projects, written expression or reading comprehension (Meltzer & Krishnan, 2007). CI have provided linguistic and academic improvements for children with hearing loss (Geers & Nicholas, 2013; Schorr et al., 2008), but some studies have shown that these improvements are not enough for them to understand a text at the same level as their TH peers in adolescence (Dillon et al., 2012; Figueroa et al., 2020). However, Geers and Hayes (2011) reported that most adolescents with CI were within or above the average range for their hearing peers in reading skills scores.

During reading, children with hearing loss have problems recognizing when comprehension is successful and when it is not (Marschark & Knoors, 2012), which indicates a problem with the participation of EF rather than a language difficulty. To the best of our knowledge, only Daza et al. (2014) have analyzed the relationship between reading and EF in children and adolescents with mild to profound hearing loss. The participants in their study were divided into competent readers (7 children with CI and 8 with hearing aids, all of whom preferred to use spoken language to communicate) and less successful readers (8 children with CI and 7 with hearing aids, 7 of whom preferred sign language). According to Daza et al. (2014), competent readers obtained better working memory and EF scores than less successful readers, so executive components involved in these tasks could be good predictors of reading success in children who are deaf. Children with hearing loss could use an alternative route to alleviate their language-based problems in order to be able to read more efficiently. In this regard, data obtained in a preliminary study (Figueroa et al., 2018) seem to support the hypothesis that the relationship between reading and EF could differ between CI and TH adolescents and these data also show that long-term CI users with better scores in EF obtained better results in reading comprehension, so EF could exercise a more decisive role in reading comprehension in people who are deaf. Notably, in middle school years, when demands on comprehension skills and text complexity increase, the need to understand the relationship between reading and EF in adolescents who are deaf becomes even more relevant.

Aim of the study

This study is part of a larger, cross-sectional research project on the relationship between reading and certain cognitive skills in adolescents with CI, which aims to observe the contribution of EF to reading comprehension in long-term CI users who are enrolled in inclusive schools. The relevance of this study lies in the scarcity of studies that have observed the relationship between EF and reading in adolescence, a sensitive period for the development of EF. Furthermore, the study of the relationship between reading and EF could show the unique features of adolescents with CI and bring out new insights to enhance educational programs and instructional practices.

For this purpose, the present study aimed to observe both executive performance and reading comprehension in adolescents with CI who were enrolled in inclusive schools, fell within a narrow age range and had similar educational characteristics. It should be noted that we focused our attention on expository texts, due to their crucial role during the learning process in secondary education.

This study, therefore, addressed the following research questions to compare adolescents with CI and adolescents with TH.

1. Is there any difference between CI and TH adolescents in their EF or reading level?
2. Is the relationship between EF and reading equal in both groups?

Methodology

Participants

Participants were recruited by contacting the Public Resource Centers for the Education of People with Hearing Loss (*Centre de Recursos Educatius per a Deficients Auditius;* CREDA) and then by contacting secondary-school teachers, speech therapists, supervisors and parents to inform them about the aim of the study. To participate in the study, the voluntary consent of adolescents and parents was required. In the case of participants with CI, the criteria for inclusion in the study were based on several variables. First, all participants had to be prelingually deaf and receive a CI during the first four years of life. Second, adolescents had to be enrolled in inclusive schools. Third, participants with CI had to be fluent in oral communication and, finally, they could not have additional disabilities or neurological disorders. Adolescents with CI are regularly evaluated for their language skills by speech therapists. The inclusion criteria were explained in the initial interview between speech therapists, the school tutor and the researcher. According to the different reports, the participants were included in the study. Adolescents with CI receive speech therapy and educational support from the CREDA in their schools. All students in the CI group receive these services from infancy through adolescence. However, if the CREDA observe adequate linguistic competence and competent academic performance, some of them could not receive this support in the last years of secondary school. The role of speech therapists is to provide assistance and support to students with severe hearing loss or language difficulties that require specific speech therapy services. In this sense, speech therapists complement educational programs implemented by schools. In middle schools, educational support is frequently related to their curriculum and mainly focused on preventing difficulties in the classroom (for example, anticipatory sets) or providing facilitating elements during regular classes, that is, allowing access to information and learning. Participants in the CI group who have lower linguistic skills have activities dedicated to, for example, increase their vocabulary or practice reading. Educational support is frequently for oral language in Catalonia, although speech therapists and teachers can provide support for another communication mode. In order to maintain consistent similarities between the two groups (mainly age, gender, and academic performance), TH participants were recruited from the same classrooms as the group with hearing loss. The study was approved by the XXX.

The participants in this study were 90 adolescents (aged 12-16) recruited from 27 different middle schools. The group of adolescents with CI was formed by 36 participants (15 males and 21 females) with a mean age of 14.03 ± 0.21. Three of them were bimodal users, 10 had bilateral implants and the other 23 had unilateral implants. The CI group had bilateral severe-profound hearing loss and received their first CI at a mean age of 2.26 ± 0.15, so their hearing age (defined as the amount of time amplification had been used from the first hearing device) was 11.98 ± 0.28. It should be clarified that the CI was not always the first hearing device. In some cases, the participants had previously received a hearing aid. The TH group comprised 54 adolescents (22 males and 32 females) and their mean age was 13.5 ± 0.18.

Procedure and materials

Three test sessions were necessary to assess each participant in their own school. EF skills were assessed in the first session. The second session consisted of the reading and working memory assessment, while the last session focused on the evaluation of non-verbal intelligence.

Following the model of EF designed by Miyake et al. (2000), three tasks were used to assess inhibition, shifting and updating. Stroop (Stroop, 1935) was used to assess inhibition, Plus-minus (Jersild, 1927) to assess shifting and the ability to carry out updating was assessed with Letter Memory (Miyake et al., 2000). These tasks are considered reliable and appropriate measures to evaluate the three EF. In fact, these tasks were used previously in adolescents with TH to assess their relationship with reading comprehension (Ober et al., 2019). The Stroop test was also used with individuals with hearing loss (Flaherty & Moran, 2007; Kronenberger et al., 2014). The materials are explained below (see Miyake et al., 2000, for a detailed procedure description of each EF task).

Inhibition. In the Stroop task, participants must name the ink color (red, blue, green or yellow) of words, inhibiting the reading of the word, which could correspond to another color (incongruent condition), the same color (congruent condition) or other words (e.g., bread; neutral condition). The variables recorded were the difference between congruent and incongruent accuracy, neutral and incongruent accuracy, congruent and incongruent reaction time and neutral and incongruent reaction time. These variables measure the ability to inhibit the incongruent stimulus. If their reaction time and the accuracy are near to zero, this means the incongruent stimulus has had no effect on their performance.

Shifting. The Plus-minus task consists of three blocks of 30 mathematical operations. In the first block, participants added 3 to each 2-digit number and, in the second block, participants subtracted 3 from 2-digit numbers. In the last block, participants added and subtracted three alternately. Accuracy and reaction time were recorded to represent the shift cost. The following formula was used to calculate the accuracy and the reaction time cost: outcomes in the third block – (outcomes in the first block + outcomes in the second block / 2).

Updating. The Letter Memory task consists of a list of letters presented individually at a rate of 2000 ms per letter. Participants had to recall the last three letters, updating their memory continually since the length of each series is unknown. Each correct response was worth one point (maximum of 12 points).

Working memory. Verbal working memory was measured by a backward digit-span task and visual working memory was evaluated by the backward version of the Corsi task from the Psychology Experiment Building Language battery (Piper et al., 2015, 2016).

Reading. The PROLEC-SE-R (Cuetos et al., 2016) was used to assess reading competence. Six subtasks from this standardized test were administered for each participant following the manual. Participants completed two subtasks related to decoding skills (word reading and non-word reading task). Afterwards, they resolved the grammatical structure comprehension. The grammatical structure comprehension subtask consists of 24 items each of which has four pictures and a sentence that describes one of the pictures. The student must read the sentence and point to the correct image. This subtask includes different types of complex sentences in Catalan language (e.g., passive voice or relative clause). Each correct response was worth one point. Reading comprehension was evaluated with three expository texts (each one with a different test condition). Expository texts are frequently used in learning environments as their purpose is to provide new information to the reader and they contain unfamiliar and low-frequency words (Snyder & Caccamise, 2010). All participants read the same expository texts. The non-mnemonic comprehension was the first text that participants should read. This text contained inferential questions without memory influence. The topic of this expository text was the Annapurna massif and the different climbing expeditions to this mountain. The second expository text, the mnemonic reading comprehension, contained literal questions with memory influence. In this case, participants read a text about the culture of indigenous people of New Guinea. In oral comprehension, participants were asked inferential questions with memory influence. This text explained the life conditions, customs and habits of Eskimos.

Other measures. Non-verbal intelligence was assessed with the Block Design, Picture Concepts and Matrix Reasoning subtests of the WISC-IV battery (Wechsler, 2007) and the socio-economic status index was calculated by parental occupation and education. The two groups did not differ in terms of non-verbal intelligence or socio-economic status ($p > 0.05$; see Table 2 for non-verbal intelligence detailed scores).

Data analysis

Reading and EF scores were analyzed by means of an analysis of variance (ANOVA) using hearing conditions as a factor between groups (two levels, CI group and TH). In order to evaluate a possible hearing age effect on the reading performance of CI-group, a complementary analysis was executed comparing three groups (the TH group, adolescents with CI and high hearing age, and adolescents with CI and low hearing age; see Table 2 for descriptive statistics). Partial eta squared (η^2) was included in order to provide effect size estimations. Correlation analyses and hierarchical multiple linear regression analyses were performed in order to examine the relationships between reading comprehension and EF scores. Significance was set at p=0.05 and data are shown as mean ± SEM.

Results

Executive functions and working memory

The analysis of EF data revealed no near to statistically significant differences in the shifting and inhibition variable measures. The updating task difference just failed to reach statistical difference ($F_{(1,88)}$= 3.91; p=.051; η^2=.086). For working memory, analysis showed that the TH group obtained significantly higher scores than the CI group in verbal working memory ($F_{(1,88)}$= 4.92; p<.05; η^2=.086), but no significant differences were observed in visuospatial working memory; $F_{(1,88)}$= 0.10; p=.752).

<insert Table 1 near here>

Reading Comprehension

Reading data analysis revealed that auditory status affects the ability to understand a text. These difficulties in the CI group were observed both in texts with memory influence ($F_{(1,88)}$= 15.92; p<.001; η^2=.153, see Table 1 for descriptive statistics) and in texts with inferential questions ($F_{(1,88)}$= 30.38; p<.001; η^2=.257). The CI group also had more difficulty answering questions when textual comprehension was processed orally ($F_{(1,88)}$= 32.02; p<.001; η^2=.267). In order to observe the performance of the CI group in tasks related to reading accuracy, we also analyzed the ability to understand different grammatical structures and to read words and non-words. The results showed that the performance of the CI group in grammatical structures comprehension and word reading was lower than that of the TH group ($F_{(1,88)}$= 8.32; p<.01; η^2=.086; $F_{(1,88)}$= 10.27; p<.01; η^2=.105, respectively). However, no significant differences were observed in non-word reading, that is, the mean of non-word reading in the CI group fell within the TH group average range ($F_{(1,88)}$= 0.99; p=.321).

The effect of hearing age on reading was also analyzed (see Table 2). The results showed that the TH group outperformed both CI groups in the three expository texts: non-mnemonic reading comprehension ($F_{(2,86)}$= 16.84; p<.001; η^2=.279), mnemonic reading comprehension ($F_{(2,86)}$= 8.08; p<.01; η^2=.157) and oral comprehension ($F_{(2,86)}$= 17.45; p<.001; η^2=.286). In addition, there was not significant difference between those adolescents with high hearing age and those with low hearing age.

<insert Table 2 near here>

Factors influencing reading comprehension

Pearson correlations were performed for the TH group and the CI group and the most significant variables were selected for each cognitive ability (see Table 3). Then, a hierarchical regression analysis was conducted to observe which EF and working memory measures can contribute to explaining non-mnemonic reading comprehension. As we described in the method section, this reading task did not require active memory participation because participants could answer and read at the same time. EF and working memory were entered separately in the first two steps of the regression in order to observe CI group and TH group differences between different models.

<insert Table 3 near here>

As displayed in Table 4, the first model variables significantly predict reading comprehension only in the CI group ($F_{(2,33)}$= 4.189; p<.05; R^2 =.282). EF accounted for almost 30% of the variance in a reading task with a low memory load. As data reveals, the second model significantly predicts non-mnemonic reading comprehension both in the CI group ($F_{(5,30)}$= 2.470; p=.055; R^2 =.292) and the TH group ($F_{(5,48)}$= 2.650; p<.05; R^2 =.216; see Table 4 for more detailed data). These regression models are highly consistent regarding the correlations between reading and neurocognitive tasks, which lends greater value to the results found.

<insert Table 4 near here>

Discussion

The present study examines the relationship of specific domains of EF with reading comprehension performance in long-term CI users. Motivated by hypotheses proposing an important role for executive functioning in language development, this study extends previous work by raising the number of participants. Our results indicate that long-term CI users achieved adequate inhibition and shifting levels in adolescence. However, unlike our preliminary study (Figueroa et al., 2018), the present data could indicate that adolescents with CI had greater difficulty in updating and verbal working memory compared to their hearing classmates.

Our results are in line with Kronenberger et al. (2014) who found a similar performance in the Stroop task between adolescents with CI and TH, though in other tasks or in parent-reported questionnaires participants with hearing loss obtained lower scores than TH (Hintermair, 2013). Similarly, in the present study, the CI group was also able to change from one activity to another without a higher cost in comparison to their hearing classmates. These results do not coincide with Hintermair (2013) who found significant differences in shifting using a parent-reported behavior checklist and, therefore, the discrepancies observed between studies can be attributed to the neuropsychological tests selected. Moreover, our participants were implanted before the age of 4, which is a critical age for having a better prognosis for language acquisition (Castillo-Castillo et al., 2012) and could also be important for cognitive development (Kronenberger et al., 2014). Our findings bring new insights into the updating capacity in adolescents with CI, suggesting that auditory and language deprivation during early development could influence updating and verbal working memory tasks. Difficulties in verbal working memory have been reported by several studies (Hintermair, 2013; Kronenberger et al., 2014), but our results provide new information on updating capacity in adolescence.

Regarding the reading performance of the CI group, this was significantly lower in comparison with TH. Our results are in line with previous studies concerning low reading comprehension in adolescents with CI (Dillon et al., 2012; Figueroa et al., 2020). Additionally, the analysis of the performance on different types of questions suggested that the CI group performed poorly on literal questions of mnemonic comprehension and on inferential questions of non-mnemonic reading comprehension. Low EF may provoke rigidity of thought processes, a predominance of more concrete answers or difficulty with abstract thinking (Silagi et al., 2018). In the CI group, difficulties on inferential questions were more obvious if questions on expository texts were asked orally. Oral comprehension needs the same language processes used to comprehend language via text, but it is free of the cognitive demands of having to decode text (Hogan et al., 2014). The relationship between reading and oral comprehension is strengthened in advanced development stages when decoding skills lose their relevance and it is likely that common language skills such as grammatical competence or pragmatic skills underlie them (Cain & Oakhill, 2007). The low performance of CI users could be unlikely related to the hearing age as the performance of CI group with high hearing age did not differ from those with low hearing age and, also, TH-group performance was higher than both groups.

Knowing that expository texts are commonly used in middle schools and that adolescents with CI could have difficulty in understanding them, it is important to know how their reading comprehension can be enhanced. For this reason, a regression analysis of non-mnemonic reading comprehension was carried out and showed that EF actively participate in the CI group's reading comprehension. It should be noted that participants could read the text at the time of answering a question, so they did not need to memorize any information. It is especially striking that EF contribute significantly to reading only among adolescents with CI. Thus, shifting and inhibition would have a greater influence during the reading comprehension and would be central to understanding the main ideas in the CI group.

Our results reinforce the previous hypothesis that EF are more relevant to adolescents with CI than TH adolescents (Figueroa et al., 2018). Less competent TH readers need a greater EF involvement to compensate for their inefficient reading comprehension (Wang et al., 2019). As the reader becomes expert and reading comprehension becomes an automatic process, EF would play a more secondary role depending on the demands of the reading activity. Our results indicate that shifting and inhibition contribute significantly to reading in adolescents with CI. In these EF, CI group members obtain similar scores to the TH group, so the more preserved skills take on a major role. Concretely, inhibition plays an important role in selecting key information during reading comprehension (Silagi et al., 2018). Adolescents with CI and low inhibitory performance could exhibit difficulty in recognizing the main parts of the text which will then be stored in the working memory, so their answers would be less accurate and vaguer. Also, inhibition could be important in locating the antecedent or the answers of causal inferential questions.

When two factors such as high textual complexity and poor reading comprehension are combined, the ability to switch attention to different demands becomes important. Teachers and speech therapists frequently adapt text complexity or provide access to less difficult texts, but what happens when these adolescents with CI are faced with age-appropriate texts? The greater contribution of EF to reading comprehension in adolescents with CI could also show the relevance of text characteristics and how adolescents with CI may have difficulty understanding a text without facilitating elements. So, when a struggling reader faces a text with high complexity, shifting skills could be important, for example, in keeping the question in mind and looking for the answer in the text or handling any task that involves maintaining several premises at once during inferences (Richard’s et al., 2014). Toggling decoding and understanding the meaning of words and sentences could also lead to greater difficulty for the CI group and require shifting skills due to the poorer ability to read words accurately. Indeed, Kieffer and Christodoulou (2020) have recently reported that EF contribute to reading comprehension through reading fluency, that is, the relationship between reading comprehension and reading fluency in struggling elementary readers could be mediated by EF. However, our results could point to a direct relation between EF and reading comprehension in adolescents with CI.

The results of the present study are consistent with the work of Daza et al. (2014) in people who are deaf. Daza et al. (2014) observed that visuospatial working memory, inhibition, and visuospatial attention could be used by people who are deaf as an alternative to relying on their language skills. It should be taken into account that in this study only 15 of 30 participants had CI and the performance could have been affected by their auditory conditions. But our results did not reveal a significant contribution of visuospatial working memory in reading. This could go against the sensory compensation hypothesis, which assumes a greater relevance of visual resources in people with hearing loss (Marschark et al., 2017). In our study, visuospatial working memory predicted reading only in the TH group, suggesting that language skills in this group would be already consolidated but also supporting the notion that there could be differentiated models for each group. The TH group would not require a great cognitive effort to comprehend a text and would only need the visuospatial working memory to identify and locate the correct answers in the text and to regulate attention and manage both phonological and visuospatial input.

Our results show that the relationship between reading and EF seems to be different in adolescents with CI compared to their TH peers. Our study, unlike other previous studies, is focused on adolescents with CI and specific educational and hearing conditions, which allows us to better understand their needs. To the best of our knowledge, until now no study had analyzed this relationship in a comparative way since, for example, Daza et al. (2014) only had participants with hearing loss. Therefore, the similarities and differences between children and adolescents with or without hearing loss could not be known. Our results suggest that adolescents could use a compensatory route to understand a text. In middle schools this is essential as students use reading to learn and can have more problems in following the academic curriculum.

Implications for practice

The present study highlights the specific role of EF, in that our results indicate that adolescents with CI need higher levels of EF in expository texts. It is therefore important to carry out a detailed psycholinguistic assessment of adolescents with hearing loss that treats EF as an influential element in their oral and written language comprehension. The benefits of school-based interventions focused on EF were reviewed by Jacob and Parkinson (2015), who found that some studies provide evidence that EF can be enhanced by direct intervention, but provide no compelling evidence that this training leads to increases in reading or math achievement. Meanwhile, other authors claim that further research is needed, as teachers will not be able to implement interventions suitable for students with EF weaknesses, given the scarcity of evidence-based interventions addressing EF (Rapoport et al., 2016). In adolescents with hearing loss, assuming that the dependence on EF could be related to poor language skills, it would be recommended to train EF skills indirectly. Educational and language interventions should focus on teaching strategies addressing the selection of key information and answers in a specific and concise way. In this regard, it is important to familiarize adolescents with CI with vocabulary and other elements that give coherence and cohesion to expository texts, as well as boosting self-monitoring reading strategies (Marschark & Knoors, 2012).

EF training could be addressed through difficult linguistic features, such as pronoun-referent structures. Sometimes the antecedent of a personal pronoun can be located in a distant sentence or not explicitly expressed, and improved antecedent identification could promote inference and global coherence during reading. Regarding text complexity, it is important for adolescents with CI to become familiar with age-appropriate texts before completing compulsory education, so teachers and speech therapists need to provide scaffolds during the reading experience that lead adolescents with CI to face, with small cues, texts of age-appropriate complexity. The term “scaffold” was used to express a way to induce learning through interactions. With this structured interaction between the child and the adult, the child could achieve a specific goal by themself (Bruner, 1978; Wood et al., 1976). This concept was developed extensively by these authors, as Bruner (1983) studied in depth the relationship between scaffolding and language acquisition, while Wood et al. (1986) adapted some scaffolding strategies to children with hearing loss and their communication with an adult. In reading interventions, these scaffolds do not have to be a text simplification—they can simply be questions, rereading certain parts or close-reading strategies (Bardack & Obradović, 2019; Meltzer, 2010). From an evolutionary perspective, educators should incorporate new strategies and elements in the elementary grades with the purpose of stimulating EF skills early to reduce the risk of reading difficulties in adolescence. It is important that children with CI become familiar with expository discourse. In this sense, expository discourse and EF skills can be improved in elementary grades by, for example, helping children to recognize text patterns (Meltzer, 2010). In addition, these educational practices recommended for improving reading comprehension in students with CI can be extrapolated to TH students with reading difficulties, since the compensatory hypothesis regarding reading comprehension was also found in students with reading difficulties.

Limitations and conclusions

To sum up, our results showed that adolescent CI users achieved adequate inhibition and shifting levels but the reading comprehension of expository texts, especially texts with inferential questions, seems to entail difficulty for adolescents with hearing loss. Our findings provide further evidence about the relationship between EF and reading comprehension in adolescents with CI. While they point to a similar performance on EF tasks in CI and TH adolescents, results also suggest a difference in the contribution of EF to reading comprehension between these groups, which would imply that adolescents with CI need greater involvement of EF in order to overcome linguistic barriers.

Nevertheless, given the difficulty in comparing studies on EF, as each one evaluates it with different neuropsychological tests, and in knowing which ones are the most appropriate for predicting reading comprehension, and given the scarcity of studies on the relationship between reading and EF in CI users, more studies are needed, analyzing larger CI samples. These future studies should consider aspects such as practices in reading interventions, materials used by speech therapists, reading instructions or reading habits of each participant, which, without doubt, can have an impact on reading and EF development.

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[1]In Spain, secondary education comprises four years of compulsory education (Educación Secundaria Obligatoria) and two years of high school (Bachillerato). In this manuscript, the term "middle schools" refers exclusively to the compulsory period of secondary education (12 to 16 years old).

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