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READING AND THEORY OF MIND IN ADOLESCENTS WITH COCHLEAR IMPLANT

Abstract

Previous research has shown a possible link between reading comprehension and theory of mind (ToM), but these findings are unclear in adolescents with cochlear implants (CI). In the present study, reading comprehension and ToM were assessed in adolescents with CI and the relation between both skills was also studied. Two sessions were performed on two groups of adolescents aged between 12 and 16 years old (36 adolescents with CI and 54 participants with typical hearing, TH). They were evaluated by means of a standardized reading battery, a false belief task and Faux Pas stories. The results indicated that reading and cognitive ToM were more developed in the TH group than in adolescents with CI. However, early-CI and binaural group performance were close to the TH group in narrative and expository comprehension and cognitive ToM. The results also indicated that cognitive ToM and reading comprehension appear to be related in deaf adolescents.

Keywords: Theory of mind, reading, cochlear implant.

Adolescence is a period in which the environmental and biological changes lead to more complex relationships and interest in other people. Adolescents need reading experiences that bring out their emotions and enable them to think about the consequences of different situations (Block & Parris, 2008). In reading, just like during conversations, the reader must understand characters' perspectives and motivations, judge their behaviors or goals. Therefore, competent reading implies various skills beyond the linguistic ones. For instance, theory of mind (ToM) or executive functions have been identified as influential factors in the reading competence (Baggetta & Alexander, 2016; Kidd & Castano, 2013). ToM is the ability to understand mental states, such as desires and intentions, and to infer others persons' thoughts and behaviours (Premack & Woolcroyff, 1978). ToM can be divided into two different processes: affective ToM, when this ability is used to understand emotions, and cognitive ToM, if tasks imply an understanding of beliefs and intentions (Shamay-Tsoory, Harari, Aharon-Peretz, & Levkovitz, 2010). The earliest precursors of ToM emerge in children with typical hearing (TH) before the first year of life when infants refer to themselves and others as intentional agents (Wellman, 2017). From the first year of life, children with TH learn different mental concepts and specialize their ToM ability as the different linguistic dimensions develop (Slade & Ruffman, 2005).

In recent years, a number of studies of deaf children have focused on the consequences of spoken-language deprivation on ToM development during infancy and childhood. For instance, Meristo et al. (2012) found that five infants with cochlear implants (CI)¹ and five with hearing aids resolved false-belief tasks with less proficiency than TH infants at 18 months of age. In the deaf group, hearing parents used spoken language supported with signs, but deaf infants had not acquired sign language.

Therefore, the difficulties in adopting the perspective of others begin before language acquisition (Zufferey, 2010).

During childhood, the gap between auditory and chronological age is reduced because of early hearing fitting and implantation, cerebral plasticity, and language development. According to certain authors (Geers & Nicholas, 2013; Mancini et al., 2016; Nicholas & Geers, 2013), CI means a major improvement in their language as well as in the quality and quantity of communicative exchanges between deaf children who use spoken language and their environment. CI surgery under 12 months was associated with good language skills, as the majority of children with CI obtained scores within or above typical range in semantics, morphology, syntax and vocabulary when they were assessed with Peabody Picture Vocabulary Test III and the Preschool Language Scale IV (Nicholas & Geers, 2013). Rather than focusing on auditory deprivation and speech skills, other authors argue that the expected development of all developmental domains (e.g., cognitive, academic, socio-emotional) is achieved with the full acquisition and accessible of a first-language such as sign language (Hall, 2017).

Learning a language, orally or signed, can be important for the development of emotional concepts. Mancini et al. (2016) considered that language and emotion development is interdependent as their origins resides in social interactions. For children with CI, an early fitting can facilitate an adequate emotion comprehension (i.e. recognition of emotions in cartoons) due to improvement in listening and language skills and their link with emotional development (Mancini et al., 2016). However, natural speech signals in everyday life present greater challenges and a significant proportion of children and adults with CI did not recognize emotions through the voice at a similar level to TH group (Chatterjee et al., 2015). CI can stimulate auditory cortex development at a

rate close to normal and some CI users even possess prosodic abilities on par with their TH peers (Jiam, Caldwell, Deroche, Chatterjee, & Limb, 2017). These prosodic and emotional perception abilities are fundamental to understanding social interactions, so it is necessary to put them into practice during educational activities such as shared reading. In this sense, Sundqvist et al. (2014) conducted a study concerning social cognition by comparing affective and cognitive ToM performance among three groups: early-implanted children, late-implanted children and a TH group. The sample was aged between 4 and 9 years and was required to solve a Sally-Anne false belief task and a set of six affective stories such as inferential, irony or Faux Pas. The early-implanted group did not differ from their hearing peers in affective ToM, while late-implanted children continued to show a delay. In cognitive ToM, the TH group outperformed early and late-implanted children. This delay in ToM can make it difficult the reading process. Indeed, deaf and hard of hearing students are less efficient in understanding ironic statements and inference-making (Li et al., 2019). Furthermore, other studies focussing on sign bilingual education found that children with CI recruited from hearing and bilingual units did not obtain better scores than deaf children without CI in mentalistic tasks (Peterson, 2016; Peterson, O'Reilly, & Wellman, 2016). Even in nonverbal tasks when language demands are kept to a minimum, such as tasks to identify facial emotions, pre-schoolers with CI who communicate in spoken or sign language exhibit less proficiency than their hearing peers when recognizing facial expressions (happiness, sadness, anger, and fear) or attributing emotions to situations (Wiefferink, Rieffe, Ketelaar, De Raeve, & Frijns, 2013). In this respect, several studies have shown that pre-schoolers and children with CI have difficulties understanding both affective and cognitive ToM, that is, beliefs, desires and emotions (Ketelaar, Rieffe, Wiefferink, & Frijns, 2012; Peterson, 2016; Peterson et al., 2016; Wiefferink et al., 2013). Although ToM development is slower and is delayed

in comparison to their hearing peers, deaf children could acquire ToM following the same evolutionary sequence as TH children (Ketelaar et al., 2012; Peterson et al., 2016).

ToM tasks have been widely used to evaluate preschoolers, children, adults and even elderly people (Brizio, Gabbatore, Tirassa, & Bosco, 2015; Kilford, Garrett, & Blakemore, 2016). However, ToM has been poorly studied during adolescence when emotional, social and cognitive changes lead to a development in mentalistic capacities (Blakemore, 2012; Bosco, Gabbatore, & Tirassa, 2014). Bosco et al. (2014) examined ToM through a semi-structured interview and point out that the development of ToM continues after childhood until adolescence, at least. In childhood, social relations usually take place within familiar or educational contexts, while adolescents are more emotionally independent and their relationships grow (Brizio et al., 2015). Adolescents possess advanced social competences and relationships characterized by their hierarchical nature and their sensitivity to acceptance and rejection by their peers (Blakemore, 2012). Although when adolescents are required to make empathetic judgments, they are not yet able to inhibit certain egocentric behaviours that decrease in adulthood (Riva, Tricoli, Lamm, Carnaghi, & Silani, 2016). Social relationships and how an individual perceives their friendships can influence affective and cognitive ToM in adolescence (Białecka-Pikul, Kołodziejczyk, & Bosacki, 2017). Friendship styles and gender are stronger predictors of both affective and cognitive ToM in middle adolescence than in early adolescence. According to certain authors (Białecka-Pikul et al., 2017; Shamay-Tsoory et al., 2010), affective and cognitive ToM could be developed in a distinct way. Adolescents solve cognitive ToM tasks better than affective ones, so cognitive ToM could be a precursor to affective ToM in adolescence.

One of the few studies on deaf adolescents reported that adolescents with CI or hearing aids can perceive and understand the other person's emotions, but they have more problems comprehending their causes and understanding the perspective of another person in self-reported empathetic questionnaires (Netten et al., 2015). Although those adolescents enrolled in mainstream schools or those who used spoken language as main mode of communication performed better on cognitive empathy than their deaf peers who used sign language or attended special schools. In addition, adolescents with CI tend to underestimate others' emotions and, for this reason, their performance in ToM tasks seems to indicate that they may have difficulties in solving affective ToM tasks such as misunderstandings (XXX, 2018). This difference in the development of emotion concepts could be related with vocabulary or syntax competence, and particularly with the richness of emotional language (Rommel & Peters, 2008). Adolescents use reading as a source of learning and could therefore be used as an educational tool for improving language and mentalistic skills in deaf population.

The contribution of core language skills (e.g. vocabulary, syntax or morphosyntax) to reading comprehension has been documented in children with CI (Dillon, de Jong, & Pisoni, 2012; Domínguez, Pérez, & Alegría, 2012; Gallego, Martín-Aragoneses, López-Higes, & Pison, 2016; Lopez-Higes, Gallego, Martin-Aragoneses, & Melle, 2015). Phonological processing skills and increased language exposure help develop vocabulary and underlie reading comprehension in children with CI (Dillon et al., 2012). Breadth of vocabulary is increased by the greater opportunities provided through CI, which is reflected in a better ability to understand written language. However, in children with CI and spoken English as main mode of communication (20% of the sample were bilingual or had a preference for using sign language) these skills remain delayed in comparison to hearing peers (Edwards & Anderson, 2014). Regarding

syntactic influence during reading, Domínguez et al. (2012) reported that the syntactic problems of children with CI are not reduced with an improvement in reading comprehension. Early CI could have a significant impact on reading, enabling them to use syntactic cues to comprehend a text (Gallego et al., 2016). Overall, deaf children who received their CI during early years can obtain a better benefit from their devices, since early-implanted children can achieve similar reading performance to their hearing classmates (Sarant, Harris, & Bennet, 2015).

In adolescence, knowing how to see from another's viewpoint and how to analyze and critique while reading and writing emerge as essential components of development (Fitzgerald & Shanahan, 2000). Given the difficulties of adolescents with CI in taking on someone else's perspective, it is important to know their reading level at this stage. Geers and Hayes (2011) investigated reading among 114 adolescents with CI of whom 83 reported using spoken language and 29 speech and sign as their first communication method. Around 50% of the deaf sample obtained similar reading scores to TH peers and 72% had demonstrated age-appropriate growth from elementary school to high school. In a preliminary study of our group (XXX, 2018), adolescents with CI were also able to achieve similar results in narrative and expository texts with literal-type questions. However, reading comprehension is still far from that of their hearing peers in children and adolescents with CI regardless they were enrolled in mainstream schools (XXX, 2018) and schools for the deaf/hard of hearing (Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007). Adolescents with CI showed difficulties specifically, among others, when the questions require inferential thinking skills (XXX, 2018). Following this line, Kyle and Cain (2015) found that deaf children with CI or hearing aids were more accurate when answering literal questions than when responding to inferential questions. At all events, questions that required global coherence were the most difficult for deaf children.

The reading process requires advanced comprehension skills to judge the intentions or other mental states of the narrator and story characters. ToM could play a crucial role in the reading comprehension of narrative texts. In fact, Dore et al. (2018) argue that certain development stages of ToM and narrative processing abilities occur at the same time. When an individual reads, she or he must put comprehension strategies into practice, for example, extracting information from the text and recalling previous knowledge to perceive the relationships between characters and the reason for their actions (Guajardo & Cartwright, 2016; Pelletier & Beatty, 2015). In childhood, books are an important source of mental state which are promoted through parent-child conversations using words with high emotional or mentalizing content such as *think*, *believe*, *be afraid* or *enjoy* (Kucirkova, 2019). Pelletier and Beatty (2015) showed that the contribution of cognitive ToM to reading is established in stories when children progress from identifying narrative facts to extracting life lessons. In this context, the contribution of ToM was higher than the contribution of general vocabulary.

In narrative texts, the reader processes the mental states of fictional individuals as if they were real. Such characters can make readers feel their sadness, loneliness or happiness, and teach social and convention-related rules that can develop social cognition (Mar, 2011). In secondary school, reading is no longer a simple decoding task and the complexity of expository and narrative texts has increased. Plots are now less simple, centring on complex characters and the links between them, providing remarkably simulating social experiences (Kozak & Recchia, 2019). For this reason, it makes sense to analyze reading globally, along with the influence of understanding characters' thoughts within global coherence. In this way, inferences provide coherence and consistency to the text as they facilitate the connection between antecedents and consequences (Cain & Oakhill, 2007). The ability to understand emotional inferences

begins by the age of 4, but the precision of the inferential process is enhanced over time (Lynch & van den Broek, 2007). Studies of discourse analysis show that adolescents can understand and identify the central structure of a text but behave more like children with respect to the comprehension of narrative elements that are more social in nature (Pavias, van den Broek, Hickendorff, Beker, & Van Leijenhorst, 2016). Immature social-cognitive abilities affect processing of story elements and thus have a negative impact on written-discourse comprehension in adolescence. Adults are able to understand and feel similar emotions to fictional characters when they read negative or positive emotions, while children rated more neutral emotions on valence and arousal scales (Mouw, Van Leijenhorst, Saab, Danel, & van den Broek, 2017). Readers who are able to understand or empathize with characters' feelings and intentions can better remember what they have read or learned (Mar, Oatley, Djikic, & Mullin, 2011; Tyng, Amin, Saad, & Malik, 2017). Neuroimaging studies support the relation between ToM and reading, as the comprehension of mentalistic content evokes a cortical network (Mason & Just, 2009). If an individual reads a narrative text, the neural substrate of discourse comprehension comprises the ToM network. ToM could also be necessary for expository texts if there are references to people or an entity capable of autonomous action (Dore et al., 2018).

Among deaf people with CI, to the best of our knowledge, only two studies have been conducted to observe the relation between ToM and reading comprehension. Roh and Yim (2013) found that the linguistic and reading abilities of children with CI between 9 and 12 years of age are associated with level of ToM. In addition, the group with deafness had greater difficulties than TH group in answering inferential questions that would be more linked to ToM performance. Our preliminary study in adolescents with CI showed that these reading problems remain in adolescence (XXX, 2018). Surprisingly, however, these difficulties did not occur in the narrative text. Our preliminary results also

showed that performance of reading comprehension tasks was significantly associated with cognitive ToM, but this relationship was not found with affective ToM.

In sum, there are solid references about the interrelationship between reading and ToM in participants with TH in two ways. On the one hand, certain ToM competences are involved in the understanding of written language, such as inferences about human behaviors in narrative texts (Dore et al., 2018). On the other hand, text complexity factors are necessary to achieve the global coherence after the reading process as, among others, the interpretation of cohesive elements. In this sense, there are studies that support the link between the function of some connectors and ToM (Zufferey, 2010). Likewise, based on the difficulties of children and adolescents with CI in both skills, it is especially interesting to analyze whether difficulties in ToM can affect to reading competence in a greater extent.

Therefore, this study aims to contribute to this emerging line of research. In our opinion, this contribution contains a double interest: to advance in the concept of ToM and, linguistically, the implications of ToM to discourse comprehension. Moreover, it certainly allows to deduce educational implications for both deaf and students with difficulties in either or both areas.

Consequently, reading competence and the ability to understand mental states require a more in-depth analysis. The aim of this present work is to observe the relationship between both processes. To this end, the following questions were addressed: How are the reading scores (e.g. global index of reading, syntactic process or lexical process) in adolescents with CI compared to those of their TH peers? Which is the level of ToM in adolescents with CI compared to the that of a TH group? Are there any differences between adolescents with CI according to CI conditions? Is there a

relationship between reading and ToM in both groups? Is this relation equal in all texts (narrative and expository) and in all groups?

Methodology

In order to include the participation of deaf students, our research required the collaboration of the six Public Resource Educational Centers for People with Hearing Loss (*Centre de Recursos Educatius per a Deficients Auditius*, CREDA). CREDA provide multidisciplinary support to children with CI and their school and family educational environment. Educational support includes different communication modalities that are agreed with schools, although the most generalized in Catalonia is the oral modality. These centres provided the initial contact with the sample group and assisted in obtaining parental informed consent. Deaf participants are enrolled in mainstream education where the mode of communication is oral language and receive speech therapy services in their school, conducted by university graduates in speech therapist. Speech therapy rehabilitation begins in most cases a few months after implantation and is standardized throughout Catalonia. To participate in this study participants with CI had to have been implanted during the first four years of life and prelingually deaf as inclusion criteria. Other requisites were being fluent in spoken language and without neurological disorders. TH adolescents and participants with CI were recruited from the same schools so there are reliable similarities in age, gender, and academic performance. Informed consent was obtained for each participant and the study was approved by the Ethics Committee on Animal and Human Experimentation of the XXX. In this informed assessment, adolescents were assured that their answers and our sound recordings would remain anonymous.

The participants were 90 adolescents aged 12-16 divided into two different groups. One group was formed by 36 participants with a CI (CI-group; 15 males and 21 females) with a mean age of 14.03 ± 0.21 . Three of them had a unilateral implant and a contralateral hearing aid, ten had bilateral implants and the other 23 had unilateral implants. The CI brand was Cochlear for all the participants. The CI-group received their first CI at a mean age of 2.26 ± 0.15 and their hearing age (time elapsed between the date of first implant activation and the date of testing) was 11.98 ± 0.28 . The TH-group was formed by 54 adolescents (22 males and 32 females) and their mean age was 13.5 ± 0.18 . CI-group was divided into adolescents implanted until 24 months (early-CI) and those implanted after 24 months (late-CI) for a complementary analysis. This segmentation followed the criteria of Nicholas and Geers (2007) who established the first 24 months of life as a critical period for auditory stimulation and language development. Late-CI was implanted between 24 and 54 months which is not considered an ideal age, but language abilities can be acquired and well-developed (Castillo-Castillo, Roque-Lee, Carranco-Hernández, & Martínez-Haro, 2012). Likewise, bilateral CI and bimodal participants formed the binaural group and those implanted unilaterally formed the monaural group. Audiological variables were extracted from the medical history and/or audiological notes (see table 2 for descriptive statistics of these subgroups).

Non-verbal intelligence was tested with the WISC-IV battery (Wechsler, 2007) and the socio-economic status score was calculated using the job and level of education of both parents. The two groups did not differ in terms of non-verbal intelligence or socio-economic status ($t_{(88)} = -1.46$ and $t_{(88)} = -1.77$, respectively, $p > .05$).

Each participant was evaluated in two sessions. To make the evaluation process comfortable, the assessment took place in the schools where the participants attended.

The first session was conducted in groups and had a duration of 45 minutes with the first part of PROLEC-SE-R. The second was individual with a duration of 45 minutes and participants completed the ToM and non-verbal intelligence assessment.

Reading. PROLEC-SE-R in the Catalan language version (Cuetos, Arribas, & Ramos, 2016) was administered to evaluate reading. This battery includes tests which assess different essential processes necessary for reading comprehension such as semantic processes, syntactic processes and lexical processes. Semantic processes comprised two different subscales to evaluate reading comprehension: expository comprehension (with memory influence) and narrative comprehension (with no memory influence). Also, all these measures form a Global Index of Reading.

Cognitive ToM. To assess cognitive ToM a false belief task from Ryskin and Brown-Schmidt (2014) adapted from Birch and Bloom (2007) was used. This task consists of two pictures and a text where participants can read the story. The first picture shows Vicki, who is playing the violin, and four boxes. Each box is a different colour: blue, purple, red, and green. The girl puts the violin in the blue box and goes out. Then her sister comes, moves the violin to the red box and rearranges the boxes in such a way that the red box is located where the blue box was originally. Participants are asked about where the girl is going to look for the violin. The correct response, thus, would be to assign a high percentage to the blue box. If a participant writes the highest percentage in the red box, her or his answer would be a false belief. Whereas if higher percentages are assigned to the green or purple boxes, their responses are considered implausible. Participants had to write their answer below the boxes and these answers could not be more than 100 %.

Affective ToM. Two stories from the Faux Pas Recognition test (Stone, Baron-Cohen, & Knight, 1998) were used. A story about a misunderstanding and a story about control were selected. In the story about misunderstandings subjects have to answer questions about the characters' feelings, while the questions about the control story are related to physical relationships. If the first question was answered incorrectly, the score was zero and the participant could not score more points. Three of the other six questions were selected because of their affective nature. *Question one (understanding the listener's mental state): Why should she or he not have said it? Question two (understanding the speaker's mental state): Why did she or he say it? Question three (understanding how the person in the story would feel): How do you think she or he felt?* Each correct response in the mentalistic test was marked with one point up to a maximum of three. Once participants read the story, the questions were formulated verbally and the participants could read the story again to reduce language and memory interference.

For data analysis, SPSS Statistics Software was used (IBM Corp. Released, 2012). Reading and ToM data were analyzed by means of an analysis of variance (ANOVA) using hearing conditions as a between-groups factor (two levels, TH and CI-group). And, as indicated, non-verbal intelligence and socioeconomic status were analyzed by means of independent two-sample t-test. Furthermore, additional analyses were conducted to study the hearing status effect, thus ANOVA was performed using auditory input (binaural, monaural or TH group) and time of implantation (early-CI, late-CI and TH group) as between-groups factors when indicated. Moreover, a multiple linear regression analysis was used to explore relationships between reading and ToM. Partial eta squared (η^2) has been included to provide effect size estimations. Significance was set at $p=.05$ and data are shown as mean \pm SEM.

Results

How are the reading scores in adolescents with CI compared to those of their TH peers?

Reading data analysis showed that CI-group performance was affected in comparison with their hearing classmates. The Global Index of Reading reflected this difference on reading between groups ($F_{(1,88)} = 39.88$; $p < .001$; $\eta^2 = .312$, see Table 1 for descriptive statistics). These differences were also observed in the lexical and syntactic indexes ($F_{(1,88)} = 26.19$; $p < .001$; $\eta^2 = .229$; $F_{(1,88)} = 30.30$; $p < .001$; $\eta^2 = .256$, respectively). For a better understanding of deaf reading difficulties, we also analysed expository and narrative comprehension. TH-group achieved higher correct responses than CI-group both in expository and in narrative comprehension ($F_{(1,88)} = 14.86$; $p < .001$; $\eta^2 = .144$; $F_{(1,88)} = 10.82$; $p < .001$; $\eta^2 = .110$, respectively). Despite of these results, 30.55% and 33.33 % of deaf sample could comprehend expository and narrative texts at TH level, respectively.

<table 1 here>

Which is the level of ToM in adolescents with CI compared to the that of a TH group?

On the other hand, ToM data analysis revealed a statistically significant difference on cognitive ToM ($F_{(1,88)} = 5.62$; $p < .05$; $\eta^2 = .060$). Judgments of the probability that Vicki

would act according to a false belief were higher in CI-group than in TH group. However, the affective ToM skill was not affected by the hearing status ($F_{(1,88)} = 1.74$; $p = .190$).

Are there any differences between adolescents with CI according to CI conditions?

In order to study the differences between CI- and TH-group in detail, deaf sample was splitted in two groups: early-CI and late-CI group (see Table 2 for descriptive statistics). The hearing status effect remained significant in the Global Index of Reading ($F_{(2,87)} = 20.94$; $p < .001$; $\eta^2 = .325$), Lexical Processes Index ($F_{(2,87)} = 13.01$; $p < .001$; $\eta^2 = .230$) and Syntactic Processes Index ($F_{(2,87)} = 16.99$; $p < .001$; $\eta^2 = .231$). TH scores were higher than both deaf groups (see Table 3 for detailed statistics and post-hocs).

<table 2 here>

Regarding expository and narrative comprehension, ANOVA showed a significant hearing status effect ($F_{(2,87)} = 7.77$; $p < .001$; $\eta^2 = .152$ and $F_{(2,87)} = 5.53$; $p < .01$; $\eta^2 = .113$, respectively; see Figure 1). However, Tukey contrasts determined that these differences were only significant between TH and late-implanted adolescents both in expository ($p < .001$) and in narrative comprehension ($p < .01$). Early-CI group performance was comparable with TH-group independently of text type ($p = .102$ for expository and $p = .152$ for narrative).

<table 3 here>

Analysis of ToM skills data also showed a significant hearing status effect on cognitive ToM ($F_{(2,87)} = 3.79; p < .05; \eta^2 = .080$). Tukey post-hoc comparisons revealed that TH scores were higher than late-CI group ($p < .05$), but not significant differences were observed between TH and early-CI group scores. As expected, there was no significant difference among groups on the affective ToM measure.

In order to evaluate a possible hearing age effect on the performance of CI-group, additional analysis was executed using only participants with a controlled range of hearing age (12-14 years). The groups for this analysis were: early-CI ($n=9$, \bar{x} chronological age = 14 ± 0.29), late-CI ($n=8$, \bar{x} chronological age = 15.38 ± 0.32) and TH group ($n=42$, \bar{x} chronological age = 11.9 ± 0.18). The results showed that early-CI performance was similar to their hearing classmates in all the reading-related measures; while late-CI were lower in comparison to early-CI and TH group in Global Index of Reading ($F_{(2,56)} = 13.18; p < .001; \eta^2 = .228$), Lexical Processes Index ($F_{(2,56)} = 8.83; p < .001; \eta^2 = .104$), Syntactic Processes Index ($F_{(2,56)} = 10.52; p < .001; \eta^2 = .193$) and expository reading comprehension ($F_{(2,56)} = 4.88; p < .05; \eta^2 = .117$).

Regarding ToM abilities, the hearing age effect only was significant in cognitive ToM ($F_{(2,56)} = 3.95; p < .05; \eta^2 = .252$). Both early-CI and TH group obtained higher scores than late-CI.

Additional analysis was conducted in order to study the effect of a better auditory input on reading and mentalistic competences. Significant differences in the Global Index of Reading ($F_{(2,87)}=19.75$; $p<.001$; $\eta^2=.312$), Lexical Processes Index ($F_{(2,87)}= 14.12$; $p<.001$; $\eta^2=.245$) and Syntactic Processes Index ($F_{(2,87)}= 14.99$; $p<.001$; $\eta^2=.256$) were found. Tukey post hoc comparisons of reading index revealed that TH-group outperformed all other groups (see Table 3 for detailed post-hoc).

<figure 1 here>

A binaural hearing status effect was also found in the two reading subtasks, for example expository comprehension ($F_{(2,87)}= 14.38$; $p<.001$; $\eta^2=.248$) and narrative comprehension ($F_{(2,87)}= 5.43$; $p<.01$; $\eta^2=.111$). Post-hoc comparisons showed that TH group obtained significantly higher scores than monaural participants in the expository text and the narrative text ($p<.001$ and $p<.01$, respectively). However, TH group and binaural group showed a similar performance in these texts (see Figure 1).

When cognitive aspects of ToM were analyzed significant differences were also observed ($F_{(2,87)}= 3.03$; $p=.053$; $\eta^2=.065$). Tukey comparisons revealed that only monaurals participants assigned lower possibilities to the blue container in comparison of their hearing classmates ($p<.05$, see Figure 2). TH scores and binaurals reported similar probabilities to the right box. On the other hand, and as it was expected, there was no significant difference between monaurals, binaurals and TH-group on *Faux Pas* task.

<figure 2 here>

Is there a relationship between reading and ToM in both groups?

A linear regression analysis was conducted to determine whether the ToM abilities and traditional linguistic aspects were predictive of students' reading scores. As data revealed, the model was significant both in CI-group ($F_{(4,31)}= 11.392$; $p<.001$; $R^2 =.595$) and TH-group ($F_{(4,49)}= 14.835$; $p<.001$; $R^2 =.548$). Table 4 shows the model and detailed coefficients for each predictive measure. Together, these variables accounted for 59.5% of the variance in reading comprehension of CI-group and 54.8% of TH-group. Significant predictors in CI-group were ToM measures and syntactic index. However, only linguistic factors predicted reading outcomes in TH-group.

<table 4 here>

Discussion

The present study focusses on reading comprehension and ToM competence in adolescents with CI and their hearing classmates. Our work reports the scarcely examined linguistic achievements of adolescents with CI in an important developmental stage of life. Overall, our results document poor reading performance and difficulties in understanding people's mental states in the CI-group. Low literacy outcomes in adolescents with CI are in line with previous studies (XXX, 2018; Geers & Hayes, 2011), while results in cognitive ToM might suggest that these skills remain delayed as in

childhood (Peterson et al., 2016; Sundqvist et al., 2014). These findings are discussed in more detail in the following paragraphs, starting with reading comprehension performance in different CI conditions to continue with ToM and its relationship with written language.

Regarding narrative or expository texts, the CI-group was outperformed by the TH group in both text types, although around 30% of deaf participants could understand narrative or expository texts within or above TH average range. As expected, the early-CI group could comprehend a text at a similar level to their hearing classmates, while late-CI results were significantly lower. Previous studies (Geers & Nicholas, 2013; Johnson & Goswami, 2010) pointed to an important effect of early implantation on literacy development and academic achievement due to the relevance of strong receptive and expressive language skills during infancy and childhood. In fact, most of the children who had received an early CI had improved their language skills at a similar rate to the rate documented for TH children. After more than 10 years of CI use, it might be thought that the improvement obtained in early CI could be due to a higher hearing age. In the present study, when hearing age was controlled, late-CI users' scores were lower than those in both the TH and early-CI group. Our results support the idea that the benefits of early implantation remain in adolescence (Geers & Nicholas, 2013). As it can be seen in Table 3, the expository or narrative comprehension were similar between early-CI and TH group, while in the late CI group the scores remained lower. Moreover, when hearing age was controlled, lexical and syntactic competence of early-CI group was also similar to their hearing classmates.

A striking finding was that the binaural group revealed better text comprehension than those who did not receive a second CI or hearing aids. Geers and Nicholas (2013) investigated the possible advantage of bilateral implantation, but there was no significant

difference in vocabulary or syntax between bilaterally and unilaterally implanted children. The benefits of bilateral versus unilateral CI were reviewed by Lammers, Van der Heijden, Pourier & Grolman (2014). This review showed that the majority of studies were focused on sound localization, while those focussing on language development were scarce. More recently, certain authors have indicated the positive effect of bimodal device use or bilateral CIs on child language development and reading (Litovsky & Gordon, 2016; Sarant et al., 2015). To the best of our knowledge, this is the first time that binaural hearing effects on reading comprehension has been reported in adolescents with CI. It is important to note that some binaural adolescents did not receive their devices early. Specifically, only 6 adolescents had worn their device since they were under two years of age. Our data support the beneficial effect of binaural hearing status on reading comprehension, but as we have indicated above, this benefit of binaural hearing on language measures has not been extensively replicated.

Linguistic exchanges and, more specifically, prosody, hold information about pragmatic understanding that is useful for inferring emotional states. For these reasons, spoken language deprivation during infancy has an important effect on the understanding of mental states. Meristo et al. (2012) found that the foundations of ToM competence are developed during the first months of life. This present work contributes towards determining how adolescents with CI can perceive others' mental states. The results show that both the early-CI and the binaural group could reach similar cognitive ToM levels to their hearing classmates, but the late-CI group remains delayed. These data are in accordance with that reported by Netten et al. (2015) who pointed out that cognitive empathy depends on the extent to which children can participate in a social environment.

To gain further insight into the possible factors that can affect reading comprehension in adolescents with CI, we investigated the relation between narrative or expository comprehension and ToM competence. Both the CI-group and TH group obtained higher scores in expository comprehension than in narrative comprehension. Although memory contributes towards providing answers efficiently in the expository text, narrative comprehension presents more and greater obstacles. Knowledge about readers' mental world and the mental world of others is required to understand, simulate and infer emotions and to select important information from narrative texts (Mouw et al., 2017). The convergence between previously cited factors, language abilities necessary to understand referential cohesion in distinct types of texts, and syntactic complexity can all affect adolescents' reading process (Denton et al., 2015) and might partially explain the poor reading performance of the deaf group.

Understanding and inferring characters' emotions is part of a ToM ability, indispensable for understanding narrative texts (Dore et al., 2018). In fact, mentalizing becomes more predictive of reading comprehension for narratives with higher levels of text complexity. Participants' performance reveals that groups with better reading scores (TH, early-CI and binaural group) executed the cognitive ToM task efficiently. Regression analysis confirms the association between cognitive ToM and reading, since the deaf model showed a significantly positive contribution of cognitive ToM and syntactic knowledge to reading comprehension. Recent studies have linked cognitive ToM tasks to listening or reading comprehension in TH children (Atkinson, Slade, Powell, & Levy, 2017; Kim, 2015, 2017). For example, Atkinson et al. (2017) argue that literacy and ToM competence could be related directly and also indirectly, mediated by linguistic comprehension. Socio-emotional cognition promotes linguistic comprehension, which may play an important role in reading during early development. Additionally,

Marschark et al (2017) indicated that limited socio-emotional experiences, social skills and emotional maturity can lead to a negative impact on the academic achievement of college deaf students. Deaf children and adolescents are frequently at risk with regard to social and emotional learning in which ToM is a central aspect. Certain social maturity concepts such as social values, conventional rules and behaviours are acquired incidentally through interactions (Marschark et al., 2017).

Incidental learning often implies overhearing conversations between others in which the dialogues are both rapid and of low intelligibility (Netten et al., 2015); missing the opportunity for this kind of learning will disadvantage children with CI. Spatial and acoustic aspects (such as noise, reverberation and distance) hinder listening and learning when binaural cues are not accessible (Gordon, Jiwani, & Papsin, 2013). Thus, bilateral devices and early-CI might be a considerable help to incidental learning and, therefore, to better reading and ToM performance. In fact, bilateral/bimodal fitting improves speech-perception skills and the opportunity to acquire verbal cognition skills (De Raeve, Vermeulen, & Snik, 2015; Jacobs et al., 2016). De Raeve et al. (2015) point out that CI users, especially those in mainstream schools, need bilateral or bimodal fitting to attain good speech perception and to facilitate incidental learning. This learning also requires certain executive functions and memory capacities in order to maintain a consistent level of self-monitoring, awareness and phonological short-term memory when interaction with family members and peers takes place (Jacobs et al., 2016; Marschark et al., 2017). Both executive functions and phonological processing are delayed in children with CI and cause language-skill difficulties such as poor reading competence (Johnson & Goswami, 2010; Kronenberger, Colson, Henning, & Pisoni, 2014; Spencer & Oleson, 2008). If children with CI cannot decode, recognize and comprehend words accurately, it

will obviously be difficult for them to learn to read effectively (Johnson & Goswami, 2010; Spencer & Oleson, 2008).

In the TH group, the impact of ToM understanding on reading comprehension was not relevant in our study. The TH model revealed the involvement of traditional linguistic aspects only, namely, lexical and syntactic knowledge. Considering that social cognition is a major challenge for deaf adolescents (Marschark et al., 2017), ToM could distinguish between those with greater opportunities to acquire language skills such as reading. In the case of TH group, performance in ToM could be more homogeneous since children have been able to learn the emotional and social concepts accidentally. The influence of syntax in reading-comprehension outcomes was also observed in the CI-group. Surprisingly, lexical knowledge was not associated with a better understanding of the texts, which could be due to the heterogeneity of the sample. Our study revealed that lexical and syntactic understanding continues to be a challenge in adolescence. The CI-group obtained lower lexical and syntactic scores, which should be fundamental to comprehend a reading task. Previous studies in the deaf children explain how these linguistic deficits might affect reading in elementary education (Gallego et al., 2016; Johnson & Goswami, 2010; Lopez-Higes et al., 2015), but to our knowledge, no study has shown the relevant contribution of syntax to reading in adolescents with cochlear implants, studying in mainstream education.

This study emphasizes the need to promote ToM in adolescents with CI who obtain low reading scores in standardized tests. Additionally, it highlights the importance of stimulating sociolinguistic aspects and the intervention of linguistic skills from infancy, but also during adolescence when research and intervention programs are reduced. Speech-language programs in adolescence should promote emotional and causal

inferences, encourage the discussion of literacy topics and make predictions about texts. To trigger inferences, which are more linked to ToM, deaf students should read texts that are not overly easy, but which focus on topics that they know in depth. An additional recommendation is to be more specific and to take into account discourse type, question type and the need to build prior knowledge in order to gain a better understanding of the written language. Reading provides a good context for teaching syntactic elements that are difficult to learn in isolation, that is, understanding pronouns, pronominalization or connectors. This is particularly relevant when considering reading during adolescence. In secondary education, a large number of adolescents reduce their reading frequency and the variability in reading performance among readers becomes much wider (Dore et al., 2018; Pavias et al., 2016). In this regard, adolescents who read a greater number of narrative texts tend to develop higher levels of ToM (Kidd & Castano, 2013).

This present study also reveals the well-documented effect of CI precocity on linguistic skills. Furthermore, a binaural-hearing status effect on reading comprehension was also found. Taking into account the design of our work, more studies are needed to confirm the extent of this effect. It is important to note that the comparisons between deaf adolescents' subgroups should be interpreted with caution given the size of groups. In addition, new-born babies with prelingual deafness are usually implanted at a younger age due to improvements in screening, intervention and in rehabilitation programmes. Binaural-hearing participants were implanted sequentially, that is, they received their second CI after a determined period of time (Moberly, Lowenstein, & Nittrouer, 2016). Simultaneously, cochlear implantation could reduce the gap between the TH group and binaural-hearing group even further, if the time lapse between the first and the second CI is not considerable. Finally, the tests selected for this study have been widely used in the

clinical setting and in research, but ToM scores might be affected by reading and linguistic problems.

In conclusion, our results add further insights into the level of ToM for cochlear-implanted adolescents and into its relation to reading comprehension. First, reading and ToM skills were more developed in the TH group than in the CI-group. Both syntactic and lexical knowledge are less consolidated in the CI-group, which could influence reading. Our findings suggest that difficulties in literacy and ToM could be reduced with early CI or with bilateral auditory devices. Second, cognitive ToM and reading seem to be related in adolescents with CI, although further research is needed in order to clarify how poor mentalizing skills affect text comprehension. Third and last, it is important to point out how the educational implications of studies in adolescence lead us to reflections on the early-childhood care of deaf children. In effect, early attention is beneficial for language development, but it is also necessary within the continuum process of ToM formation, given the delay indicated in certain studies on ToM precursors when oral language is not even acquired in children with TH.

¹ Throughout the manuscript, the term "CI" is referred to, at least, one cochlear implant. The term "binaural" includes participants with a cochlear implant and a hearing aid or two cochlear implants, whereas "bilateral CI" specifically include people with two cochlear implants.

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Table 1

Descriptive statistics on reading and ToM.

	TH-group (n=54)		CI-group (n=36)		Sig.
	Mean	SEM	Mean	SEM	
Global Index of Reading	105.76	2.2	83.25	2.85	<.001
Lexical Processes Index	105.24	1.99	89.47	2.31	<.001
Syntactic Processes Index	110.74	2.2	88.94	3.56	<.001
Expository Comprehension	7.06	0.25	5.39	0.37	<.001
Narrative Comprehension	5.2	0.26	3.83	0.32	<.001
Affective ToM	1.5	0.11	1.25	0.16	.190
Cognitive ToM	55.54	3.94	39.92	5.51	<.05

Note. Cochlear implanted group (CI-group), Typical hearing group (TH-group), Affective Theory of Mind (Affective ToM) and Cognitive Theory of Mind (Cognitive ToM).

^aOne way ANOVA.

Table 2

Descriptive statistics of implant characteristics for the different subgroups of adolescents with CI.

	Early-CI (n=13)	Late-CI (n=23)	Binaural (n=13)	Monaural (n=23)
Bilateral CI	6	4	10	0
CI+HA	0	3	3	0
Unilateral CI	7	16	0	23
Age	14 ± 0.38	14.04 ± 0.25	13.92 ± 0.33	14.09 ± 0.27
Hearing age	13.08 ± 0.38	11.36 ± 0.31	12.25 ± 0.49	11.82 ± 0.34
Age at first CI	1.39 ± 0.06	2.76 ± 0.16	1.86 ± 0.2	2.49 ± 0.19
Delay CI1-CI2	4.77 ± 1.28	1.29 ± 0.98	2.81 ± 0.82	
Delay CI-HA		0.92 ± 0.45	0.92 ± 0.45	

Note. Cochlear implant (CI), Hearing aid (HA), Early cochlear implanted group (Early-CI), late cochlear implanted group (Late-CI), binaural hearing group (Binaural), monaural hearing group (Monaural), time between first and second cochlear implant (Delay CI1-CI2) and time between cochlear implant and hearing aid (Delay CI-HA).

Table 3

Descriptive statistics on reading and ToM in early cochlear-implemented adolescents, late cochlear-implemented adolescents, binaural hearing and monaural hearing.

	TH (<i>n</i> =54)	Early-CI (<i>n</i> =13)	Late-CI (<i>n</i> =23)	Monaural (<i>n</i> =23)	Binaural (<i>n</i> =13)
Global Index of Reading	105.76 ± 2.2	88** ± 6.01	80.57** ± 2.86	82.83** ± 3.63	84** ± 4.78
Lexical Processes Index	105.24 ± 1.99	90.46** ± 4.6	88.91** ± 2.6	91.87** ± 2.8	85,23** ± 3.93
Syntactic Processes Index	110.74 ± 2.2	95.92* ± 7.25	85** ± 3.66	88.65** ± 4.86	89.46** ± 5.05
Expository Comprehension	7.06 ± 0.25	5.77 ± 0.64	5.17** ± 0.46	4.57** ± 0.42	6.85 ± 0.54
Narrative Comprehension	5.2 ± 0.26	4.08 ± 0.67	3.7** ± 0.34	3.74** ± 0.36	4 ± 0.65
Affective ToM	1.5 ± 0.11	1.15 ± 0.27	1.3 ± 0.19	1.22 ± 0.20	1.31 ± 0.26
Cognitive ToM	55.54 ± 3.94	49.23 ± 10.6	34.65* ± 6.11	37.26* ± 7.01	44.62 ± 9.1

Note. Typical hearing group (TH), early cochlear implanted group (Early-CI), late cochlear implanted group (Late-CI), binaural hearing group (Binaural) and monaural hearing group (Monaural). **p*<.05; ***p*<.01 vs TH.

Table 4

Multiple linear regression model of reading comprehension

	β	T	p	R^2	R^2 adjusted
CI-group model (Constant)		2.485	.019	.595	.543
Cognitive ToM	.330	2.882	.007		
Affective ToM	-.304	-2.477	.019		
Lexical index	.185	1.066	.295		
Syntactic index	.595	3.269	.003		
TH-group model (Constant)		2.375	.022	.548	.511
Cognitive ToM	-.129	-1.329	.190		
Affective ToM	-.074	-.753	.455		
Lexical index	.260	2.253	.029		
Syntactic index	.557	4.813	<.001		

Note. Cochlear implanted group (CI-group), typical hearing group (TH-group), cognitive theory of mind (Cognitive ToM) and affective theory of mind (Affective ToM). In bold statistically significant predictive variables.