THEORY OF MIND AND READING COMPREHENSION IN ADOLESCENTS WITH COCHLEAR IMPLANT: A PRELIMINARY STUDY

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Abstract

Adolescence is a period in which emotions and social relations become increasingly important. Throughout this period, the theory of mind (ToM), the ability to understand mental states, is essential to an individual's social and academic success. Deaf adolescents (DA) have been observed having difficulties with the comprehension of mental states. Recent studies have shown a possible link between reading comprehension and theory of mind, but these findings are unclear DA with cochlear implants. The purpose of this study is to explore the relation between ToM and reading comprehension in DA with a cochlear implant. Two tests sessions were performed on two groups of adolescents between 12 and 14 years old: 10 DA implanted before 4 years of age and the other group formed by 16 typical hearing development. The evaluation was focused on reading comprehension and theory of mind (affective and cognitive). Reading comprehension was assessed by PROLEC-SE-R (Catalan version) and affective and cognitive theory of mind was assessed by faux pass test and a false belief-task, respectively. Results indicated that DA scores in affective ToM were lower than their peers, while cognitive ToM saw no significant difference. DA performance in reading tasks was not as good as their classmates. Correlation analysis showed that implausible responses in cognitive ToM were negatively related to poor reading performance among deaf individuals. Furthermore, reading comprehension with inferential questions was associated with cognitive ToM. Other subtests of reading, however, had no relation to mentalistic tasks. In conclusion, the capacity for understanding mental states in DA is still a challenge in adolescence and could be involved in text comprehension.

Keywords: Theory of mind, reading comprehension, deaf, cochlear implant, adolescence.

1 INTRODUCTION

Theory of Mind (ToM) is the ability to understand mental states, such as desires and intentions, and to infer others person's thoughts and behaviours [1]. There are two different cognitive processes for understanding ToM: cognitive ToM and affective ToM. On one hand, cognitive ToM requires inferences of beliefs, intentions, and desires. On another hand, affective ToM gets involved inferences of feelings and emotional states for a correct response [2]. It is known ToM development has an important impact on children's friendships and popularity, game-playing skills, strategies for persuading or arguing [3], but the discussion of the evolutionary character of ToM is booming. During adolescence, relevant changes in social, cognitive and affective nature happen and these skills could be fundamental in their everyday life. Even at these ages, the concept of social cognition turns into something totally different respect childhood and more similar respect adulthood. The social relations in childhood usually take place inside families or schools, while adolescents are more emotionally independent and their social relations swell [4]. The effect of these changes and their academic consequences in deaf adolescents (DA) is unclear, whereas some studies with typical hearing population claim that ToM advances are associated with children's learning reading and mathematics content [3].

The cochlear implant (CI) has improved educational outcomes for deaf students since some researchers have found that at least 40-47% of DA perform as well as typical hearing development (THD) [5], [6]. Nevertheless, DA have not achieved the same level of reading competence as THD [7] and there are a number of factors can influence this low text comprehension. One factor may be that they do not possess some advanced comprehension skills with which judge narrator's and story characters' intentions or other mental states. To understand a story, a reader must put comprehension strategies into practice,

that is, extract information from the text and prior knowledge to perceive the relations among characters and the reason for their actions [8], [9].

Some authors argue that there is a wide variability among readers which becomes wider in adolescence [10]. These investigators suggest that this variability for reading comprehension can be explained by their ToM level. When the reader must understand a narrative text, ToM acquires relevancy because of the necessity of interpreting the characters' thoughts and behaviors. Although ToM could also be necessary for expositive texts if in them there are references to people or living beings with feelings.

However, research about ToM has scarcely been studied in adolescence because of, among other reasons, the majority of ToM tasks are addressed to preschoolers and children. ToM emerge in THD before the first year of life when infants refer to themselves and others as intentional agents [3]. Dore et al. [10] results have revealed coincidences between ToM developing and listening and reading comprehension developing in three important stages. In this way, preschoolers begin to comprehend the character's spatial perspective during the third year of life at the same time as the progress to comprehend others' subjective visual perspectives. Thus, children could change their perspective and adopt other persons view both in a book and in a conversation. Around 4 or 5 years of age, children are able to take account of the character's mental perspective in a narrative text, their feelings, and thoughts. At that age, children develop the ability to infer what the other person beliefs, typically associated with false belief tasks. Later, children at age 7 begin to understand characters' goals in short stories considering they can perceive contradictions between what characters want and what characters do. Dore et al. [10] link this progress in narrative comprehension with an advanced ToM development such as misunderstandings.

Among deaf children, ToM has been found significantly delayed respect their hearing pairs despite early cochlear implantation could improve their ToM development [11]. The delay would not be linked to language skills due to ToM was also impaired in deaf children with good language competences Nevertheless, some researchers point that CI can benefit language abilities which enhance the access to language related with mental states [12]. Peterson et al. showed that deaf students follow the same evolutive sequence of ToM as THD, but their acquisition is slower [13]. However, previously cited findings, deaf children CI did not perform significantly better than deaf children without CI [13], [14].

Autism spectrum disorder and deafness share difficulties to understand mental states. Studies about the relationship between reading comprehension and ToM in adolescents with the autism spectrum disorder have been published [15], [16]. Regarding deaf, to the best of our knowledge, only two studies have been conducted in deaf children, one of them in a deaf and hard-of-hearing signing sample. Concretely, the study conducted by Roh and Yim [18] claimed that an intervention on ToM capacities could affect positively language and reading comprehension. On the other hand, deaf children answered better in literal questions than in inference questions, which ones are more associated with mentalistic processes [18], [19].

The contribution of mental states comprehension in reading and, by extension, in academical achievement has been poorly studied in DA. The aim of the present work is to evaluate reading comprehension and ToM performance in DA with a CI and to study the possible relationship between these cognitive abilities. Thus, the following research questions were addressed: How is DA scores in reading comprehension in comparison to THD? How is the DA performance in ToM? Is there any relation between reading comprehension and ToM both in DA and THD? Can a ToM deficit be related to a reading comprehension delay?

2 METHODOLOGY

In order to include the participation of deaf students, our research required the collaboration of the *Centre de Recursos Educatius per a Deficients Auditius* (CREDA). This institution provided the initial contact with the sample group and assisted in obtaining parental and participant informed consent. Deaf participants are enrolled into mainstream education and receive speech therapy services inside school. Speech therapy rehabilitation begin in most cases a few months after implantation and is homogenized throughout Catalonia. To participate in this study deaf participants had to be implanted before five years old and prelingually deaf as inclusion criteria. Other requisites were being fluent in oral communication and without neurological disorders. THD and DA participants were recruited from the same schools so there are reliable similarities in age, gender, and academical performance. Consent was obtained for THD and the study was approved by the UAB Ethics Committee on Animal and Human Experimentation.

Participants were 26 adolescents aged 12-14 divided into two different groups. One group was formed by 10 participants with a CI (6 males and 4 females) with a mean age of 13,1 ± 0,23. One of them had unilateral implant and hearing aid, two had bilateral implants and the other seven had unilateral implants. DA received their first CI at a mean age of 2,36 ± 0,251 and their hearing age was 10,67 ± 0,368. THD group was formed by 16 adolescents (9 males and 7 females) and their mean age was 12,63 ± 0,12.

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 one was individual with a duration of 60 minutes and participants were evaluated with the second part of PROLEC-SE-R, and ToM competence.

In relation to the materials, PROLEC-SE-R [20] was administrated to evaluate reading. This battery includes tests which assess different essential processes necessary for reading comprehension like semantic processes, syntactic processes and lexical processes. Semantic processes comprised five subtests to evaluate reading comprehension: expositive comprehension (with memory influence), narrative comprehension (with no memory influence), pure reading comprehension (an expositive text with inferential questions and no memory influence), mnemonic reading comprehension (an expositive text) and oral comprehension (an expositive text with inferential questions). Also, all these measures form a Global Index of Reading.

To assess cognitive ToM was used a false belief task from Ryskin and Brown-Schmidt [21] adapted from Birch and Bloom [22]. This task consists of two pictures and a text where participants can read the story. In the first picture appears Vicki, who is playing the violin, and four boxes. Each box has a different color: blue, purple, red, and green. The girl saves the violin in the blue box and goes out. Then her sister comes, moves the violin to the red box and rearrange the boxes in such a way that the red box is located where the blue box position was. Participants are asked about where the girl is going to search 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 were assigned to 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 task was measured with two stories from Faux Pas Recognition test [23]. It was selected a story about a misunderstanding and a control story. In the story of the misunderstandings subjects have to answer questions referring to the characters feelings, while the control questions are related to physical relationships. Each correct response in the mentalistic text was marked with one point until a maximum of 6. If the first question was answered incorrectly, the punctuation was zero and the participant could not get more points. The control story has one question valued at two points. 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 [24]. Reading and ToM data were analyzed by means of an analysis of variance (ANOVA) using hearing conditions as a between-groups factor (two levels, DA and THD). Partial eta squared (η2) has been included to provide effect size estimations. Moreover, correlation analyses between reading variables and ToM scores were performed. Significance was set at P=0.05 and data are shown as mean ± SEM.

3 RESULTS

3.1 Reading

Reading data analysis showed that DA scores are considerably affected in comparison with their classmates. The Global Index of Reading reflects this difference on reading level between groups ($F_{(1,24)}$=6,81; p=0,015; η2=0,221, see Table 1 for means). However, these differences were not generalized to other subindex: there are no statistical differences in lexical and semantic scores ($F_{(1,24)}$=2,541; p=0,124 and $F_{(1,24)}$=1,824; p=0,189, respectively; see Figure 1). On the other hand, scores on the Syntactic Index were lower in the DA compared to THD group ($F_{(1,24)}$=10,348; p=0,004; η2=0,301).

Table 1. Descriptive statistics on reading.

	DA group	THD group
Global Index of Reading	87,80 ± 5,41*	104,44 ± 3,74
Lexical Processes Index	94,30 ± 4,35	102,19 ± 2,81
Syntactic Processes Index	88,10 ± 6,45**	112,88 ± 4,56
Semantic Processes Index	91,60 ± 4,89	98,94 ± 3,02
Expositive Comprehension	5,70 ± 0,79	6,13 ± 0,48
Narrative Comprehension	4,10 ± 0,58	4,56 ± 0,36
Pure Reading Comprehension	4,40 ± 0,60**	6,31 ± 0,37
Mnemonic Reading Comprehension	5,20 ± 0,74	5,81 ± 0,48
Oral Comprehension	4,10 ± 0,90**	6,88 ± 0,37

Note. DA (Deaf adolescents) and THD (Typical Hearing Development). *: $p < 0,05$; **: $p < 0,01$

In order to study in detail the differences in reading comprehension between DA and THD, different comprehension tasks were analyzed meticulously and revealed some differences (see Figure 1). DA scores were decreased in Pure Reading Comprehension compared to THD ($F_{(1,24)}=8,205$; $p<0,01$; $\eta 2=0,255$). However, other reading comprehension tasks with memory influence such as Expositive Comprehension and Mnemonic Reading Comprehension were not statistically distinguishable from their classmates ($F_{(1,24)}=0,239$ and $F_{(1,24)}=0,523$, respectively). Narrative Comprehension scores were not different between DA and THD groups ($F_{(1,24)}=0,503$). The hearing status affects to listening comprehension when the information is received verbally ($F_{(1,24)}=10,664$; $p<0,01$; $\eta 2=0,308$).

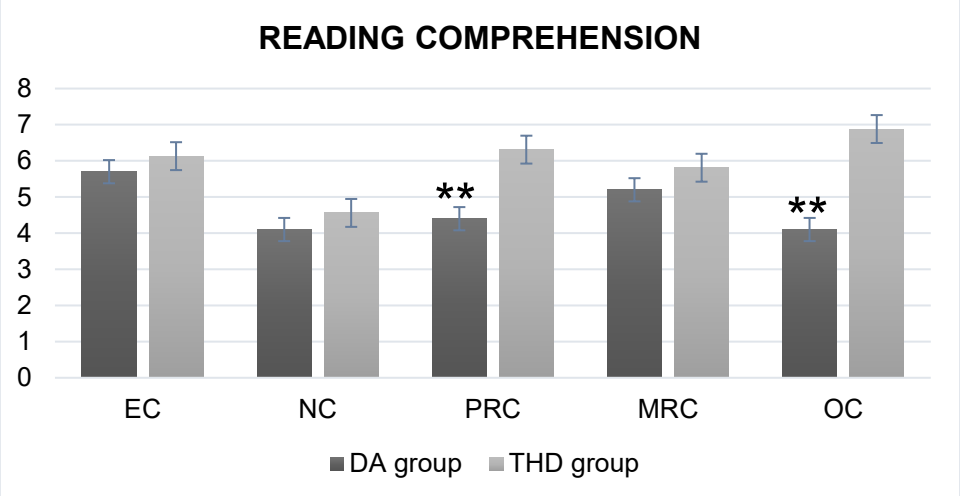

Figure 1. Means of reading comprehension.

Note. DA group (Deaf adolescents group) and THD (Typical Hearing Development group). EC (Expositive Comprehension), NC (Narrative Comprehension), PRC (Pure Reading Comprehension), MRC (Mnemonic Reading Comprehension), OC (Oral Reading Comprehension). **: $p < 0,01$

3.2 Theory of Mind

ANOVA of ToM data showed that affective aspects of ToM were affected ($F_{(1,24)}$=4,747; p=0,039; η2=0,165, see Figure 2). It is important to emphasize that both groups' scores obtained were similar in the control stories of Faux Pas test $F_{(1,24)}$=0,248).

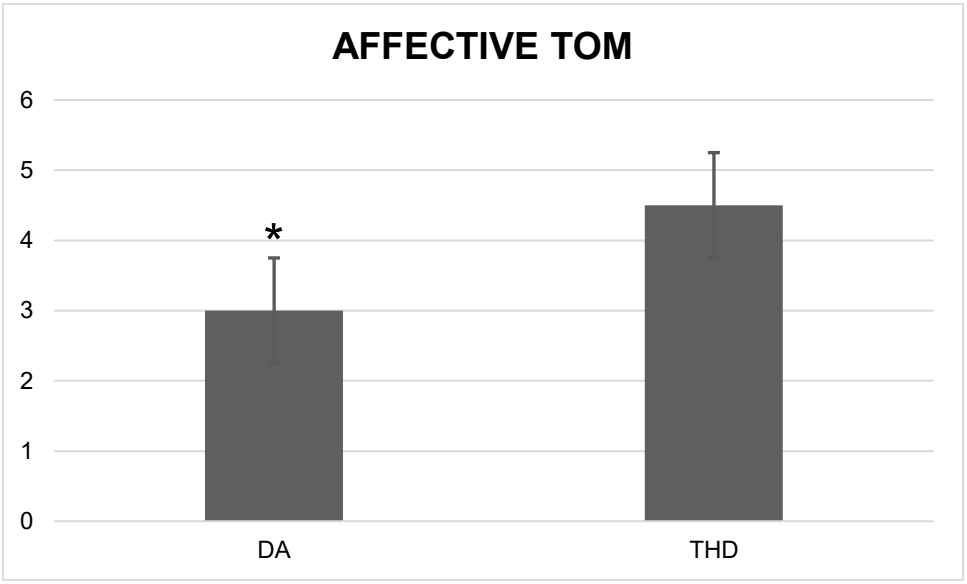

Figure 2. Means of affective ToM.

Note. DA (Deaf adolescents) and THD (Typical Hearing Development). *: p < 0,05

However, when cognitive aspects of ToM were analyzed no significant differences were observed. Judgments of the probability that Vicki would act according to a false belief were not higher in THD than in DA ($F_{(1,24)}$= 0,372, see Figure 3). In the same way, judgments about Vicki would look where she saves the violin originally were not statistically distinguishable $F_{(1,24)}$=0,035). Also, implausible options did not show significant difference (green and purple boxes; $F_{(1,24)}$=0,028 and $F_{(1,24)}$=0,197, respectively)

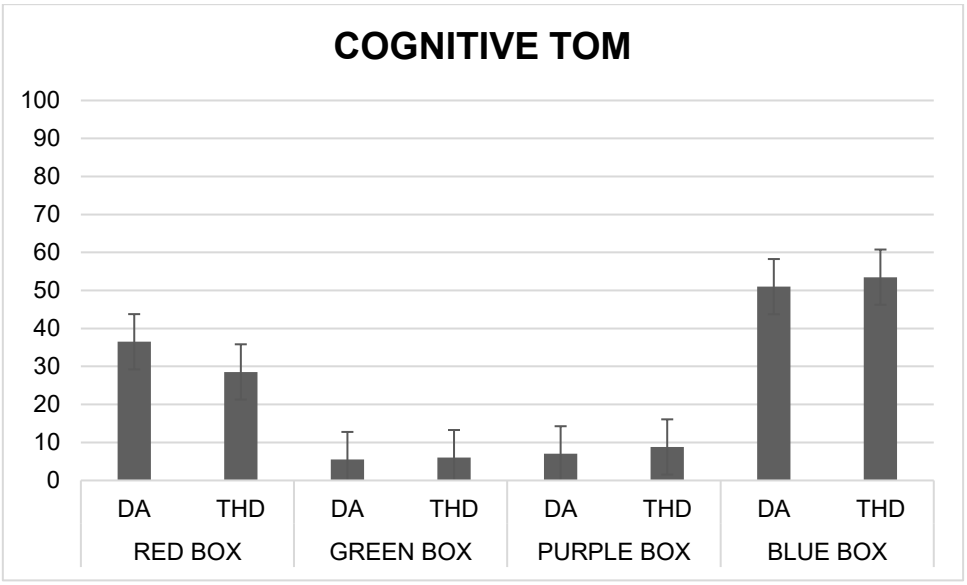

Figure 3. Mean of Probability Judgments.

Note. DA group (Deaf adolescents) and THD (Typical Hearing Development).

3.3 Relationship between Reading Comprehension and Theory of Mind

Finally, additional correlational analyses were performed separately for DA and THD. In DA findings suggested that Pure Reading comprehension is linked to the performance on blue box choice (r= 0,642; p=0,045, see Table 2). In relation to the affective ToM variables, there was no significant relation between the reading variables.

*Table 2. Pearson correlations between ToM and reading variables in DA. *: p < 0,05*

Reading variables	Cognitive ToM		Affective ToM	
	Red Box	Blue Box	Faux Pas	Faux Pas Control
Global Index	-,276	,480	,086	,044
Semantic Index	-,265	,479	-,089	-,087
Expressive comprehension	,069	,229	-,062	-,133
Narrative comprehension	-,525	,313	-,321	,133
Pure Reading comprehension	-,342	,642*	,278	-,309
Mnemonic Reading comprehension	,022	,193	-,194	0,000
Oral comprehension	-,157	,325	-,119	-,045

Regarding THD, some associations were found between reading performance and ToM: findings suggested that Expressive comprehension and Mnemonic Reading Comprehension were associated with blue box judgements in cognitive ToM (r=-0,600; p=0,014 and r=-0,596; p=0,015, respectively; see Table 3). The affective ToM variables had no significant relation with the reading variables.

*Table 3. Pearson correlations between ToM and reading variables in THD. *: p < 0,05*

Reading variables	Cognitive ToM		Affective ToM	
	Red Box	Blue Box	Faux Pas	Faux Pas Control
Global Index	,066	-,275	,128	,144
Semantic Index	,139	-,440	,292	,021
Expressive comprehension	,308	-,600*	,324	-,312
Narrative comprehension	-,360	-,002	,086	,146
Pure Reading comprehension	-,261	,131	-,090	,430
Mnemonic Reading comprehension	,397	-,596*	,467	-,295
Oral comprehension	,451	-,373	,173	-,147

4 DISCUSSION & CONCLUSIONS

The present work is focused on reading comprehension and ToM competence in DA and their classmates. Our findings suggest that in DA the delay in reading are caused by their low performance on the syntactic process which coincides with previous studies in deaf children with CI [25], [26].

To our knowledge, this is the first study about ToM in DA with a CI. Our results indicate a probable affective ToM deficit in DA compared to their classmates. These results are in accordance with previous data reported in children [11], [12], [14]. While DA seems to experience difficulties to understand correctly characters feelings, their answers in the false belief task are comparable to THD group. Cognitive ToM, thus, would be acquired before or in the onset of adolescence. This fact would be in the same line with Peterson et al. [13] who asserted that ToM is just a delay and their acquisition is slower in deaf population. If this point is confirmed, this study could have three possible implications. The first implication is that DA could finish their obligatory education with affective ToM problems with all the consequences that this entailed. The second implication suggests that there could be a different development of cognitive and affective ToM and, therefore, some participants could not reach their classmates' affective ToM. Lastly, we cannot consider ToM as an isolate construct. Factors such as executive functions are implied in ToM understanding and are related with deaf adolescents [27]. So future studies must count on with other factors that can influence the ToM and clarify the mentalistic difference between groups.

Our results, unexpectedly, showed a non-significant difference between both groups in narrative reading comprehension. It has been hypothesized that ToM could be related with comprehension of narrative texts [18], but present data do not seem to support this hypothesis. Knowledge about readers mental world and the mental world of others is required to understand, simulate, infer the emotions and select important information from this kind of texts [28]. Despite the emotional complexity of the narrative structure and the demonstrated association between narrative competence and reading in deaf children [29], in our study DA have similar scores in texts with narrative structure. In addition, the correlational analysis did not show any significative relation in narrative and ToM scores in DA.

Surely, it would be a misleading analysis paying attention to the results superficially and conclude that ToM have no relevance in DA' reading. Curiously, deaf participants obtained their worse results in Pure Reading Comprehension. Performance on this task was associated positively to cognitive ToM in students with deafness. This reading task is characterized by having inferential questions and other factors lessened. So, as in ToM, more aspects are probably playing a role during reading in DA and that factors could participate or mediate in ToM and reading relationship. In relation to the questions, previous studies have already observed comprehension problems during inferential questions among deaf children [18], [19]. Reading inferences connect text elements with important background knowledge. Weakness in the inferential domain could be provoked by the lack of prior knowledge where deaf individuals with and without CIs have problems accessing other environmental information [30], [31]. Besides general information inferences, emotional inferencing is important to understand a text, even in expositive texts with characters feelings like the present case. There is a developmental difference between children and adults in emotional inferencing [28]. Mauw et al. [28] found that adults were able to feel similar emotions as the stories characters while children were more neutral. Our results cannot conclude if DA are closer to a neutral position or a more empathic one, but they expose the possibility of including ToM assessment in reading tests and put it on the same level as lexical or syntactic competences.

In any way, our results should be interpreted with caution given the preliminary nature of our study and its limitations. One of them is the size of our sample in a deaf group. The deaf reading level is characterized to be very heterogeneous, so more investigations are needed to obtain more data. In addition, tests selected for this study have been widely used in clinical and investigation, but ToM scores and, especially affective ToM, could be affected by reading and linguistic problems.

In conclusion, our preliminary results emphasize that an affective ToM deficit remain in DA even though the cochlear implant improves their auditory input. However, it is not clear how can affect this deficit in reading and must be clarified the participation of other factors. Additionally, this study highlights the importance of emotional understanding and the need to promote them in a school or secondary education environment because emotions implications can go beyond expected limits.

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