Understanding minds: Early cochlear implantation and the development of theory of mind in children with profound hearing impairment

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ABSTRACT
Objective: The present study investigates how auditory stimulation from cochlear implants (CI) is associated with the development of Theory of Mind (ToM) in severely and profoundly hearing impaired children with hearing parents. Previous research has shown that deaf children of hearing parents have a delayed ToM development. This is, however, not always the case with deaf children of deaf parents, who presumably are immersed in a more vivid signing environment.

Methods: Sixteen children with CI (4.25 to 9.5 years of age) were tested on measures of cognitive and emotional ToM, language and cognition. Eight of the children received their first implant relatively early (before 27 months) and half of them late (after 27 months). The two groups did not differ in age, gender, language or cognition at entry of the study. ToM tests included the unexpected location task and a newly developed Swedish social–emotional ToM test. The tests aimed to test both cognitive and emotional ToM. A comparison group of typically developing hearing age matched children was also added (n = 18).

Results: Compared to the comparison group, the early CI-group did not differ in emotional ToM. The late CI-group differed significantly from the comparison group on both the cognitive and emotional ToM tests.

Conclusion: The results revealed that children with early cochlear implants solved ToM problems to a significantly higher degree than children with late implants, although the groups did not differ on language or cognitive measures at baseline. The outcome suggests that early cochlear implantation for deaf children in hearing families, in conjunction with early social and communicative stimulation in a language that is native to the parents, can provide a foundation for a more normalized ToM development.

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1. Introduction
A caregiver’s early social interaction is a powerful catalyst for the infant’s learning and development [1]. The way a caregiver talks to and interacts with an infant will have an impact on the child’s social development and learning. The ability to understand and react to thoughts, emotions and feelings in oneself and in others is often referred to as Theory of Mind (ToM) [2]. The development of ToM has been tied to how a mother uses language when interacting with her infant as early as 6 months of age [3]. Thus, a child’s experiences of social interaction together with an early exposure to language have been proposed to be important prerequisites for development of ToM during the first years of life [4–6]. This implies that infants and children not exposed to verbal language, such as children with various degrees of sensory impairment (e.g., hearing loss), may receive limited interactional experiences [7–11]. Deaf children, with hearing parents not fluent in sign language, often display a delayed development of ToM compared to typically developing hearing children. This difference is also evident when compared to deaf children with deaf parents [8]. The present study will further explore the effects of age of cochlear implantation and, specifically, how this is related to the development of cognitive and emotional aspects of ToM.

The ability to attach a subjective meaning to inner events is dependent on the child’s ability to understand that his or her own, as well as other individuals’ feelings, thoughts and actions are guided by mental operations not visible to other people [12]. Humans are not able to see what other people think or plan, but can understand that intentions as well as perspectives are different for
other people compared to what we ourselves experience. ToM research to date has mainly focused on the cognitive aspects of ToM, i.e., the understanding of desires and knowledge of others while the emotional aspect of ToM has received less focus [13]. The understanding of emotional ToM is, however, also of vital importance for the development of communication and interactional practices. In an interaction one needs not only to consider the other persons’ thoughts and desires, but also the other persons’ feelings and emotional motives [14].

The development of ToM is often described as occurring in stages [15], where early interactional abilities such as imitation and joint attention are referred to as precursors ToM abilities [16]. Wellman and Liu [15], propose that theory of mind develops in a stepwise fashion and the first step includes an understanding that different people want different things, which is understood by children around the age of three. This is followed by an understanding that different people may have different beliefs about the same thing and by an understanding that different people may have different access to knowledge to help them to understand a certain situation. By age 4 the child usually understands that people may hold false beliefs about an event or an object. This ability to understand that another person may think in perhaps a contrasting way to what the child knows is true is called first-order ToM and is an important prerequisite for efficient communication [8]. A year later, the child can correctly recognize different emotions and may understand their external cause [17], and at around 7 years of age the child understands that another person’s different beliefs and desires will evoke different emotions. Furthermore, the child now understands that these emotions might trigger different actions in that individual [16]. By the age of 7 the child is also able to understand second order ToM which means that the child can reason about what another person may think about a third person’s thoughts and feelings [18]. The child is now able to make sense of an individual’s reactions to a situation as well as of other person’s reactions to the child’s behaviour within an interaction [19]. ToM continues to develop throughout the school years but is dependent on the cultural and social stimulation that the child experiences [12]. Advanced ToM abilities that develop around 8–11 years of age are, for example, understanding of irony and understanding of faux pas (social blunders) [15,19,20].

The understanding of the mental states such as wants, beliefs, knowledge, and emotions of other people is essential for deep reciprocal interactions with others. Deaf children of deaf parents that are merged in a vibrant sign language world often display a ToM development comparable to that of typically developing hearing children whereas deaf children of hearing parents, not as proficient in sign language, often show a delay in the ToM development [21–23]. This still holds if the researchers use nonverbal or pictorial test material. It is, thus, not only a delay of language that is responsible for the theory of mind problems; it is also a deficient conceptual understanding of mental-state words [17]. Thus, early abundant exposure to spoken or signed language may promote the development of ToM [21].

The early communication and interactional patterns are equally important to the development of language and theory of mind in typically developing children [24,25]. Few studies have, however, examined ToM in deaf children who have received cochlear implant (CI), and the results from these studies are not cohesive. A CI is an implantable biomedical device providing auditory sensations to individuals with severe and profound sensorineural hearing loss [26]. A CI does not bring hearing to a normal level, but a relatively high proportion of deaf children with cochlear implants can participate and follow oral communication [27,28]. How the child’s speech production and speech perception develop are related to the child’s age of CI-implementation, where early implantation is more beneficial for development than later implantation [28–31]. Thus, the child’s age at implantation may affect the course of development of ToM skills, as the auditory stimulation provided by the CI will give an opportunity to experience important social verbal interaction during a developmental period when the central pathways in the child’s brain show maximal plasticity [32,33]. A recent study [11] examined the conversational experience in mother-infant dyads at 23 months. The interactional patterns of mothers of deaf children compared with mothers of the hearing children were different. Deaf children experience less talk about the mind and the interaction includes fewer mental-state words compared to hearing children. As numerous studies on hearing children have concluded before, the maternal use of mental-state language is a predictor of later developing ToM, the finding is of importance [3–6]. It is not caused by a lack of secure attachment [34], but seems rather to be caused by a maternal adjustment to the child’s delayed communication and language skills [11].

Peterson [35] investigated ToM performance in four groups; children with cochlear implants, children with hearing aids, children with autism, and a group of normally hearing children. The findings indicated that the only significant difference in ToM outcome was between all three groups of children with disabilities and the hearing children, who performed significantly better. The children with CI in the study ranged from 4 to 11 years of age (age at implantation ranged from 2 to 5 years), but no information about the performance of children receiving CI early compared with those receiving CI at a later age was presented. The children with deafness using cochlear implants or hearing aids and those with autism displayed a delay in ToM performance of about 3 to 5 years compared to typically developing children. Peterson [35] suggested that the child’s experience of early fluent interactions might be especially important for developing theory of mind and pointed out the importance of studying ToM development in deaf children having received their cochlear implant before two years of age. Early interactional input would promote language and theory of mind development. A similar finding was reported by Macaulay and Ford [36], who studied children implanted at about four years of age and reported a delay of approximately four years in ToM development. The children were between 4 and 11 years of age at the time of testing and they used total communication (sign and oral communication). In contrast, a study by Remmel and Peters [37] did not show any significant delay of ToM or language among 30 children with CI compared to hearing children. The children in this study were implanted at 2.9 years of age and were predominantly using speech and hearing as their main communicative mode.

The age at which a child is implanted is also important for how the auditory cortex is activated, and how it develops. In their review article, Kral and Sharma [32] pointed out the existence of a sensitive period lasting from birth up to 3:6 years, during which the brain’s plasticity is at its height. Cortical reorganizations are more likely at younger ages; thus the possibility for activation of the auditory cortex is reduced, as the child grows older. There also seems to be a sensitive period for the development of ToM that occurs in the formative early preschool years [8,38]. However, exactly at what time this critical period of ToM development occurs has not yet been determined.

Most of the children in the Macaulay and Ford [36] and Peterson [35] studies were implanted at 3:6 years or later, while most children in Remmel and Peter’s [37] study had received their CI somewhat earlier, before 3 years of age. This difference in age at cochlear implantation between the children in the studies may partly explain the different results of the studies. That is, an earlier CI would promote a faster socio-communucative development and this in turn would affect how ToM develops. A fluent language could entail more possibilities to play and interact with both peers
and family members, which may scaffold the socio-cognitive ToM development [35].

Early access to mental-state language is important for development of ToM, and we would expect that children who receive a cochlear implant for audition relatively early in life will have a higher level of performance on tests assessing ToM in comparison with children who receive implants relatively late. Our aim is to assess the cognitive theory of mind ability as well as the child’s ability to understand emotional theory of mind of others in social situations. Thus, the ToM tasks used were selected to assess both of these aspects, i.e., the cognitive as well as the emotional ToM abilities of the children. In addition, a central aim of the present study was to examine and compare the cognitive and emotional ToM ability in children, aged 4–9, who had received a CI early (at about 2 years of age or earlier) with those who had received the CI later (after 2 years of age).

2. Methods

2.1. Participants

2.1.1. Children with CI

In cooperation with the Cochlear Implant team at Sahlgrenska University Hospital, families of all the children (n = 32) who had received a uni- or bilateral cochlear implant between 2000 and 2005 and were living in western Sweden in 2010 (Regions Västra Götaland and Halland representing a total population of approximately 1.8 million) were identified for the study. Children who met the following criteria were included: no known intellectual disability, no additional disability, and proficient Swedish ability. After identification, 25 families could be invited to the study. The selection process is shown in Fig. 1.

Sixteen children were enrolled in the study after written consent by their caretaker. This final sample consisted of nine boys and seven girls (age range 4.25–9.5 years). The mean age of the group was 6.5 years (SD = 1.64). Mean age when receiving the first, or both implants simultaneously, was 29.1 months (SD = 15.2; range 13–65). The children’s median pre-implantation pure tone average was 89 dB (M = 87.6; 95% CI: 80.9–94.4). All but one of the children were diagnosed with pre-lingual severe/profound hearing impairment, one child had a peri-lingual severe/profound hearing impairment. The aetiology of the children’s hearing loss was unknown for seven of the children. For the remaining nine, several different main causes had been identified: enlarged vestibular aqueduct malformations (n = 3), Connexin 26 mutations (n = 2), Mondini malformation (n = 1), bacterial meningitis (n = 1), auditory nerve hypoplasia (n = 1), and Bartter syndrome (n = 1). At the time of the study, 14 children had bilateral cochlear implants (4 received both implants simultaneously, 10 had two separate operations performed), while two had unilateral implants.

The children had a Swedish speaking home environment. Twelve of the children attended mainstream schools in their neighbourhood, three attended classes geared towards children with hearing impairments and one child attended a state school for the deaf. Nine children received special education support (mostly by speech and language pathologists, educational audiologists or teachers of the hearing impaired) during their whole school day, two received support for 3 to 5 h a day and five received special education support for less than one hour a day.

Based on the pre-implantation clinical evaluation of the children’s cognitive and verbal abilities (as evident from the medical records), verbal and non-verbal developmental quotient (DQ) at the time when they received their first CI, could be estimated for 15 of the 16 participating children. This estimation was based on results from four standardized instruments: Griffiths and/or Bayley (n = 12), Merrill-Palmer (n = 1), Wechsler preschool and primary scale of intelligence (n = 2). Mean pre-implantation non-verbal DQ was estimated to 109 (SD = 19.7; min = 80.0, max = 143.0) and mean verbal DQ was estimated to 92 (SD = 24.12; min = 80.0, max = 146.0). The verbal DQ was assessed through speech and sign language.

A median split was performed based on the time when the children had received their first CI (Md = 27 months). This resulted in two groups, one group of children were implanted early (M = 17.6 months; SD = 5.2) and one late (M = 40.6 months; SD = 13.3). The two groups did not differ significantly in time lived with CI (p = .14). A renewed evaluation at the time of the current study found that the groups did not differ significantly (p > .05) on nonverbal mental age or receptive vocabulary. To test the nonverbal mental age the Colored Progressive Matrices was administered. This is a commonly used test of visuospatial nonverbal cognitive functions [39]. The children’s receptive vocabulary understanding was tested with the well-known Peabody Picture Vocabulary Test (PPVT-III; [40] in a commonly used Swedish translation [41]. The objective of this test is for the child to match the word spoken by the test leader to the most appropriate picture out of four. One boy could not be tested with PPVT-III due to fatigue (see Table 1).

2.1.2. Comparison group

A comparison group of age-matched hearing children was also included. This group consisted of 18 typically developing children (6 boys and 12 girls) with a chronological age of 6.6 (SD = .60, range 6.0–8.0) and a mean IQ of 96.55 (SD = 24.67, range 62–145). They were recruited from mainstream schools in a median income area in Sweden and had Swedish as their first language.

2.2. Procedure

Testing and ethical considerations were explained to the parents and consent to participate was signed by the parents. The testing was executed at the child’s school or, in rare cases, at the child’s home. The examination procedure lasted for approximately two hours and was completed in two sessions. The same certified and experienced speech and language pathologist tested all children with CI. The children in the comparison group were
tested by two testers individually at the children’s respective schools. The study was conducted in accordance with the Helsinki Declaration of the World Medical Association Assembly and approved by the Regional Ethical Review Board, Linköping University (No. 61-09).

2.3. Theory-of-mind tasks

Two tests assessing both cognitive (unexpected location task) and emotional (social–emotional ToM task) aspects of the ToM ability were administered.

The cognitive ToM measure: The Sally–Anne procedure [29,42–44] was used to assess cognitive ToM and understanding of first and second order ToM false belief. This version of the test is commonly used in Sweden [43,44]. The story play-acted by the experimenter was as follows: The dolls Anna and Pelle were playing together. They were hiding a key under an upturned box or its lid. Pelle first hid the key under the lid. When Pelle had left the room, Anna removed the key from under the lid and placed it under the upturned box. When Pelle returned, the experimenter asked the child, “Where does Pelle think the key is?” (First order false belief question). To ensure that the child remembered and understood the story, a reality question (“Where is the key?”) and a remember question (“Where was the key?”) were asked. The second-order false-belief task was a modification of the previous task. This story was play-acted by the experimenter as follows. Instead of not being able to see Anna moving the key, Pelle looked through the keyhole and saw her move the key. The child was then asked two questions pertaining ToM, “Where does Anna think that Pelle will look for the key?” (Second order false belief) and “Where will Pelle look for the key?” (First order false belief) as well as the reality and remember questions above [19,44].

Emotional ToM measure: The social–emotional ToM test (SET) consisted of a test-battery composed of six stories portraying ordinary situations that might occur in a child’s life [44]. This test focuses on the child’s ability to impute emotions and feelings to individuals in a story in questions pertaining to both first and second order theory of mind. The stories were inspired by research of the development of ToM [15,19,45,46] but adapted to Swedish. All the stories were composed in a similar way. They consisted of a short story with simple linguistic structure. The stories were read out loud to the child by the tester and illustrated with a picture. This was followed by one literal and one inferential comprehension question about the story, and questions pertaining to first and second order ToM. The first order ToM question focuses on correctly recognizing different emotions of an individual and understanding the external cause. The second order ToM question focuses on the understanding that another person’s beliefs and desires will evoke different emotions in a third person. Two stories additionally targeted irony understanding, and two stories added a faux pas aspect. Posing faux pas and irony questions is one way of testing ToM that is more complex than understanding the emotions of the individuals in the story [19,47]. The same procedure to gather stories as that used by Baron-Cohen et al. was implemented [19]. Authentic stories of childhood social faux pas were collected from adults via a mailing group on the Internet. Two stories were included in the test. Two other stories targeting understanding of irony were developed accordingly. Irony has in several different studies shown to be successful in assessing an advanced ToM [19,46,48]. The child had the possibility when asked questions concerning feelings to indicate the right answer by pointing to one of seven emotions symbolizing the mental states of happiness (e.g., ☻), a neutral expression, anger, sadness, fright, embarrassment, and irony. The meaning of each emotion had been explained and checked before the test commenced.

Example story

Steve is at the mall. He sees his friend from school. His friend looks happy and says “Hi”. Steve says “Hi” as well. Where is Steve? (Literal aspect)
Does his friend see him? (Inferential aspect)
How does Steve feel? (First order ToM aspect)
Does Steve believe that the boy is happy to see him? (Second order ToM aspect)
Steve then realizes that his friend didn’t say hi to him. He was talking to someone behind Steve.
How does Steve feel? (Social blunder)
Did he know that the friend didn’t say “hi” to him? (Rational)

Scoring of the theory of mind tasks: The unexpected location task consists of three questions regarding ToM each yielding one point (max 3) if the control questions were answered correctly as well. Each correct answer in the SET task yielded one point (Literal 12 p, Inferential 12 p, ToM 1 and 2 16 p, Irony 2 p, Faux Pas 2 p) with a maximum of 44 points. The internal consistency of the test is good. Cronbach alpha for the whole test is .81, and for the subscales (first order ToM and second order ToM) the Cronbach alpha is .71 and .70.

2.4. Statistical analysis

Parametric and non-parametric analyses of group differences yielded identical results; thus only results based on one-way ANOVAs are presented. Pearson product-moment correlation was used to estimate correlations for subgroups of children with CI. Effect size was estimated with partial eta square.

3. Results

First, the results are presented for all children with CI compared with the group of typically developing hearing children. Thereafter,
results are presented as a consequence of the median-split by age of first cochlear implantation, creating one group of children implanted before 27 months of age and one group implanted at a later age. These two groups’ results are also compared with the group of normally hearing children.

3.1. Theory of mind performance for the CI-group and the comparison group

*Cognitive ToM measure*: The mean result on the unexpected location task of the children in the CI-group was 45.85% (SD 40.15) correct responses and for the comparison group 96.29% (SD 10.77) correct responses. The comparison between the typically developing group and the CI-group yielded a statistically significant difference with respect to the cognitive ToM measure \( F(1,32) = 26.36, p < .01, \) partial \( \eta^2 = .45 \). When compared to age-appropriate responses where first order ToM is claimed to be solved at 4 years of age and second order ToM at 7 years of age \( [41] \) approximately 40% of the children in the CI-group performed up to par on this. About 50% of the children in the CI-group were able to solve some aspects of the theory of mind questions in the cognitive ToM task.

*Emotional ToM measure*: On the social–emotional ToM test, the children achieved on average 41.61% (SD 29.32) correct responses. In the comparison group the average result was 62.33% (SD 8.63) correct responses. The comparison between the typically developing group and the CI-group yielded a statistically significant difference with respect to the emotional ToM measure \( F(1,31) = 33.69, p < .01, \) partial \( \eta^2 = .52 \).

*Correlations in the CI-group*: A strong positive correlation was observed between the two ToM tests (i.e., unexpected location and SET; \( r_{15} = .65, p < .01 \)). The correlation analysis (Table 2) for the separate tests revealed a positive correlation between the children’s vocabulary performance and the SET-test \( (r_{15} = .66, p < .01) \) and a positive correlation between the nonverbal intelligence measure and the unexpected location task \( (r_{16} = .55, p < .05) \).

3.2. Early versus late cochlear implantation

The early CI-group was implanted at 17.6 months (SD = 5.2) while the late group received the implanted on average at 40.6 months (SD = 13.3). There was no statistically significant difference between the early and late CI-group with regards to time since CI implantation \( (p = .14) \). The children in the early CI-group had, however, used their implant on average five years compared with a little more than three and a half years for the children in the late CI-group. The two groups did not differ on measures of chronological age, vocabulary or nonverbal intelligence (see Table 1, \( p > .05 \) for all comparisons).

A visual inspection of the cognitive ToM task and the emotional ToM task revealed that the early CI-group produced a higher proportion of correct responses when compared with the late CI-group (see Fig. 2). The variability within both groups as expressed through the error bars should however also be noted. None the less, the comparison group produced the highest proportion of correct responses (see Table 3). This result was also evident in the mean values of the different tasks comprising the SET-test, with the exception of irony and faux pas questions that proved to be difficult for all children.

A one-way between groups ANOVA was conducted to compare the results of the ToM tasks between the early CI-group, late CI-group and the comparison group. There was a significant main effect of the cognitive ToM task \( (F_{(2,31)} = 12.77, p = .000, \) partial \( \eta^2 = .46 \) and of the emotional ToM task \( (F_{(2,30)} = 9.84, p = .001, \)

### Table 2

<table>
<thead>
<tr>
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<th>1 (Early)</th>
<th>2 (Late)</th>
<th>3 (CI)</th>
<th>4 (Comparison)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson correlation</td>
<td>( r = .02 )</td>
<td>( r = .19 )</td>
<td>( r = .38 )</td>
<td>( r = .55 )</td>
</tr>
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*Note:* \( p < .05 \).

### Table 3

<table>
<thead>
<tr>
<th></th>
<th>Early CI n = 8</th>
<th>Late CI n = 8</th>
<th>Comparison n = 18</th>
<th>( p = .a )</th>
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<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
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<td>1. Cognitive ToM task</td>
<td>41.63</td>
<td>42.77</td>
<td>20.88</td>
<td>39.65</td>
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<td>2. Emotional ToM task</td>
<td>53.69</td>
<td>24.38</td>
<td>25.65</td>
<td>28.68</td>
</tr>
<tr>
<td>Literal</td>
<td>25.02</td>
<td>28.08</td>
<td>21.43</td>
<td>28.81</td>
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<tr>
<td>Inferential</td>
<td>58.33</td>
<td>55.29</td>
<td>28.57</td>
<td>36.60</td>
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<tr>
<td>1st ToM</td>
<td>57.81</td>
<td>26.67</td>
<td>30.36</td>
<td>31.33</td>
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<tr>
<td>2nd ToM</td>
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<td>26.51</td>
<td>33.93</td>
<td>30.37</td>
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<tr>
<td>Irony</td>
<td>12.50</td>
<td>23.15</td>
<td>7.14</td>
<td>18.90</td>
</tr>
<tr>
<td>Faux Pas</td>
<td>12.50</td>
<td>23.15</td>
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<td>0</td>
</tr>
</tbody>
</table>

*Note:* \( a \) One-way ANOVA.
partial $\eta^2 = .63$) and of all the sub-tasks comprising emotional ToM task (SET), with the exception of irony and faux pas.

Post hoc comparisons (Bonferroni) with regard to the emotional ToM task indicated that the early CI-group did not differ from the comparison group ($M = 53.69$; $SD = 24.38$ vs. $M = 65.33$; $SD = 8.63$). The late CI-group differed from both the early CI-group and the comparison group ($M = 25.65$, $SD = 28.68$). The cognitive ToM task reveals a significant difference between the two CI-groups and the comparison group ($M = 41.63$, $SD = 42.77$ and $M = 20.88$, $SD = 39.65$ vs. $M = 96.29$, $SD = 10.77$). There was no significant difference between the late and the early CI-group on the cognitive ToM measure.

4. Discussion

The results of the present study support our main hypothesis that age at which deaf children receive their first cochlear implant is associated with the development of their theory of mind. In our study, children with early implantation, and thus early audition, solved ToM problems to a significantly higher degree than children who were later implanted, although the groups did not differ on measures of language or nonverbal intelligence.

4.1. Theory of mind performance for the whole CI-group

The ToM tests proved to be difficult for the CI-group, as a whole, and the average per cent correct responses did not exceed 50%. The skills and abilities needed to be able to perform these ToM tasks were delayed. It may to some extent be due to less developed codeopted systems, such as cognitive and language ability, needed to solve these ToM tasks [49]. To be able to understand the questions and reasoning behind the ToM tasks a certain degree of vocabulary understanding, as well as cognitive reasoning is necessary. The significant correlation between vocabulary and the emotional ToM and the correlation between nonverbal intelligence and the cognitive ToM are two indications of this.

Another explanation might be that the caregiver (not fluent in sign-language) limited the child’s early learning by using few or no mental-state words when interacting with the child at an early age, which might have had a negative effect on the development of ToM [3,11]. The development of ToM may be triggered by the social interaction the child experiences [49].

In the present study, there was a negative correlation between the age when the child received CI and the two ToM tasks, it was however not statistically significant in this sample. Comparing the children who received a relatively early auditory and verbal interactional input (i.e., the early CI-group) with the group who had a longer delay in experiencing auditory and verbal interactional input (i.e., the late CI-group) did reveal differences between the groups with regard to their ToM abilities.

4.2. Early vs. late CI: Comparing theory of mind performance

The main aim of this study was to investigate if an early or a late intervention with a CI is associated with the development of ToM. Our results point to a clear difference in how the deaf children with CI solve various ToM tasks. Although the early and late CI-group did not differ on age at testing, nor on language or nonverbal intelligence, a significant difference in the ability to understand the emotional aspect of ToM was observed. In addition, no gender differences were observed between the two groups constructed.

Since age, language and nonverbal intelligence did not vary between the two groups, the concurrent function of the co-opting systems does not seem to influence the ToM performance. As a whole, the early CI-group performed on a similar level as the typically developing normally hearing group, while the late CI-group performed at a lower level than both the comparison group and the early CI-group. It should be noted that the ToM abilities tested are under development during these ages, for the typically developing group as well. The emotional ToM test did not present any ceiling effects for any group. A possible explanation to the result of the early CI-group might be vested in the early exposure to a fluent spoken language and interactional patterns well-known to the caregiver, as the caregiver is able to talk to the child in his or her mother tongue.

Our results point to the possibility of an early developmental window comprising the first two years of life at which ToM in a wider sense is easier attained [22]. Although there was a difference in the length of time the children had lived with a CI at the time of the study, the early CI-group had used a CI on average 5:1 years and the late CI-group 3:8 years; this difference did not prove to be statistically significant. A larger sample would increase the statistical power, and the time lived with CI may be one of the factors related to ToM development. The length of time living with a CI might, thus, be of importance for developing ToM skills, but it is probable that an early implantation also is of importance. The early exposure to vivid and fluent communication with the caregiver’s mother tongue, made possible by auditory stimulation after cochlear implantation, is proposed to enhance and trigger the development of ToM [11,49]. The children’s ability to hear their caregivers communicate about emotions from infancy is likely to trigger the timely development of ToM [3,11]. This is, however, also a dynamic relationship, and as the child becomes able to respond in a multifaceted way to the caregiver’s talk the interaction is developed and broadened. The CI intervention will change the interaction and interactional patterns that are possible between the caregiver and the child [50]. The results of the CI intervention may also broaden the child’s social network to include other adults and other children; which has also been shown to impact the development of ToM [51].

Examining the individual results on the ToM tests in the children with CI indicated that difficulty with ToM is still present within this group of children as a whole. About 60% of the children with CI displayed a delayed development of the cognitive ToM, measured with false belief tasks, compared to what is expected at their age. But, it is important to consider that 40% of the children, consequently, did present age-appropriate false belief skills. It was not solely children from the early CI-group that passed the false belief tests at the expected age, although it was more common in this group. There is, thus, more to the development of ToM than just being able to perceive the caregiver’s talk at an early age. One important contributing factor might be the configuration of the caregiver’s early interaction, which may serve as an important trigger for the development of ToM. We need to further explore what constitutes the early interaction experience of children born with severe and profound deafness in hearing families; this is an important pathway for further studies.

It is also important to consider that children with CI are a heterogeneous group, with different causes of hearing loss, with varying impact of the hearing impairment, and with several other factors influencing the child’s ability to partake in interaction and communication, that are expected to influence the data presented here. The present results may be representative for young cochlear implant recipients with a normal cognitive developmental pattern, using predominantly bilateral CIs and having special education support in mainstream units or special hearing units. There is a need to further examine the impact of the age at cochlear implantation on the cognitive and emotional factors of ToM, as well as the impact on ToM on other psychological and developmental factors.

4.3. Conclusion

The age at which children with severe and profound pre-lingual hearing loss receive their first cochlear implant seems to be...
associated with the development of ToM. An implantation before the age of two years seems to provide a better start for the child’s development of ToM. At the age of testing, ToM skills were more developed in the early CI-group in comparison with the late CI-group, although language and nonverbal skills did not differ between them. Thus, as suggested by Paterson [35], a fluent and uninterrupted early verbal interaction between the mother and her child with hearing impairment might set the framework for the early social cognitive development and, thus, the ToM skills observed later in the preschool years.

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