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Theory-of-mind development in oral deaf children with cochlear implants or conventional hearing aids

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Background: In the context of the established finding that theory-of-mind (ToM) growth is seriously delayed in late-signing deaf children, and some evidence of equivalent delays in those learning speech with conventional hearing aids, this study's novel contribution was to explore ToM development in deaf children with cochlear implants. Implants can substantially boost auditory acuity and rates of language growth. Despite the implant, there are often problems socialising with hearing peers and some language difficulties, lending special theoretical interest to the present comparative design. **Methods:** A total of 52 children aged 4 to 12 years took a battery of false belief tests of ToM. There were 26 oral deaf children, half with implants and half with hearing aids, evenly divided between oral-only versus sign-plus-oral schools. Comparison groups of age-matched high-functioning children with autism and younger hearing children were also included. **Results:** No significant ToM differences emerged between deaf children with implants and those with hearing aids, nor between those in oral-only versus sign-plus-oral schools. Nor did the deaf children perform any better on the ToM tasks than their age peers with autism. Hearing preschoolers scored significantly higher than all other groups. For the deaf and the autistic children, as well as the preschoolers, rate of language development and verbal maturity significantly predicted variability in ToM, over and above chronological age. **Conclusions:** The finding that deaf children with cochlear implants are as delayed in ToM development as children with autism and their deaf peers with hearing aids or late sign language highlights the likely significance of peer interaction and early fluent communication with peers and family, whether in sign or in speech, in order to optimally facilitate the growth of social cognition and language. **Keywords:** Deafness, children, social cognition, theory-of-mind, cochlear implant. **Abbreviations:** DSM-IV: *Diagnostic and Statistical Manual of Mental Disorders* – IVth revision; PPVT: Peabody Picture Vocabulary Test; ToM: theory of mind; VMA: verbal mental age.

The ability to recognise people's inner mental states of mistaken memory, foiled intention, fantasy, or false belief, while using these inferred psychological attributes to understand and predict behaviour, is 'one of the quintessential abilities that makes us human' (Baron-Cohen, Tager-Flusberg, & Cohen, 2000, p. 3). Known as a 'theory of mind' (ToM), this capacity is typically assessed by means of standard false belief tests requiring children to predict what a protagonist will do, say, or think when in the grips of a mistaken belief (Astington, 2001; Wellman, 1993). A large body of research over the past two decades shows that most normally developing 3-year-olds fail these tests, whereas by age 5, they mostly pass them. Indeed, Wellman, Cross, and Watson's (2001) meta-analysis of 178 separate false belief studies of preschoolers from many different countries indicated such a consistent pattern of developmental gains across varied tasks and sample populations as to prompt the conclusion that, in normal developers: 'The understanding of belief, and, relatedly, understanding of mind, exhibit genuine conceptual change in the preschool years' (p. 655).

However, important deviations from this predictable developmental pattern have been observed with almost equal consistency when researchers have administered standard false belief tests to children from certain special populations. For example, Baron-Cohen, Leslie, and Frith's (1985) seminal finding of seriously impaired ToM performance in high-functioning children with autism has been consistently replicated. Thus from a review of 28 separate studies of false belief performance by older children and adolescents with autism in several different countries, Happé (1995) obtained strong evidence of a severe ToM deficit. Collectively sampling more than 300 autistic participants (all with mean verbal mental ages of 5 years and over), these studies consistently revealed high failure rates (e.g., an average pass rate of 33% by participants in their early teens). Yirmiya, Erel, Shaked, and Solomonica-Levi (1998) conducted a meta-analysis confirming that individuals with autism were outperformed by chronological and verbal-age-matched individuals with normal development on a broad range of ToM tests. Significant deficits were also found in individuals with mental retardation, relative to normal controls, albeit of a less severe nature than those linked with autism, prompting the conclusion that: 'ToM deficits can no longer be conceptualised as a core deficit that is unique to autism' (Yirmiya et al., p. 302). Blind children's performance on false belief tests has been compared with that of sighted children in at least three separate studies. Results all indicate that children with severe visual impairment, or total blindness, generally do not achieve the mastery of false belief that most sighted children display at age 4 until age 8 or 9, or even later (McAlpine & Moore, 1995; Minter, Hobson, & Bishop, 1998; Peterson, Peterson, & Webb, 2000).

Peterson and Siegal (2000) reviewed the results of 11 separate investigations, published between 1995 and 1999, of false belief performance by late-signing deaf children. As the offspring of hearing parents, most of these children, who presently signed fluently, had acquired sign language belatedly after entering school (Power & Carty, 1990) and had spent their preschool years in a conversationally restricted family environment where, according to Vaccari and Marschark (1997), 'most hearing parents lack sufficient sign language skill to be able to optimise social interactions with their deaf children' (p. 799). Results of these studies revealed delays in late-signing deaf children's ToM development that, despite normal intelligence and freedom from the clinical impairments associated with autism, were on a par with those observed among high-functioning autistic children. Agreement among the 11 studies was also striking, given their representation of deaf children from different countries who were being exposed to varied sign languages and philosophies of deaf education. However, there was also agreement among the studies that it was not deafness *per se*, but rather deafness arising in a family devoid of fluent signers, that predicted delayed false belief understanding. Profoundly deaf offspring of signing deaf parents (second generation deaf signers), along with those who have another native speaker of sign language in their immediate household (e.g., a signing deaf grandparent or an older deaf sibling who has become a fluent signer at school), can be dubbed *native signers* owing to their access, throughout their growing up, to a fluently signing conversational partner. Native signers are consistently found to score higher on theory of mind tasks than late-signing deaf children from hearing families (Peterson & Siegal, 1999, 2000; Remmel, Bettger, & Weinberg, 1998) and, indeed, may even acquire an understanding of false belief at a slightly earlier age than preschoolers of normal hearing from hearing families (Courtin & Melot, 1998).

Native signers are nevertheless rare among deaf children. Some 90% of severely and profoundly deaf children are born to hearing parents (Marschark, 1993). Not all of these children end up using sign language. Some hearing parents of deaf children opt for a purely oral approach to family communication and for mainstream oral-only schooling. Language development is generally delayed in orally educated profoundly deaf children who use conventional hearing aids (Svirsky, Robbins, Iler-Kirk, Pisoni, & Miyamoto, 2000), and restrictions upon the flow of family conversation patterns are apt to be as severe, if not more so, as in hearing families attempting to sign with imperfect proficiency (Greenberg, 1984). Thus when Meadow, Greenberg, Erting, and Carmichael (1981) compared hearing mothers of deaf preschoolers with deaf natively signing dyads, they found that deaf mother–deaf child and hearing–hearing dyads achieved conversational versatility, mutual understanding and spontaneity of reference. But dyads with a hearing mother and a deaf child had problems communicating, regardless of whether the child was being taught to communicate orally or in sign. Indeed, discourse about absent people or objects was almost never observed in either of these latter dyads. Along with delayed language, restrictions upon the oral deaf child's opportunities to exchange information about thoughts, feelings, or intentions with hearing parents, peers and siblings may curtail ToM development. As de Villiers and de Villiers (1999) explained: 'With an orally-taught deaf child not exposed to Sign, the limited speech, vocabulary and syntax typically present at age 4 years is insufficient to support elaborate mind-talk, especially reference to others' beliefs' (p. 206).

Consequently, if language and early family conversation are critical factors for ToM development, orally educated deaf children with hearing aids should be delayed in mastering concepts of false belief. To date, seven known published studies have tested this prediction. Their results are summarised in Table 1. A majority of these studies discovered delays among oral deaf children of a similar magnitude to those reported among late signers in other research (see Peterson & Siegal, 2000, Table 1 for a comparable summary). Few of the oral deaf children of hearing parents under age 7 in Table 1 performed as well as hearing 4-year-olds on either verbal or nonverbal false belief tests. There was one exception. Peterson and Siegal (1999) observed high levels of false belief success in oral deaf children with a mean age of 9 years. These children scored as high as same-age native signers and hearing 4-year-olds. However, this particular oral group had better hearing than others in Table 1. (Their losses were only moderate to severe rather than profound.) Milder hearing impairments may have enabled more access to spoken family conversation (Greenberg, 1984; Marschark, 1993; Vaccari & Marschark, 1997). Alternatively, these children may previously have experienced ToM delays that had been overcome by the time of being tested, which was at a somewhat older age than most of the others in Table 1. Nevertheless, such a discrepancy warrants empirical clarification. One aim of the present study is therefore to gather further evidence on how oral deaf children who use conventional, amplifying hearing aids acquire a ToM.

Virtually all of the oral deaf participants in the studies in Table 1 used amplifying hearing aids worn behind the ear. However, recent medical technology

Table 1 Summary of previous studies of ToM performance by oral deaf children with conventional hearing aids

Author(s) (date)	Oral deaf sample	Control group	False belief tests	Control questions	Results
Courtin (2000)	$N = 45$ oral profoundly deaf children, age 5 to 8 yrs ($M = 6–11$)	Hearing 5-year-olds and deaf native signers age 5 to 8 years	Standard misleading container and changed location	Yes: failers excluded	27% of oral deaf, 40% of hearing, 90% of native signers pass 2 of 3 trials
Courtin & Melot (1998)	$N = 44$ oral profoundly deaf children, age 6 to 10 years	$N = 9$ hearing preschoolers and $N = 13$ deaf native signers (5 to 6 yrs)	3 unspecified first-order tasks	Unknown	23% of oral deaf, 76% of hearing, 100% of native signers, pass 2 of 3 trials
De Villiers & de Villiers (1999)	*Experiment 1:* $N = 23$ oral moderately to profoundly deaf children, age 4 to 9 yrs *Experiment 2:* $N = 27$ oral moderately to profoundly deaf children, age 5–2 to 10–1 yrs	Hearing preschoolers, 3 to 5 yrs	Standard misleading container and changed location, nonverbal sticker hunt and nonverbal surprise face	Yes: failers excluded	Hearing outperform deaf; 55–58% of deaf pass changed location; 38% of deaf pass container; 48% of deaf pass stickers at mean age = 7.31 yrs (cf 4–4 for hearing); 32% of deaf pass faces at mean age = 7.31 yrs (cf 4–6 for hearing)
Figueras-Costa & Harris (2001)	$N = 21$ oral severely and profoundly deaf children aged 5 years (Group 1) and 9 years (Group 2)	None	Standard verbal changed location task plus 7 nonverbal changed location trials (NVCL)	Yes: failers excluded	9% pass at age 5 & 50% pass at age 9 on standard task; on nonverbal: mean = 3.7/7 correct at age 5; mean = 6/7 correct at age 9
Jackson (2001)	$N = 14$ oral severely to profoundly deaf children, 5 to 12 yrs. (mean = 9–2), 21% with cochlear implants	$N = 24$ hearing age matched primary schoolers (mean age = 7 yrs)	Standard misleading container and changed location first-order tasks and ice-cream van second-order task	Yes: failers scored as failing ToM	50% deaf pass container (cf. 100% hearing) 21% deaf pass changed location (cf. 83% hearing) and 25% deaf pass second order
Lundy (2002)	$N = 9$ oral deaf children aged 5 to 10 years (mean = 7–10) all with losses over 65dB; 33% with cochlear implants	None	3 standard misleading stimulus tests and 1 video changed location test (9 trials in total).	Yes: failers excluded	Zero deaf (0%) pass 5 of 9 trials at age 5 to 7; 100% do so at age 8 to 10
Peterson & Siegal (1999)	$N = 14$ oral moderately to severely deaf TC pupils, age 6 to 13 years (mean = 9–2)	4-yr-old hearing preschoolers & age-matched deaf native signers	Standard misleading container and changed location tasks plus a changed appearance task	Yes: failers excluded	86% of oral deaf, 76% of hearing & 91% native signers pass container; 64% of oral deaf, 86% of hearing & 82% native signers pass location; 71% of oral deaf, 90% of hearing & 100% native signers pass appearance

has made available a new kind of auditory prosthesis for deafness. The cochlear implant bypasses the external ear and works on the principle of direct neural stimulation. An electronic device, programmed to decode signals from an external transmitter, is surgically implanted into the cochlea. By sending messages along the auditory nerve, hearing percepts are produced (Svirsky et al., 2000). When optimally successful, cochlear implants enable large gains in pure auditory perception, and can facilitate speech recognition, boosting acuities to levels rarely reached with external amplification (Niparko, 2000). With the aid of speech training, a deaf child's rate of language development can also be expected to progress more quickly than before implantation (Svirsky et al., 2000), and oral deaf children with implants have been found to achieve a higher level of spoken language skill than their peers with conventional hearing aids (Archbold et al., 2000). However, the pragmatic and social communication skills of a child with a cochlear implant may still not rise to the same level as those of a hearing child, especially during preschool and the early years of primary school while speech perception and language are still developing (Archbold et al., 2000). In addition to language problems, deaf children may miss out on peer socialisation experiences through being withdrawn from the classroom frequently for speech therapy sessions. Thus oral deaf children with cochlear implants who are mainstreamed into hearing classrooms may have difficulties engaging in spontaneous peer interaction and conversation, which could potentially interfere with the growth of social cognitive abilities, including ToM.

There has been little published research on the social cognitive development of children with cochlear implants. One study (Archbold et al., 2000) comparing language levels of implanted children who were being taught in oral-only versus signing classrooms did reveal better language development in the former group, but no measures of the social use of language for peer communication were included, and there was no hearing comparison group. Anecdotal reports from parents have suggested that, despite some improvement in social relationships with peers as compared to pre-implantation levels, primary school pupils with cochlear implants in mainstream hearing classrooms often continue to have social difficulties that may include lack of peer acceptance, loneliness, lack of friends, deficient skills for initiating peer contact, aloofness, and problems communicating with peers or sustaining conversations (Bat-Chava & Deignan, 2001).

Thus in order to better understand the roles of language development, communication modality and peer relations in the growth of social cognition, it is important to investigate the ToM performance of oral deaf children with cochlear implants, in order to discover whether these children, like native signers, may escape the ToM problems that are well documented among late-signers and oral deaf children with hearing aids. This was one of the novel aims of the present study. Additional, theoretically driven goals included systematic comparisons between: (a) children with cochlear implants in mainstream oral versus signing TC schools, (b) oral deaf children with implants and those with conventional hearing aids, (c) both of these groups of deaf children and control groups with autism or typical development. Hearing preschoolers were chosen for one control group to mark the normal age of acquisition of ToM, and high-functioning autistic children, matched to the deaf groups by chronological and nonverbal mental age, were chosen for the other as the anchor point for known ToM delays.

Method

Participants

After the exclusion of three children who failed control questions on the false belief tasks, the sample consisted of 52 Australian children aged 4 to 12 years. They were divided into four groups. Group 1 consisted of 13 children (6 boys and 7 girls) who had cochlear implants. They ranged in age from 4 years 2 months to 11 years 2 months, with a mean age of 8 years 0 months. Prior to implantation, they had all been classified as profoundly deaf (losses in excess of 91 dB in the better ear). Their ages at cochlear implantation ranged from 2 years to 5 years. Six of them (46%) were attending mainstream (oral-only) schools and had never been instructed in sign language. They received individual speech training sessions with a qualified speech pathologist averaging once per week. The remaining seven children in Group 1 (54%) were pupils in Total Communication (TC) special classrooms where the medium of instruction was a simultaneous combination of spoken and signed English. None of these children had older signing deaf family members. One had a younger sister who was profoundly deaf. Group 1's mean verbal mental age (VMA) was 5 years 11 months.

Group 2 consisted of 13 severely to profoundly deaf children without cochlear implants. All these children had conventional amplifying hearing aids which they used in class and on the playground. Nine of them were boys. The mean age for Group 2 was 7 years 6 (range: 5–0 to 12–1). Eight children (62%) were attending mainstream (oral-only) schools and had never been instructed in sign language. The remaining five (38%) were pupils in the same Total Communication (TC) special classroom as the TC subgroup of Group 1. None of the children in Group 2 had any deaf relatives, or native signers, in their immediate family. Group 2's mean VMA was 6 years 10 months.

In the classroom and with signing deaf playmates, children in both TC subgroups used some sign as well as speech. Their teachers rated each of these children as at least 'fluent enough in signed English to communicate basic ideas' and as predominantly 'oral' rather than as 'signing'. However, these children were all capable of some vocal speech which they used in school, at home, and on the playground shared with an adjacent mainstream primary school.

Group 3 consisted of 9 children with autism who had been diagnosed according to DSM-IV criteria and were attending a special school for autism. Seven of them (78%) were boys. They had a mean chronological age of 8 years 6 months (range: 5–3 to 12–6) and a mean VMA of 7 years 3 months. Group 4 consisted of 17 normally developing preschoolers who had English as their first language, and no significant developmental disabilities, according to teachers' reports. They were attending preschools in predominantly middle-class neighbourhoods and seven of them (41%) were boys. Their mean age was 4 years 10 months (range: 4–1 to 5–8) and their mean VMA, after selecting from a larger group tested to match that of the other diagnostic groups, was 5 years 11 months.

Tasks and scoring

Each child completed a battery of three standard 2-trial false belief tests, along with standard measures of verbal and nonverbal ability, generally in 2 sessions. Orders of task presentation were varied within each group. The tasks were as follows.

Changed Location False Belief. This 2-trial changed-location test was modelled on Baron-Cohen et al.'s (1985) 'Sally-Ann' procedure. The first trial involved a boy doll, a girl doll, a ball, a covered basket and a covered box. One character (boy or girl, counterbalanced) put the ball in the basket, closed the lid, and left the scene. The other character shifted the ball to the covered box. The first character returned, and the child was asked the test question, followed by two control questions ('Where is the ball now?' 'Where did [the girl] put the ball in the beginning?').

For all the children apart from a subgroup of 12 of those with deafness, the test question was: 'Where will the girl look for her marble?' and the second trial was identical to the first except that the boy hid the marble in the experimenter's pocket. However, in order to examine the possibility of benefits for deaf children of stimulus novelty and of the temporal marking of test questions (Siegal & Beattie, 1991), a subgroup of 12 deaf children was exposed to a slightly modified procedure. For these children, the second trial involved new dolls and props (girl and mother dolls, a toy apple and a toy fridge) but the same procedure. In addition, in counterbalanced order, either the first or the second test question was temporally marked with the adverb 'first' ('Where will the girl look *first* for her apple/marble?').

Preliminary comparisons by *t*-test were conducted of the effects of these procedural variations. As none made any difference, the data were collapsed together for all of the main analyses. (In fact, 2 of the 12 deaf children who were exposed to the temporally modified wording failed the test question on both trials and 9 passed on both, leaving only 3 who performed differentially. Of these, 2 passed with 'look for' wording, and 1 with 'look first'.) Similarly, the mean false belief scores of the 12 deaf children who had received varied stimulus materials did not differ from those of the 14 who had the standard task, $t < 1$). Children who passed control questions could earn a score of 1 for each test question to which they replied with the object's original location. Otherwise they scored zero. Scores were summed over trials to produce a changed location total false belief (TFB) score of 0 to 2. A pass on the task as a whole required success on both test questions, so that the odds of passing by chance were only 25%.

Misleading Container False Belief. The first trial of this 2-trial standard unexpected contents test (Gopnik & Slaughter, 1991) employed a familiar box (Smarties, Koolmints or Bandaids) that was shown closed up. All children named the expected contents when asked 'What's in this?' Unexpected contents were then revealed (e.g., birthday candles). The container was resealed and children were asked: 'What is really in it?' [control question], then: 'X [a classmate] is coming next. He [she] hasn't seen this. When I show it to him [her] all closed up like this, what will he [she] think is in it?' followed by: 'When you first saw the box, before we opened it, what did you think was inside?' If a child made no response, a single prompt in the format: 'Does she think Smarties or pencils?' was given. 'Don't know' responses were deemed incorrect. All children in the final sample passed the control question. They earned 1 point for each test question by naming the standard contents. As before, a pass on the task as a whole required correct responses to both test questions, so that the odds of this occurring by chance were only 25%. The second trial used different containers and contents (e.g., an egg or milk carton containing rubber balls, or a hamburger wrapper containing a sock). Otherwise, the two were identical. Children could earn up to 4 points for correctly answering all test questions correctly.

Total False Belief Score. A total false belief score (TFB) was computed by summing the children's scores on the changed location and misleading containers tests. Thus TFB totals across the battery could (and did) range from 0 to 6.

Verbal Mental Age. Verbal mental age (VMA) was assessed using standardised receptive vocabulary tests. Two different tests were used. For all of the children with autism, all of those with normal development, and approximately half of those with deafness, the revised Peabody Picture Vocabulary Test (PPVT-R: Dunn & Dunn, 1981) was used, as in much previous ToM research (Wellman et al., 2001). For the remainder of the deaf children, in response to a request from their speech therapist, the Word Classes and Relations Subscale of the Test of Auditory Comprehension of Language (TACL-R: Carrow-Woolfolk, 1985) was substituted for the PPVT. Like the PPVT-R, this test requires a point-to-picture response to spoken vocabulary items (e.g., 'bird', 'no eyes', 'jumping') and has favourable psychometric properties (Carrow-Woolfolk, 1985). Using test norms (based on hearing children), participants' raw test scores were converted to a verbal mental age (VMA).

Nonverbal Mental Ability. The Goodenough-Harris Drawing Test (Harris, 1963), a largely nonverbal normative measure of general intellectual ability that involves the complexity of children's drawings of the human figure, was administered in standard format as per the test manual. This test was chosen because standard scores on it have been shown to correlate well with other IQ measures in hearing children (Harris, 1963) as well as in those with hearing impairments (Clarke School for the Deaf, 1953) and also because it has been used in previous ToM research with deaf children (Peterson & Siegal, 1995; Russell et al., 1998). The test yields a nonverbal IQ estimate, with a mean score of 100 and a standard deviation of 15.

Testing procedure

Each child was tested individually. For all of the false belief tests, in order to preclude the problem of poor task comprehension that would be seen in control question failure, special care was taken to present all information with optimal clarity while children's attention was focused appropriately. The tester spoke loudly and distinctly with his or her lips clearly visible, and monitored the child's gaze, pausing when this was inappropriately directed. Each child's familiar mode of classroom communication was used for the ToM tests. Thus the deaf children from the mainstream schools had oral speech that was fully enunciated and accompanied by visible lip movements, and those from the TC classrooms had simultaneous speech with manual translation into grammatically complete Signed English.

Some of the test words on the PPVT had highly iconic signs. (For example, the sign for the test word 'knee' is a point at the knee). Consequently, as a conservative testing procedure to avoid spuriously inflating VMA scores, the children in TC schools were also given the language test purely orally. A different tester gave it and, to preclude requests for signed translations, the children were told he had no fluency in sign.

Results

Preliminary analyses

Table 2 shows mean scores on the dependent measures for children in each of the diagnostic groups, along with standard deviations (SD). ANOVAs were computed to check that the matching of groups by verbal mental age had been successful. Results confirmed the adequacy of the matching by showing that there were no statistically significant differences among the groups either in mean verbal mental age, F (3,48) = 1.98, $p = .13$, or in mean nonverbal intelligence scores, F (3,48) = 2.56, $p = .07$. Thus each of the diagnostic groups could be deemed roughly equivalent, at the group level, in both verbal and nonverbal domains of intellectual ability. A chi-square test also indicated no statistically significant difference among the groups in frequencies of boys and girls, χ^2 (3) = 4.66, $p > .10$, enabling the combining of the sexes to enhance group size.

As predicted, there was a statistically significant group difference in mean chronological age, F (2,48) = 11.59, $p < .001$. A post-hoc Scheffé test ($p < .05$) was used to locate the basis for this difference. Results showed that, as anticipated, matching by VMA had resulted in the normally hearing preschoolers being significantly younger than the children in each of the three remaining groups, whereas children in these latter three groups did not differ significantly from one another.

Language development in oral deaf children with implants versus amplification

To test the prediction that language development would be more advanced in deaf children with cochlear implants rather than conventional amplification, the mean verbal mental ages of Groups 1 and 2 were compared by *t*-test. With a mean VMA of 71.19 months, the cochlear implant children did not differ significantly from the conventional amplification group, whose mean VMA was 81.65 months, t (24) = 1.30, $p = .21$. Thus there was no evidence of an overall benefit of cochlear implant over amplification for rates of language mastery, as indexed by

Table 2 Sample characteristics, language and false belief performance for children with cochlear implants, conventional amplification, autism and typical development

Diagnostic category	Group 1 Deaf implant	2 Deaf/Amplification	3 Autism	4 Hearing preschool	Total
Sample characteristics					
N	13	13	9	17	52
Mean age (months) (SD)	96.23 (24.96)	90.08 (28.94)	102.44 (27.11)	57.65 (5.05)	83.15 (28.38)
Mean VMA (months) (SD)	71.19 (18.79)	81.65 (22.25)	86.89 (26.57)	71.29 (9.53)	76.56 (19.52)
Mean Nonverbal IQ (SD)	93.77 (12.45)	98.00 (18.42)	87.22 (12.38)	85.65 (8.51)	90.90 (13.63)
False belief					
Mean TFB (SD)	3.77 (1.64)	4.08 (1.98)	3.22 (1.92)	5.35 (1.32)	4.27 (1.83)
Mean tasks passed (SD)	1.38 (.87)	1.69 (1.25)	1.22 (1.20)	2.53 (.87)	1.81 (1.14)
Percent errorless	8%	38%	11%	71%	36%
Language delay (LD)					
Mean LD (months) (SD)	25.04 (19.13)	8.42 (14.80)	15.56 (30.72)	−13.65 (8.44)	6.60 (21.42)
Percent advanced	0	15	33	76	35
Percent on-time	23	23	11	24	21
Percent delayed	77	62	56	0	42

VMA. However, it was possible that type of schooling (mainstream vs. TC) could interact with prosthesis in language development. To test this, a 2 (schooling) by 2 (prosthesis: implant vs. amplification) ANOVA was conducted on VMA scores. There were no main effects either for type of schooling, $F(1,22) = 1.10$, $p = .31$, or for prosthesis, $F(1,22) = 2.37$, $p = .14$, and no significant interaction between these variables, $F(1,22) = 1.39$, $p = .26$. In other words, there was no evidence in this sample of faster linguistic development by children with cochlear implant or in mainstream or TC schooling, and the conservative precaution of requiring the TC children to take the VMA test purely orally (see above) had evidently not depressed these children's scores, relative to their oral-only peers.

The finding of no better language mastery by cochlear implant children in mainstream than in oral-only schools contradicts a previous finding by Archbold et al. (2000). However, before placing undue emphasis on the present results, a number of cautions should be sounded. The present sample was small. Language was developing relatively well in both the hearing-aid and the implant children, given their degree of auditory impairment (Svirsky et al., 2000). Furthermore, the present measure of linguistic maturity consisted solely of a receptive test of vocabulary development that had been normed on hearing children. It must be acknowledged that receptive vocabulary is a limited aspect of the overall acquisition of language. Ideally, for a more complete comparative picture of language growth, tests of syntax should also be included, and test norms should represent children from the deaf population. Nevertheless, given the present focus on ToM development rather than language *per se*, the absence of VMA differences among the groups was opportune. In view of this, it was possible to collapse across prosthesis and type of schooling to enhance sample size for the comparisons between deaf children and those with autism and typical development.

False belief understanding in oral deaf children, typical developers, and children with autism

Table 2 shows the mean total false belief (TFB) scores and mean total false belief tasks passed for children in each of the four groups. A one-way ANOVA on TFB scores yielded a statistically significant group difference, $F(3,48) = 3.93$, $p = .004$. A series of single-df planned comparisons (Keppel, 1982) showed that the hearing preschoolers scored higher than the children in each of the other diagnostic groups ($p = .014$, .046, and .004 for comparisons of preschoolers with Groups, 1, 2, and 3, respectively). But there were no statistically significant differences between the deaf children with cochlear implants versus those with conventional amplification ($p = .644$), or between the combined deaf group and the children with autism ($p = .288$).

Table 2 also shows the numbers and percentages of children in each group who performed at ceiling on ToM by making no mistakes at all on the false belief battery. A substantial majority (71%) of the hearing preschool children achieved this high level of performance. Few children in the other groups did so, despite being older than the preschoolers. A chi-square comparison of frequencies of perfect, versus less-than-perfect, false belief performance yielded a statistically significant group difference, $\chi^2(3) = 15.70$, $p < .01$. The deaf children with cochlear implants did not differ significantly from those with conventional hearing aids, $p > .05$, Fisher's Exact Test, and Groups 1 and 2 did not differ significantly from the children with autism, $\chi^2(1) = .60$, $N = 35$, $p =$ ns. Thus only the hearing preschoolers stood out for more advanced ToM performance.

Within the deaf group (implant and conventional aids combined), chronological age was significantly positively correlated with TFB scores, $r(24) = .50$, $p = .010$. Furthermore, 5 of the 6 deaf children (83%) who displayed perfect ToM performance were aged 9 years or older, significantly more than in the group under 9, $p = .014$, Fisher's Exact Test. In other words, the deaf children's poor false belief performance appears to reflect a delay in development rather than a lasting deficit.

In the cochlear implant group, the exact date of implantation was available for a subsample of 6 children. (For the remainder, school records contained only categorical information such as: 'at <4 years'). There were no statistically significant correlations for the former subgroup between TFB scores and either age at implant, $r(4) = .46$, $p = .36$, or duration of implant use $r(4) = -.04$, $p = .95$. However, these results require cautious interpretation in view of the very small numbers of children involved.

Language development, deafness, and ToM

In order to examine whether the children with deafness and with autism were delayed in language development relative to the hearing preschooler control group, a language-delay (LD) composite score was created by subtracting VMA score from chronological age. The means are shown in Table 2. A one-way ANOVA on mean LD scores yielded a statistically significant difference among the groups, $F(3,48) = 11.80$, $p < .001$. Planned comparisons showed hearing preschoolers to be significantly less delayed in language development than Group 1, $p < .001$, Group 2, $p < .01$, and Group 3, $p < .001$. As Table 2 shows, none of the hearing preschoolers, but most children in the other groups, had language delays of more than 6 months. Single-df planned comparisons showed that the autistic children's mean LD scores did not differ significantly from the combined deaf children's, $p = .87$, and Groups 1 and

2 did not differ significantly from one another, $p = .14$.

Verbal mental age was significantly correlated with TFB for the sample as a whole, $r\,(50) = .30$, $p < .05$. Furthermore, with chronological age partialled out, the correlation rose to $r\,(49) = .39$, $p = .005$, suggesting that language ability was directly linked to greater false belief understanding.

Hierarchical multiple regression analyses

In order to more closely examine the extent to which language contributed separately to children's rate of development of false belief understanding, over and above the influences of age and disability diagnosis, two hierarchical multiple regression analyses were conducted. TFB scores served as the dependent variable for both analyses. For the first analysis, the control variable of chronological age was entered first as an independent variable (IV) at Step 1, along with two new dichotomous IV's: Autism (present vs. absent) and Deafness (present vs. absent), which were created by dummy coding as recommended by Tabachnick and Fidell (1989, p. 125). The resulting multiple regression equation was statistically significant, Mult. $R = .54$, $R2 = .30$, Adj. $R2 = .25$, $F\,(3,48) = 6.72$, $p = .001$. At Step 2, with the entry of VMA scores into the equation, there was a statistically significant increment in the prediction of variability in children's TFB scores, F (change) $= 6.62$, $p = .013$. The overall equation likewise remained significant at the end of this final step, Mult. $R = .62$, $R2 = .38$, Adj. $R2 = .33$, $F\,(4,47) = 7.29$, $p < .001$. The final beta weights indicated that VMA (beta $= .37$, $t = 2.57$, $p = .013$), deafness (beta $= -.54$, $t = 3.24$, $p = .002$) and autism (beta $= -.65$, $t = 4.10$, $p < .001$) each made statistically significant independent contributions to predicting variability in TFB. But chronological age (beta $= .15$, $t < 1$), which had been significant at the end of Step 1, no longer contributed independently once the influence of linguistic maturity had been taken into account. Thus the maturity of a child's language development added significantly to the prediction of variability in false belief understanding even after the influences of chronological age, and diagnoses of deafness or autism, had been statistically accounted for.

A similar hierarchical multiple regression analysis that used LD scores (reflecting the gap between children's chronological and verbal mental ages) in place of VMA produced a very similar result. With TFB scores as the dependent variable, Age, Autism and Deafness were entered, as previously, as predictors at Step 1. The resulting equation was statistically significant, Mult. $R = .54$, $R2 = .30$, Adj. $R2 = .25$, $F\,(3,48) = 6.72$, $p = .001$. At Step 2, with the entry of LD scores into the equation, there was a statistically significant increment in the prediction of variability in TFB scores, F (change) $= 6.62$, $p = .013$. The overall equation likewise remained statistically significant at this final step, Mult. $R = .62$, $R2 = .38$, Adj. $R2 = .33$, $F\,(4,47) = 7.29$, $p < .001$. Thus the extent to which a child's linguistic maturity lagged behind chronological age significantly predicted ToM, over and above the effects of age, deafness and autism. In the full equation at the final step, beta weights were .69, −.54, −.65 and −.45 for the predictor variables of age, deafness, autism, and language delay, and all of these were statistically significant (all t's > 2.55, all p's $< .02$).

Discussion

In line with previous findings of delayed ToM development in oral deaf children with hearing aids and late signers, the present study made the novel contribution of revealing equivalent delays in oral deaf children of primary school age with cochlear implants. In fact, both groups of oral deaf children in this study scored similarly to VMA-matched autistic children, and significantly below VMA-matched hearing preschoolers, on the battery of standard false belief tests of ToM. These results for deaf children with hearing aids were consistent with seven previous studies summarised in Table 1. False belief has been studied collectively, including the present study, in more than 200 orally educated deaf children aged 4 to 13 years from several different countries on a variety of standard tasks. The consistency that emerges, despite these variations, argues against attributing oral deaf children's problems to task variables or to varied local approaches to deaf education. Indeed, the present findings showed, further, that education in a TC classroom where sign was used along with speech neither enhanced nor detracted from ToM development, relative to mainstream schooling. Overall, it would seem false belief performance by oral deaf children with implants or hearing aids closely parallels that of late-signing deaf children from hearing families (see Peterson & Siegal, 2000, for a summary). The body of research on ToM development in deaf children thus suggests that, provided a child's hearing loss is severe to profound, and provided that no other family member is a fluent native signer, a lag of some 3 to 5 years behind normally hearing children is apt to be observed.

Similar delays were observed among high-functioning children with autism in this and previous research (Happé, 1995; Yirmiya et al., 1998). It is possible that equivalent ToM problems in deaf and autistic populations may have a common explanation. As Bruner and Feldman (1993) have noted, autism's triad of diagnostically salient impairments in: (a) language, (b) imagination and (c) socialisation are all likely to inhibit full participation in spontaneous conversations with family members and peers. For the oral or deaf child of hearing parents, family conversation is often rendered problematic by the lack of a fluently shared common language. Thus restricted discourse, especially about intangible concepts like mental states, could conceivably underpin the ToM difficulties that are observed in both groups.

However, it is also conceivable that ToM delays of similar magnitude could arise for quite different reasons in children with autism, as compared with deafness. The neurobiological hypothesis of autism ascribes these children's problems on ToM tasks to a congenitally damaged, innate ToM module within the brain (Baron-Cohen, 1995; Frith, Morton, & Leslie, 1991). Such a possibility cannot be ruled out by the present findings, and further research is clearly needed, ideally employing longitudinal designs, in order to supply convincing answers to questions of root causality in both deaf and autistic populations.

Given the small sample size and the specific characteristics of the children with cochlear implants who took part in this study, further research would likewise be desirable in order to examine oral deaf children's ToM development more fully. It would be particularly useful to have data on children who received cochlear implants before age 2, along with more detailed assessments of language ability both before and after the implant than was available for the present sample. The fact that all the implant users in the present study had been implanted relatively late, by current standards (Svirsky et al., 2000), may help to explain their comparable linguistic maturity to hearing-aid users. But this likewise suggests the need to investigate a larger sample, ideally one including children who had the implant in infancy.

The present findings do, however, help to clarify questions arising out of previous research over the extent to which oral deaf children's delayed ToM development is bound up their language delay. Lundy (2002) concluded that only chronological age, and not language skill, predicted ToM development for her sample of oral deaf children aged 5 to 10 years (see Table 1). She obtained false belief scores and teachers' reports of expressive language proficiency, along with an assessment (for children who could sign) of the parents' fluency with mental state vocabulary in sign, and found that 'expressive language skills of the children and sign language skills of the parents who signed were not found to be significantly related to the children's theory of mind development' (p. 41) She reasoned that: 'It may be that increasing age provides benefits, independent of language, that deaf children can access as they strive to understand the human mind' (p. 53).

However, de Villiers and de Villiers (1999) tested oral deaf children on a specific language test of complementation syntax (e.g., 'X says that [sentence]' or 'X thinks that [sentence]') and found that scores on it predicted false belief scores even after age and other language skills were statistically controlled. Linguistic skill with complementation may be critical to the growth of ToM, according to the deVilliers, because it provides a tool for mentally representing cognitive states. As they explained: 'Subtle social deficits in deaf children seem to be causally tied to their development of language and communicative skills' (p. 206).

Jackson (2001) tested a sample of 14 oral deaf children (along with groups of native and late signers) on false belief tasks and on a language measure that had been specially created to test receptive vocabulary and syntax for British Sign Language. For oral deaf children and late signers, language test scores were not significantly correlated with false belief performance once chronological age was partialled out. But the fact that the language skills of the oral deaf children lagged behind those of an age-matched hearing control group led Jackson to postulate that: 'severe to profoundly deaf children experienced a greater delay in access to language that may have affected their ToM development and/or performance' (p. 171).

The present results shed new light on these contrasting results of previous research by showing that language ability is directly associated with oral deaf children's false belief understanding. In fact, the present results, reflected in both partial correlations and hierarchical multiple regression analyses, showed that for oral deaf children who had cochlear implants or hearing aids, verbal mental age stood out independently as a predictor of ToM performance, even after provision was made for the link between ToM and chronological age. Furthermore, the size of the gap between children's chronological and linguistic ages also emerged as an independent predictor of ToM performance in the second multiple regression analysis, suggesting that the child's *rate* of developing language is relevant, along with the final outcome in terms of linguistic skills.

Children who acquire language swiftly will have more chances than their peers with delayed language to take a full part in a broad range of interactions with others, including talk about mental states. Their attention to ToM terms in conversation may focus their early cognitive development around people's feelings and states of mind. They may also be more likely to take part in language-mediated pretend play than children who are slow to master language. This is consistent with the finding by Bat-Chava and Deignan (2001) that, even when cochlear implant is optimally successful surgically so that auditory acuity improves dramatically, 'children with implants still face communication obstacles, which impede their social relationships with hearing peers' (p. 186), at least in part because 'spoken language skills remain inadequate for full functioning within a hearing community' (p. 188). These authors found that hearing parents of mainstreamed oral deaf children with cochlear implants complained that their children suffered problems with peer conversation and peer social relations. Such problems could limit access to social interactions that facilitate ToM development.

It should be noted, however, that identical implant technology can have different outcomes for different children, both in terms of degree of restoration of basic auditory acuity that is gained, and in relation to sensitivity to subtle social, pragmatic and nonverbal cues needed for full participation in spontaneous peer conversations. Thus generalisations based on group averages can be problematic. Indeed, considerable individual variability in ToM performance was seen even in the small sample of children with cochlear implants tested in this research. Two of these children (aged 7 and 8.5 years, respectively) failed all 3 of the false belief tasks, and an additional 5 failed all tasks but one, whereas one child (aged 6 years) reached ceiling by passing all 3 tasks. While neither age at implant or duration of implant use were found to predict ToM success for the children for whom detailed information on these variables was available, it is evident that some factors in addition to age, auditory prosthesis and classroom communication modality must have been bound up with these striking individual differences.

It would be useful in future research into the ToM development of children with cochlear implants to directly observe the frequency, modality and content of the spontaneous conversations these children engage in both at school and with family members during the crucial preschool years. In fact, if a child's level of hearing of loss is only moderate, spontaneous participation in family conversation may be possible from an early age. This could help to explain Peterson and Siegal's (1999) finding that a group of oral communicators with moderate to severe hearing losses were better able than their late signing classmates to pass false belief tests when tested at the average age of 9 years. But for many young children who are severely or profoundly deaf, the option of sharing fluent conversational exchanges with peers or family members about topics like false beliefs may be difficult, even after a cochlear implant has been fitted (Bat-Chava & Deignan, 2001). Ideally spontaneous speech should be studied longitudinally from pre-implantation to several years after, and the topics of conversation, as well as language skill, should be evaluated. In the absence of direct evidence of this kind, any suggestions as to the likely benefits for ToM of children's involvement in conversations about mentalistic content with peers and family members must remain purely speculative.

Of course, it must be emphasised that the findings reported here require cautious interpretation. In common with many studies of children from special populations, the present sample was small, there was much variability within it, and factors such as age at implantation, though potentially influential, were not accessible to experimental or statistical control. Consequently, the findings cannot be considered definitive, and any attempt to identify unique directions of causality is problematic. Further research is clearly warranted in order to more fully specify the conditions under which hearing impairment, and its method of remediation, may interact with parenting and with characteristics of the deaf child's conversational, educational and social situations to influence the rate of growth of social understanding.

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