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Empirical Article

Family Influences on the Cognitive Development of Profoundly Deaf Children: Exploring the Effects of Socioeconomic Status and Siblings

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We evaluated the cognitive development of 48 profoundly deaf children from hearing families (born 1994–2002, mean age *M* = 8.0 years at time of test, none of whom had received early auditory–verbal therapy) as a function of family socioeconomic status and number of siblings. Overall, the deaf children matched a younger group of 47 hearing controls (*M* = 4.6 years) on verbal ability, theory of mind, and cognitive inhibition. Partial correlations (controlling for age) revealed positive relations in the hearing group between maternal education and inhibition, between number of younger siblings and references to emotions, and between number of close-in-age siblings and references to desires and false beliefs. In the deaf group, there were positive relations between household income and memory span, between maternal education and references to false beliefs, and between number of younger siblings and nonverbal ability. In contrast, deaf children with a greater number of older siblings aged ≤12 years showed inferior memory span, inhibition, belief understanding, picture-sequencing accuracy, and mental-state language, suggesting that they failed to compete successfully with older siblings for their parents' attention and material resources. We consider the implications of the findings for understanding birth-order effects on deaf and language-impaired children.

It is well documented that prelingually deaf children from hearing families (DH) are at risk of delayed cognitive and social development, despite normal nonverbal intelligence. Such problems are attributed to the central role of language in human learning. Through language, children can participate in social interactions that impart factual knowledge about the world; such interactions also teach thinking skills and promote sharing of attitudes and ideas (Marschark & Wauters, 2011).

Deafness and Theory of Mind

DH children have been reported to show impairments of *theory of mind* (ToM), that is, the ability to draw accurate inferences regarding other people's mental states (review by Peterson & Siegal, 2000). In a seminal study, Peterson and Siegal (1995) demonstrated that DH children perform below age-expected levels in tests evaluating the understanding of false belief. Indeed, whereas most typically developing children begin to reason correctly about false belief at around the age of 4 years 6 months (review by Perner, 1991), Peterson and Siegal found that only 35% of a group of DH children aged 8–13 years did so. To explain these remarkable findings, they suggested that DH children lack opportunities to develop ToM due to limited participation in conversations and other kinds of social interactions that draw attention to thoughts, feelings, and beliefs. Consistent with their conclusion, observational studies of hearing preschoolers' interactions with their mothers have shown that ToM development is fostered by early conversational experiences that refer to mental states (Brown, Donelan-McCall, & Dunn, 1996; Ensor & Hughes, 2008; Peterson & Slaughter, 2003;

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Ruffman, Slade, & Crowe, 2002; Slaughter, Peterson, & Mackintosh, 2007; Taumoepeau & Ruffman, 2008).

Evidence that ToM develops normally in deaf children raised by deaf parents indicates it is not deafness per se that impedes understanding of mental states; rather, what impedes understanding is being brought up in a hearing family that lacks members who are sufficiently fluent in sign language to serve as conversational partners (Courtin, 2000; Schick, de Villiers, de Villiers, & Hoffmeister, 2007). Moreover, it does not appear to be the case that DH children fail false-belief tests merely because their poor language skills make it difficult for them to comprehend the narratives. To evaluate this possibility, Figueras-Costa and Harris (2001) tested a group of 24 DH children ranging in age from 4–11 years using a nonverbal paradigm designed to minimize linguistic demands. Although the new task yielded better performance than standard verbal tests, accuracy remained low relative to that of hearing children (for similar findings, see de Villiers & de Villiers, 2000; Woolfe, Want, & Siegal, 2002).

Deafness and Executive Functions

Other work suggests that growing up deaf in a hearing family might also be a risk factor for delayed development of executive functions (EF). According to Vygotsky (1978), higher mental processes such as planning, inhibition, and set shifting have their origins in interpersonal exchanges such that when children engage in collaborative activities, they internalize steps for completing the activity and thus reconstruct their cognition. Language is considered central to the process of internalization, progressing from external speech through to overt, gradually subvocalized speech, and finally to inner speech. In line with Vygotsky's theory, preschoolers' powers of self-regulation are greater among those with superior language development (e.g., Hughes, 1998) and among those whose mothers provide more effective scaffolding (Landry, Miller-Loncar, Smith, & Swank, 2002) in addition to being more sensitive and responsive (Bernier, Carlson, & Whipple, 2010).

DH children are outperformed by hearing children in tests of planning (Marschark & Everhart, 1999) and working memory (Cleary, Pisoni, & Geers, 2001) and they show abnormal neural organization of the bilateral frontal cortex, an area implicated in executive abilities (Wolff & Thatcher, 1990). Figueras-Costa, Edwards, and Langdon (2008) administered a battery of tests of EF to DH children aged 8–12 years, finding impairments of inhibition, working memory, set shifting, and verbal fluency. Similarly, in a study that analyzed parents' ratings of their 5- to 10-year-old DH children's EF in naturalistic settings, Pisoni, Conway, Kronenberger, Henning, and Anaya (2010) uncovered significant difficulties of working memory, planning, and organization. Although such difficulties might partly reflect disruptions of neural system development stemming from auditory deprivation (Conway, Pisoni, & Kronenberger, 2009), Figueras-Costa et al. (2008) reported that DH children performed equivalently to age-matched hearing children in tests of design fluency, problem solving, and attention. To explain why some aspects of EF and not others were impaired in the DH group, they suggested that DH children are disadvantaged mainly in executive skills that depend on inner speech. Indeed, group differences in inhibition, working memory, set shifting, and verbal fluency all disappeared after controlling for verbal ability.

Socioeconomic Status, Siblings, and Cognitive Development

For hearing preschoolers, the important contribution of social interactions to cognitive development is underscored by research on the effects of family socioeconomic status (SES; Hollingshead, 1975) and number of siblings. In terms of SES (usually gauged by household income and maternal education), it has been reported that low-SES children perform more poorly than high-SES children on measures of vocabulary (Whitehurst, 1997), EF (Ardila, Rosselli, Matute, & Guajardo, 2005; Hughes & Ensor, 2005; 2007), and ToM (Cole & Mitchell, 1998; Cutting & Dunn, 1999; Weimar & Guajardo, 2005). It is generally agreed that high-SES homes tend to provide more intellectual stimulation, a greater frequency of responsive one-on-one social interactions, and fewer negative experiences that cause stress (Bradley & Corwyn, 2002; Schofield et al., 2011). Supporting a causal impact of family environment on hearing preschoolers' EF, Hughes and Ensor (2009) reported that maternal planning behavior, maternal scaffolding, and family chaos explained 14% of the variance in children's EF at age 4 years, even after controlling for verbal ability and EF at age 2 years.

In terms of siblings, Dunn (1988) suggested that social interactions between brothers and sisters, particularly those involving deception and conflict resolution, constitute a powerful influence on ToM development. This possibility was first addressed by Perner, Ruffman, and Leekam (1994) in a study that examined whether preschoolers' success on a false-belief test was predicted by their total number of siblings. Results showed that the pass rate of only children was less than half that of children who had two or more siblings, a difference as large as that typically observed between 3- and 4-year-old children. Jenkins and Astington (1996) likewise observed a linear relation between the number of siblings and false-belief performance, which remained robust even after controlling for language ability. In contrast, Ruffman, Perner, Naito, Parkin, and Clements (1998) found that children's success on ToM tasks increased only with the number of older siblings, whereas Peterson (2000) reported that the best ToM performance was exhibited by middle-born children with larger numbers of siblings aged 1–12 years (see also McAlister & Peterson, 2006, 2007).

Effects of SES and siblings have received far less attention from deafness researchers. Mimicking hearing children, DH children from financially advantaged families generally do better than those from financially disadvantaged families on tests of academic ability (review by Mayberry, 2002). Recently, Holt, Beer, Kronenberger, Pisoni, and Lalonde (2012) examined speech and EF in DH children with cochlear implants as a function of a range of family variables associated with SES, including quality of relationships, personal growth and goals, and the family's focus on system maintenance. Further to impaired EF relative to norms for hearing children, this study found significant correlations between the family and cognitive variables. First, participants from families with higher levels of self-reported control tended to have smaller vocabularies. Second, participants from families with a higher emphasis on achievement showed superior EF and working memory, whereas those from families with a higher emphasis on organization (i.e., system maintenance) showed superior inhibition (i.e., self-control).

In the only study to date to have examined the influence of siblings on ToM in DH children, Woolfe, Want, and Siegal (2003) found that outcomes reflected the *quality* of sibling relationships rather than number of siblings per se, such that children with closer ties to their siblings (as reported by their siblings) showed better ToM than children with more distant ties to their siblings. As acknowledged by the authors, however, siblings' ratings of relationship quality might have reflected the sociability of the DH children—with higher levels of sociability associated with better and more frequent social interactions in general. The direction of cause and effect from these data are also unclear considering that DH children with superior ToM might have better negotiating skills than DH children with inferior ToM and, hence, be more skilled at avoiding confrontation.

Interestingly, not all research has reported a beneficial influence of siblings on ToM, at least when considering nonnormative development. In a study of children diagnosed with autism spectrum disorder (ASD), O'Brien, Slaughter, and Peterson (2011) found that participants with only older (typically developing) siblings were reliably outperformed by participants with only younger (typically developing) siblings on a battery of ToM tests assessing understanding of false belief, the distinction between appearance and reality, and pretence. These researchers suggested that when a child with ASD is their parents' first-born child, they tend to receive more specialized intervention and help, both within and outside the home, than would be the case if they have older siblings. They further speculated that the presence of older siblings is likely to diminish the ASD child's opportunities for the kinds of everyday one-on-one social interactions with their primary caregiver that would normally promote ToM development. Indeed, O'Brien et al. (2011) raised the possibility that the older siblings of ASD children might add to their difficulties by generally taking the lead in communication and avoiding complex interactions.

The Present Study

The present study reports a preliminary investigation of the effects of SES and siblings on the cognition of deaf children born into hearing families. As described earlier, little is known about family influences on the developmental outcomes of DH children; moreover, one recent study (O'Brien et al., 2011) showed an *adverse* influence of older siblings on ToM in ASD children—a population that, similar to deaf children, is hampered by poor language skills. Our DH group comprised children with either cochlear implants or conventional hearing aids, born during the period 1994–2002, none of whom had received early auditory–verbal therapy or received their hearing device before 2 years of age. Although we acknowledge that this sample differs in important ways from DH children born today, we report our data with the aim of providing initial evidence that may serve to guide future research on the topic. The DH children's performance was compared with that of younger hearing children who were matched with them for verbal ability to equate the groups for comprehension of the test procedures. Although our focus was ToM, we also measured nonverbal intelligence, memory span, and cognitive inhibition. Children were assessed on two occasions, a little more than a year apart, to gauge the effects of the family environment on cognitive development over time.

Family SES was assessed in terms of household income and level of maternal education. Extending the study of Woolfe et al. (2003), we recorded not only the total number of siblings but also (1) the number of younger versus older siblings aged 1–12 years (e.g., Peterson, 2000), and (2) the number of close-in-age siblings who were likely to understand false belief (namely, siblings aged at least 5 years who were not more than 3 years younger or older than the target child). We included the latter measure on the grounds that close-in-age siblings are more likely than distant-in-age siblings to be play mates and, hence, should exert greater force on each other's socialization (Milevsky, 2011). Based on previous research, we expected that ToM in the hearing group would be positively associated with the number of siblings, particularly older siblings. Although Woolfe et al. (2003) reported no association between ToM and total number of siblings (i.e., those aged up to 17 years) among DH children, their study did not look specifically at the effects of either 1- to 12-year-old siblings or close-in-age siblings. Moreover, it assessed ToM only in terms of false-belief performance.

To thoroughly gauge ToM, we assessed children's understanding of simple false beliefs, second-order false beliefs, true beliefs, and explicitly stated beliefs. Given the concern that DH children's poor performance on such tests might reflect linguistic difficulties that make it difficult for them to follow the narratives or questions, participants completed both standard and pictorial paradigms. In the standard procedures, the researcher described the events verbally while manipulating some simple props that were mentioned in the story; here, children had no access to a permanent visual record of events at the time they were queried about belief. In the pictorial procedures, children viewed either a single picture or a sequence of pictures that illustrated the main events in the story and that remained on display throughout the test phase; under these latter circumstances, children had a visual reminder of events in front of them as they considered their answer. In two previous studies that compared standard and pictorial false-belief tests, it was reported that the performance of deaf children improved when events were presented pictorially but was still impaired relative to that of hearing children (Figueras-Costa & Harris, 2001; Woolfe et al., 2002).

Additionally, ToM was assessed using a picture-sequencing task for which children were confronted with small sets of pictures of people engaged in everyday activities and asked to put the pictures in order to create a meaningful story. The picture-sequencing task has been used previously to yield a nonverbal measure of belief understanding in participants with schizophrenia (Langdon & Coltheart, 1999), Williams syndrome (Porter, Coltheart, & Langdon, 2008), and autism (Baron-Cohen, Leslie, & Frith, 1986) and has been shown to be a sensitive measure of ToM. In our study, after completing their sequences, participants were asked to describe verbally the story being conveyed by the pictures, with their narratives being scored for the frequency of references to emotions, desires, and false beliefs. This enabled us to look for influences of SES and siblings on DH children's use of different kinds of mental-state language.

Method

Participants

At the time of initial testing, the hearing sample ($n = 47$) ranged in age from 3 to 5 years (born 1999–2001, *M* = 54.7 months, standard deviation (*SD*) = 8.3; 24 boys and 23 girls). All participants were recruited from the same fee-exempt primary school located in a predominantly low- to middle-class area, and their participation in the study was subject to written parental consent. All were deemed by their teachers to be showing typical intellectual development.

At the time of initial testing, the deaf sample (*n* = 48) ranged in age from 4 to 11 years (born 1994–2002, *M* = 96.4 months, *SD* = 21.8; 31 boys and 17 girls) and comprised DH children who were profoundly deaf (i.e., an unaided hearing loss in excess of 91 dB). We aimed for a wide age span in the DH group to maximize variability in the number of older versus younger siblings. All children were recruited from hearing-impaired units within mainstream schools that adopted a Total Communication approach (i.e., a simultaneous combination of oral speech, sign language, and fingerspelling) and their participation in the study was subject to written parental consent. Family SES was primarily low to middle class. The sample excluded children with other known disabilities (e.g., ASD, cerebral palsy) except visual impairment that was corrected by lenses (with four children being excluded on the basis of these screening processes).

Within the deaf sample, 21 children were cochlear implant (CI) recipients (15 boys and 6 girls), and 27 wore conventional amplifying (CA) bilateral hearing aids (16 boys and 11 girls). The CI group ranged in age from 4 years 0 months to 10 years 9 months (*M* = 8.3 years), whereas the CA group ranged in age from 4 years 11 months to 11 years 4 months (*M* = 7.9 years). The etiology of deafness, as detailed in parental reports, included genetic causes (*n* = 5), prematurity or birth complications (*n* = 9), acquired deafness such as due to meningitis (*n* = 10), and unknown causes (*n* = 24). Within the CI group, 20 mothers were hearing and one was deaf; all of them used a combination of sign and speech to communicate with their deaf child. Within the CA group, 26 mothers were hearing and one was deaf; 25 used a combination of sign and speech to communicate with their deaf child and two used speech only.

Table 1 shows the descriptive statistics for SES as gauged by household income and level of maternal education, number of siblings, age at onset of deafness (in months), and age at cochlear implantation (in months). Although we did not record individual differences in age when the children were fitted with hearing aids, we were advised by the children's teachers that none of the group received their device before they were 2 years old. Household income was graded from 1 to 6 based on occupation of the main earner as follows: 1 = homemaker, 2 = unemployed/student/pensioner/casual worker, 3 = semi- and unskilled manual worker, 4 = supervisory or clerical and junior managerial, administrative, or professional, 5 = intermediate managerial, administrative, or professional, and 6 = higher managerial, administrative, or professional. Maternal education was graded from 1 to 6 as follows: 1 = less than General Certificate of Secondary Education (GCSE), 2 = GCSE, 3 = A level or BTech, 4 = some tertiary, 5 = degree, and 6 = postgraduate. Statistics for siblings are presented separately for younger siblings aged at least 1 year, older siblings aged up to 12 years, and number of close-in-age siblings (i.e., within 3 years either side of the child and aged at least 5 years). The

Table 1 Descriptive statistics of SES, number of siblings, AOD (in months), and AAI (in months)

	Cochlear implants				Conventional aids				Hearing			
	Min.	Max.	*M*	*SD*	Min.	Max.	*M*	*SD*	Min.	Max.	*M*	*SD*
Household income	1	6	3.47	1.78	1	6	2.64	1.84	1	6	3.73	1.61
Maternal education	1	5	2.62	1.56	1	5	2.00	1.27	1	6	3.33	1.49
Younger siblings ≥ 1 year	0	2	0.57	0.68	0	2	0.38	0.64	0	1	0.07	0.25
Older siblings ≤ 12 years	0	2	0.43	0.68	0	3	0.65	0.85	0	3	0.65	0.74
Total siblings 1—12 years	0	2	1.00	0.77	0	3	0.96	0.92	0	3	0.72	0.72
Close-in-age siblings	0	2	0.57	0.68	0	2	0.69	0.70	0	2	0.39	0.58
AOD (months)	0	30	4.81	9.00	0	60	7.24	15.16	—	—	—	—
AAI (months)	25	118	44.57	21.85	—	—	—	—	—	—	—	—

Note. Household income and maternal education both graded 1–6; SES, socioeconomic status; AOD, age at onset of deafness; AAI, age at implantation.

table also includes descriptive statistics regarding SES and siblings in the hearing group.

The two groups of deaf children did not differ significantly in terms of current age: $t(46) = 0.96, p = .340$, $\eta_p^2 = .03$; age at onset of deafness: $t(46) = -0.65, p = .522$, two-tailed tests; or gender, Pearson chi-square = 0.77, $df = 1$, $p = .382$. A multivariate analysis of variance (MANOVA) that compared the three groups for household income and maternal education produced a significant outcome: Pillai's trace = .128; $F(4,166) = 2.84$, $p = .026$, $\eta_p^2 = .06$. Univariate tests found that the group discrepancy in household income was not quite significant: $F(2,92) = 3.07, p = .052$, $\eta_p^2 = .07$; however, there was a reliable difference in maternal education: $F(2,92) = 7.32, p = .001$, $\eta_p^2 = .14$. Scheffé tests revealed that the average maternal education of the hearing group was higher than that of the deaf children with conventional aids ($p = .001$) but equivalent to that of the deaf children with cochlear implants ($p = .181$). The mean maternal education of the two groups of deaf children did not differ reliably ($p = .345$).

Procedure

When providing informed consent, parents completed a brief questionnaire about their occupation, maternal education, and the age and gender of their child's siblings. In the case of the deaf children, parents were additionally asked about cause and duration of deafness, mode of communication, and age of cochlear implantation (if any). Cognitive data were collected on two occasions that took place a little over a year apart (mean test–retest interval = 14.5 months, $SD = 1.7$), with children being assessed by the researcher in roughly the same order each time. All the hearing group participants were retested the following year. Of the deaf group, all the CI children and all but two of the CA children ($n = 25$, 9 girls and 16 boys) were retested the following year. The correlation between the ages (in months) at Times 1 and 2 was 1.00 in the hearing group and .98 in the deaf group (p values $< .001$).

On both occasions, testing took place individually in a quiet room at the child's school during three separate sessions (spread over approximately 6 weeks) that lasted up to 30 min each. In the case of the deaf participants, children were seated opposite the researcher with their back toward a window such that the researcher's lip patterns were clearly visible and they were tested in their preferred mode of classroom communication. Those children who relied solely on sign were tested in British Sign Language (BSL) by the researcher, who was qualified up to CACDP (Council for the Advancement of Communication with Deaf People) Stage II Level. Testing was discontinued if the child showed signs of boredom or fatigue and, if possible, resumed another day. The same female researcher was responsible for data collection for both groups on both occasions.

Verbal ability. Verbal ability was assessed using the *British Picture Vocabulary Scale* (BPVS, 2nd Edition: Dunn, Dunn, Whetton, & Burley, 1997) and was measured at Times 1 and 2.

Nonverbal ability. Nonverbal ability was assessed using the Block Design subtest from the *British Ability Scales* (Elliott, Smith, & McCulloch, 1996). The hearing children took the test at Time 1 only, whereas the DH children took the test on both occasions.

Memory span. Memory span was assessed for both groups at Time 1 using the Digits Forward subtest of the *British Ability Scales* (Elliott et al., 1996).

Inhibitory control. Inhibitory control was assessed for both groups at Time 1 using four response-conflict tasks, namely, (1) the Day/Night Task (Gerstadt, Hong, & Diamond, 1994), scored 1 = pass, 0 = fail on each trial; maximum possible score = 16, (2) the Grass/Snow Task (Carlson & Moses, 2001), scored 1 = pass, 0 = fail on each trial; maximum possible score = 16, (3) the Hand Shape Task (Hughes, 1996), scored 1 = pass, 0 = fail on each trial, maximum possible total score = 16, and the Dimensional Change Card Sort (Zelazo, Müller, Frye, & Marcovitch, 2003), scored 1 = pass, 0 = fail on each trial; maximum possible total score = 3. All tasks required children to suppress their prepotent response in favor of a new and incongruent response; for example, in the Day/Night task, children were presented with a series of pictures of either the sun or the moon and requested to say "night" whenever shown the sun and to say "day" whenever shown the moon.

Belief understanding. The tests of belief understanding either replicated or closely mimicked previous research. At Time 1, the nonpictorial tests of belief understanding comprised (1) the Buzz/Woody Test—an unexpected-transfer test modeled on the classic Sally-Ann test by Baron-Cohen et al. (1985), involving the Buzz and Woody characters from Disney's Toy Story along with two small toy boxes, (2) the Smarties Test—an unexpected-contents task modeled following Perner, Leekam, and Wimmer (1987), involving a teddy and a Smarties tube containing crayons, and (3) the Appearance/Reality Test—devised by Flavell, Flavell, and Green (1983), involving a sponge that was painted to look like a stone. The pictorial tests comprised (1) the 'What face?' Test—devised by de Villiers and de Villiers (2000), using a picture strip illustrating events that led up to a character's false belief, (2) the Max Picture Strip—a cartoon strip version of the classic unexpected-transfer Maxi task devised by Wimmer and Perner (1983), and (3) the Thought Bubbles procedure devised by Woolfe et al. (2002). In the last task, children were shown a series of three pictures, each one used to illustrate a central character's false belief. The three thought pictures were the following: (1) a boy who is fishing thinks he has caught a fish when really the object on his line is a boot; (2) a girl thinks she has seen a tall boy over a fence when really it is a little boy standing on a box; (3) a man thinks he sees a fish in the sea when really it is a mermaid.

At Time 2, the What Face? and Thought Bubbles tests were repeated. Additionally, children were subjected to (1) the Not Own Belief Test—a pictorial procedure devised by Wellman and Bartsch (1988), in which children were asked to predict a character's behavior based on a belief that was explicitly provided by the researcher but that conflicted with the child's assumption; (2) the Explicit False Belief Test—a pictorial procedure devised by Wellman and Bartsch (1988), in which children were asked to predict a central character's behavior on the basis of a false belief that was explicitly described but which differed from the true state of affairs also described within the story; (3) the Animate False Belief Test—a nonpictorial procedure modeled following Rai and Mitchell (2006), using a model house and two small dolls, for which children were asked to reason about the false belief of one character concerning the whereabouts of the second character who unexpectedly changed location; (4) the Animate True Belief Test—a nonpictorial procedure based on that of Riggs and Simpson (2005), using Play people and simple props, for which children were asked to ascribe a past true belief to a character after events had rendered that belief obsolete; and (5) the Second-Order False Belief Test—a pictorial procedure devised by Perner and Wimmer (1985), in which children were questioned about one character's belief about what another character was thinking.

Questions accompanying each test are listed fully in the appendix. Responses to the test questions (e.g., "What does the boy think is on the end of his fishing line?") were scored 1 = pass, 0 = fail. Following the lead of Peterson and Siegal (1995), most tasks also involved control questions, which were also scored 1 = pass and 0 = fail and which probed children's memory for important events in the narratives (e.g., "What is on the end of the fishing line really?").

Picture sequencing and mental-state language. The picture-sequencing task was taken from Baron-Cohen et al. (1986) and it assessed children's ability to put sets of pictures in order to tell meaningful stories. There were eight sets, each with four pictures, and each of these picture sets showed people engaged in various everyday activities (e.g., making a pizza and serving it to some children). Three picture sets depicted scenarios with the potential to give rise to a false belief in one of the characters. Following Baron-Cohen et al. (1986), the first picture of each story was placed in front of the child such that he or she had only to arrange the remaining three pictures to complete the sequence. The latter three pictures were placed above the initial picture in random order. For each story, the child was given the following instructions: "This is the first picture. Have a look at the other pictures and see if you can make a story with them." Only one attempt was allowed for each story. A wholly correct sequence was awarded two points. If only the last picture card was positioned correctly, then one point was awarded. Any other incorrect order of pictures earned a score of zero.

After each set of pictures had been ordered, regardless of whether this was done correctly or incorrectly, the child was asked to narrate their story. Narratives were scored for the frequency with which children mentioned different kinds of mental states, namely, (1) emotions (e.g., "The boy was *mad* when the girl took his ice cream"), (2) desires (e.g., "she *wanted* to buy some sweets at the shop"), and (3) false beliefs. False beliefs could be referred to either explicitly (e.g., "The girl *didn't know* that the boy stole her teddy," "The boy was *surprised* that his chocolate box was empty," "The boy *realized* (or *found out*) that his sweets were gone") or implicitly (e.g., describing the theft of the bear and then commenting, "When the girl turned around, she went *'oh oh!'*"). In the latter case, children attributed a reaction of surprise or shock to the character that implied a false belief.

Tests were presented in the same fixed order for all participants, with each session containing a mixture of activities. At Time 1, one hearing child failed to complete the Pattern Construction Test, one hearing child failed to complete the Smarties Test, one DH child failed to complete the picture-sequencing task, two DH children failed to complete the Thought Bubbles Test, and two DH children failed to complete the test of verbal ability. At Time 2, two DH children were not tested at all. There were no other missing data.

Results

Results for the BPVS, the Pattern Construction Test, and the Digits Forward Test were graded to yield age-equivalent scores. Results of the tests of inhibition (all marked on different scales) were converted to z scores and averaged. Results for the belief inference questions and associated control questions were each averaged to create a mean score that ranged between zero and one. Results for the picture-sequencing tests were averaged to create a mean score that ranged between zero and two. Results for the associated narratives were scored for the frequency with which children mentioned emotions, desires, and false beliefs. Mentions of false beliefs were totaled separately for explicit versus implicit references.

Group Differences in Cognitive Ability

Table 2 presents group means and standard deviations of cognitive ability, separately for Times 1 and 2. Prior analyses found no hint of a reliable difference between the CA and CI children on any measures on either occasion (p values > .10), and therefore their results were

Table 2 Descriptive statistics for the measures of cognitive ability and theory of mind

	Deaf		Hearing				
	M	*SD*	*M*	*SD*	*t*	*p*	η_p^2
Time 1							
VA	60.98	20.64	58.53	14.27	0.67	.507	.01
NVA	97.25	32.98	54.80	10.42	8.34**	<.001	.43
Memory span	80.75	30.85	53.77	13.16	5.52**	<.001	.28
Inhibition	0.11	0.69	−0.11	0.83	1.39	.167	.03
Belief understanding	0.63	0.29	0.72	0.22	−1.87	.065	.03
Belief control questions	0.83	0.21	0.89	0.16	−1.76	.081	.02
Picture sequencing	1.27	0.68	0.60	0.56	5.29**	<.001	.22
MSL-emotions	1.04	1.04	0.87	0.90	0.85	.399	.01
MSL-desires	0.77	1.51	0.43	0.62	1.43	.155	.04
MSL-explicit FB	0.19	0.45	0.23	0.52	−0.43	.672	.00
MSL-implicit FB	0.94	1.07	0.36	0.61	3.20**	.002	.08
Time 2							
VA	68.65	24.49	73.06	16.02	−1.03	.306	.01
NVA	109.85	32.60	—	—	—	—	—
Belief understanding	0.61	0.23	0.78	0.18	−3.86**	<.001	.11
Belief control questions	0.92	0.15	0.99	0.05	−2.97**	.004	.06
Picture sequencing	1.55	0.47	1.28	0.44	2.89**	.005	.10
MSL-emotions	1.15	1.03	0.89	1.03	1.21	.229	.01
MSL-desires	0.83	1.20	0.49	0.88	1.55	.126	.01
MSL-explicit FB	0.87	1.20	0.70	1.23	0.66	.509	.01
MSL-implicit FB	0.69	0.97	0.32	0.59	2.21	.030	.04

Note. VA = verbal age, NVA = nonverbal age, MSL = mental-state language, FB = false beliefs
*p < .05; **p < .01, two-tailed test.

combined. In the hearing group, scores for verbal ability, nonverbal ability, and memory span were all commensurate with chronological age (p values > .05). In the deaf group, nonverbal ability was commensurate with chronological age on both occasions ($p > 0.05$). In contrast, the deaf children performed significantly below age-expected levels on the tests of verbal ability—Time 1: $t(47) = -11.65, p < .001$; Time 2: $t(45) = -11.56, p < .001$; and memory span: $t(47) = -3.52, p = .001$.

Independent-samples t tests showed that the deaf group outperformed the hearing group on nonverbal ability (Time 1), memory span (Time 1), picture-sequencing accuracy (Times 1 and 2), and frequency of implicit references to beliefs (Times 1 and 2). In contrast, the hearing group outperformed the deaf group on belief understanding and belief narrative comprehension (Time 2). The group difference in belief understanding at Time 2 remained significant after controlling for narrative comprehension: $F(1,88) = 6.42$, $p = .013$, $\eta_p^2 = .07$; hearing-adjusted mean $M = .75$, standard error (SE) = .03; deaf-adjusted $M = .65$, SE = .03. After averaging the data from the two test occasions, results showed that the hearing children outperformed the DH children on the standard tests of belief understanding (hearing $M = 0.71, SD = .19$; deaf $M = 0.59, SD = 0.26$), $t(93) = 2.58$, $p = .011$, $\eta_p^2 = .07$, and in the pictorial tests (hearing $M = 0.82$, $SD = 0.19$; deaf $M = 0.66$, $SD = 0.30$), $t(93) = 2.96, p = .004$, $\eta_p^2 = .09$.

Correlations Between Measures

Table 3 presents partial correlations between measures, controlling for age. Both groups showed reliable, positive correlations between (1) belief understanding at Time 1 and verbal ability at Time 1, (2) belief understanding at Time 1 and inhibition at Time 1, (3) belief understanding at Time 2 and verbal ability at Time 2, (4) belief understanding at Times 1 and 2, and (5) frequency of mental-state language at Times 1 and 2 (i.e., totaling references to emotions, desires, and beliefs).

Table 3 Partial correlations between the measures of cognitive ability and theory of mind, after controlling for age

Measure	1	2	3	4	5	6	7	8	9	10	11
Deaf group											
1. VA-T1	—	—	—	—	—	—	—	—	—	—	—
2. NVA-T1	.17	—	—	—	—	—	—	—	—	—	—
3. Memory span-T1	.29	.32*	—	—	—	—	—	—	—	—	—
4. Inhibition-T1	.32*	.27	.36*	—	—	—	—	—	—	—	—
5. Belief understanding-T1	.61**	.06	.23	.45**	—	—	—	—	—	—	—
6. Picture sequencing-T1	.27	.54**	.28	.42**	.14	—	—	—	—	—	—
7. MSL-T1	.08	.33*	.06	.25	.02	.56**	—	—	—	—	—
8. VA-T2	.74**	.06	.21	.30*	.56**	.11	.00	—	—	—	—
9. NVA-T2	.08	.44**	.18	.23	.09	.51**	.28	−.02	—	—	—
10. Belief understanding-T2	.43**	.27	.28	.23	.67**	.19	.11	.53**	.04	—	—
11. Picture sequencing-T2	.22	.41**	.45**	.45**	.22	.59**	.19	.28	.22	.26	—
12. MSL-T2	.04	.05	.20	.38**	.03	.32*	.42**	−.06	.08	−.13	.23
Hearing group											
1. VA-T1	—	—	—	—	—	—	—	—	—	—	—
2. NVA-T1	−.02	—	—	—	—	—	—	—	—	—	—
3. Memory span-T1	.17	.07	—	—	—	—	—	—	—	—	—
4. Inhibition-T1	.27	.05	.26	—	—	—	—	—	—	—	—
5. Belief understanding-T1	.39*	.13	.24	.47**	—	—	—	—	—	—	—
6. Picture sequencing-T1	.28	−.09	.26	−.13	.05	—	—	—	—	—	—
7. MSL-T1	.19	.06	.06	.01	.11	−.04	—	—	—	—	—
8. VA-T2	.76**	−.06	.23	.28	.29	.44**	.12	—	—	—	—
9. NVA-T2	—	—	—	—	—	—	—	—	—	—	—
10. Belief understanding-T2	.13	.15	.10	.25	.41**	.32*	−.05	.46**	—	—	—
11. Picture sequencing-T2	.41**	.14	.14	.18	.44**	.35*	.17	.49**	—	.51**	—
12. MSL-T2	.16	−.09	.08	−.25	−.28	.23	.31*	.01	—	.04	.15

Note. VA = verbal age, NVA = nonverbal age, MSL = mental-state language. T1 = Time 1, T2 = Time 2. Significant correlations are shown in bold.
*p < .05; **p < .01, two-tailed test.

However, only the hearing group showed a link between belief understanding and picture-sequencing accuracy. Simultaneous-entry regression analyses were conducted to evaluate the unique contributions of age, verbal ability, and inhibition to belief understanding at Time 1. In the hearing group, the outcome was significant—adjusted $R^2 = .56$, $F(3,43) = 18.53$, $p < .001$—and showed a marginal effect of age ($\beta = .27$, $t = 1.98$, $p = .055$) and independent effects of verbal ability ($\beta = .28$, $t = 2.07$, $p = .044$) and inhibition ($\beta = .36$, $t = 2.97$, $p = .005$). In the DH group, the outcome was significant—adjusted $R^2 = .55$, $F(3,42) = 19.24$, $p < .001$—and showed no reliable effect of age ($\beta = .01$, $t = 0.04$, $p = .972$) and independent effects of verbal ability ($\beta = .55$, $t = 4.27$, $p < .001$) and inhibition ($\beta = .29$, $t = 2.10$, $p = .042$).

Effects of SES and Siblings in the Hearing Group

Preliminary analyses revealed that household income for the hearing children was reliably, positively correlated with maternal education: r (47) = .52, $p < .001$. However, neither SES variable was reliably correlated with number of younger siblings, number of older siblings, or number of close-in-age siblings (p values > .05). Child's age at Time 1 was marginally correlated with household income—r (47) = .29, $p = .053$—but not number of younger siblings, older siblings, or close-in-age siblings (p values > .05).

Table 4 shows Pearson correlations between (1) the family variables (household income, maternal education, number of younger siblings, number of older siblings, and number of close-in-age siblings) and (2) the cognitive measures (verbal ability, nonverbal ability, memory span, inhibition, and ToM as gauged by belief inferences, picture sequencing, and the frequency of different kinds of mental-state references), separately for the two test occasions. Considering the marginal correlation between household income and child's age, we also calculated partial correlations between all pairs of variables that controlled for age (shown in parentheses). In relation to SES, household income was positively associated with the frequency of children's implicit references to false belief at Time 1, whereas maternal education was positively associated with inhibitory control. Number of younger siblings was positively associated with the frequency of references to emotions at Time 2, whereas number of close-in-age siblings was positively associated with the frequency of

Table 4 Correlations in the hearing group between (1) family characteristics and (2) the measures of cognitive ability and theory of mind (with partial correlations, controlling for age, shown in parentheses)

	Family income	Maternal education	Younger siblings ≥ 1 year	Older siblings ≤ 12 years	Total siblings 1-12 years	Close-in-age siblings
Time 1						
VA	.22 (.04)	.02 (.05)	−.13 (−.18)	−.27 (−.16)	**−.32*** (−.23)	.02 (−.12)
NVA	.19 (−.08)	−.08 (−.12)	.03 (.07)	−.12 (.13)	−.11 (.16)	.12 (−.02)
Memory span	**.30*** (.21)	.17 (.27)	−.02 (−.02)	−.16 (−.08)	−.17 (−.09)	.16 (.08)
Inhibition	.09 (−.07)	**.29* (.36*)**	.19 (.22)	−.05 (.08)	.01 (.16)	.15 (.08)
Belief understanding	.07 (−.17)	.09 (.11)	.07 (.09)	−.22 (−.08)	−.21 (−.05)	.07 (−.03)
Picture sequencing	.09 (−.01)	−.12 (−.08)	−.10 (−.12)	−.13 (−.07)	−.17 (−.11)	.19 (.13)
MSL-emotions	.17 (.11)	.11 (.12)	.13 (.14)	−.09 (−.04)	−.05 (.00)	−.05 (−.08)
MSL-desires	.09 (.09)	.04 (.00)	−.19 (−.18)	**.29* (.31*)**	.23 (.25)	**.54** (.57**)**
MSL-explicit FB	−.03 (−.13)	−.02 (.01)	−.12 (−.14)	−.07 (.01)	−.11 (−.04)	−.08 (−.15)
MSL-implicit FB	**.36* (.38*)**	.23 (.27)	−.16 (−.17)	.10 (.10)	.04 (.05)	.17 (.16)
Time 2						
VA	.17 (−.03)	.00 (.02)	.03 (.05)	−.27 (−.11)	−.26 (−.10)	.05 (−.04)
Belief understanding	.02 (−.03)	.13 (.13)	.03 (.03)	−.05 (−.02)	−.04 (−.01)	.19 (.16)
Picture sequencing	.09 (−.05)	−.08 (−.09)	.08 (.10)	**−.32*** (−.20)	**−.30*** (−.17)	.25 (.26)
MSL-emotions	−.02 (−.01)	.07 (.06)	**.30* (.35*)**	.09 (.04)	.19 (.17)	.12 (.11)
MSL-desires	.22 (.24)	.07 (.08)	−.05 (−.06)	−.03 (−.05)	−.05 (−.08)	.15 (.14)
MSL-explicit FB	.12 (.12)	.07 (.09)	−.15 (−.16)	.11 (.14)	.06 (.09)	**.40* (.42**)**
MSL-implicit FB	.19 (.24)	.03 (.03)	−.15 (−.16)	.06 (.01)	.01 (−.04)	.16 (.17)

Note. VA = verbal age, NVA = nonverbal age, MSL= mental-state language, FB = false belief. Significant correlations are shown in bold.
*$p < .05$; **$p < .01$, two-tailed test.

references to desires at Time 1 and the frequency of references to false beliefs at Time 2.

Because we also had information regarding siblings aged 13–18 years, we examined whether the pattern of correlations was altered when including them. There were no new significant outcomes, but the association between older siblings and frequency of references to desires at Time 1 disappeared—*r* (47) = .12, *p* = .421—indicating that it depended mainly on older siblings who were close in age to the participants.

Effects of SES and Siblings in the DH Group

Preliminary analyses found that household income for the DH children was reliably, positively correlated with maternal education: *r* (46) = .39, *p* = .012. However, neither SES variable was reliably correlated with number of younger siblings, number of older siblings, or number of close-in-age siblings (*p* values > .05). There were no reliable correlations between any of the family variables and child's age at Time 1 (*p* values > .05).

Table 5 shows Pearson correlations between (1) the family variables (household income, maternal education, number of younger siblings, number of older siblings, and number of close-in-age siblings) and (2) the cognitive measures (verbal ability, nonverbal ability, memory span, inhibition, and ToM), separately for the two test occasions. To ensure consistency with the analyses conducted on the hearing group, Table 5 also shows partial correlations after controlling for age. In relation to SES, household income was positively associated with memory span at Time 1, whereas maternal education was positively associated with picture-sequencing accuracy and the frequency of explicit references to false beliefs at Time 1. Number of younger siblings was positively associated with nonverbal ability at Time 1. In contrast, number of older siblings was negatively associated with memory span at Time 1, inhibition at Time 1, belief understanding at Time 1, picture-sequencing accuracy at both Times 1 and 2, and frequency of references to emotions at Time 2. The total number of siblings aged 1–12 years was negatively associated with the frequency of references to desires at Time 1.

After including older siblings aged up to 18 years, reliable negative relations once again emerged between

Table 5 Correlations in the deaf group between (1) family characteristics and (2) the measures of cognitive ability and theory of mind (with partial correlations, controlling for age, shown in parentheses)

	Family income	Maternal education	Siblings ≥ 1 year	Siblings ≤ 12 years	Siblings 1-12 years	Close-in-age siblings
Time 1						
VA	.12 (.01)	.07 (.12)	.10 (.05)	−.23 (−.16)	−.12 (−.11)	−.04 (−.01)
NVA	.13 (−.02)	.17 (.29)	.14 (.08)	**−.30*** (−.25)	−.15 (−.15)	−.19 (−.09)
Memory span	**.38* (.43**)**	.16 (.23)	.18 (.13)	**−.45** (−.41*)**	−.24 (−.27)	−.21 (−.21)
Inhibition	.16 (.02)	.05 (.14)	.06 (.01)	**−.35* (−.41*)**	−.25 **(−.29*)**	−.15 (−.23)
Belief understanding	−.09 (−.20)	−.12 (−.08)	.17 (.13)	**−.37* (−.40*)**	−.19 (−.20)	−.13 (−.24)
Picture sequencing	.16 (.07)	.14 **(.33*)**	.14 (.09)	**−.29*** (−.26)	−.14 (−.17)	−.16 (−.18)
MSL-emotions	.17 (.08)	−.07 (.03)	.07 (.09)	−.02 (−.17)	.04 (.07)	.00 (−.11)
MSL-desires	.07 (.06)	.04 (.16)	−.21 (−.23)	−.24 (−.17)	**−.37* (−.37*)**	**−.31*** (−.25)
MSL-explicit FB	.25 (.23)	**.41** (.39*)**	.13 (.12)	−.18 (−.13)	−.05 (−.05)	.08 (.14)
MSL-implicit FB	.04 (−.04)	.21 (.18)	−.18 (−.25)	−.01 (.16)	−.15 (−.15)	−.21 (−.14)
Time 2						
VA	.24 (.10)	.13 (.22)	.03 (.02)	−.12 (−.06)	−.08 (−.05)	.06 (.14)
NVA	.19 (.04)	.04 (.10)	**.36* (.40**)**	−.20 (−.10)	.12 (.21)	.04 (.14)
Belief understanding	.06 (−.09)	.18 (.19)	.19 (.17)	−.27 (−.26)	−.08 (−.06)	−.16 (−.15)
Picture sequencing	.28 (.15)	.19 (.30)	.14 (.12)	**−.45** (−.49**)**	**−.35* (−.32*)**	−.21 (−.18)
MSL-emotions	.05 (.01)	.15 (.12)	−.01 (.00)	**−.32* (−.43**)**	**−.30*** (−.28)	**−.32* (−.35*)**
MSL-desires	−.06 (.01)	−.27 (−.27)	−.06 (−.07)	−.15 (−.11)	−.18 (−.19)	−.13 (−.10)
MSL-explicit FB	.06 (−.06)	.09 (.11)	−.11 (−.15)	−.10 (−.08)	−.18 (−.16)	.15 (.17)
MSL-implicit FB	.05 (.01)	−.15 (−.09)	.07 (.06)	.00 (.02)	.06 (.07)	.00 (−.05)

Note. VA = verbal age, NVA=nonverbal age, MSL= mental-state language, FB = false beliefs. Significant correlations are shown in bold.
*p < .05; **p < .01, two-tailed test.

number of older siblings and memory span at Time 1—r (48) = −.43; partial r (45) = −.39, p values < .05—and between number of older siblings and picture-sequencing accuracy at Time 2—r (46) = −.34; partial r (43)= −.31, p values < .05. However, the negative associations with inhibition, belief understanding, and references to emotions were below significance (p values > .05).

Hierarchical regressions were used to quantify the variance contributed by older siblings up to 12 years (Step 2) after taking account of age, household income, and maternal education (Step 1). Adding older siblings to the model produced significant increases in explained variance in the cases of memory span at Time 1 (ΔR^2 = 12%, F change = 8.39, p = .006), inhibition at Time 1 (ΔR^2 = 8%, F change = 5.78, p = .022), belief understanding at Time 1 (ΔR^2 = 10%, F change = 6.99, p = .012), picture sequencing at Time 2 (ΔR^2 = 9%, F change = 9.22, p = .005), and emotion referencing at Time 2 (ΔR^2 = 12%, F change = 8.39, p = .006).

Finally, the preceding full and partial correlations were considered separately for the CI and CA groups. In the CI group, number of older siblings was negatively related to belief understanding at Time 1: r (21) = −.48, p = .030; partial r (18) = −.50, p = .026; belief understanding at Time 2: r (21) = −.43, p = .049; partial r (18) = −.55, p = .014; and references to emotions at Time 2: r (21) = −.37, p = .098; partial r (18) = −.46, p = .047. In the CA group, number of older siblings was negatively related to verbal ability at Time 1: r (25) = −.42, p = .043; partial r (22) = −.43, p = .047; memory span at Time 1: r (27) = −.56, p = .003; partial r (24) = −.57, p = .006; inhibition at Time 1: r (27) = −.53, p = .006; partial r (24) = −.58, p = .005; picture sequencing at Time 1: r (27) = −.38, p = .056; partial r (24) = −.44, p = .043; and picture sequencing at Time 2: r (25) = −.57, p = .004; partial r (22) = −.67, p = .001.

Discussion

Our study explored the effects of family SES and number of older versus younger siblings on the cognitive development of profoundly deaf children born into hearing families, a topic that has received little attention in previous research. As discussed in the following sections, influences of SES were similar for the two groups, but influences of siblings differed in important ways between the DH children and the hearing controls. Before considering these novel findings in detail, we first summarize the pattern of group differences on the tests of ToM and EF.

The Development of ToM and EF in Deaf Children

Despite their normal nonverbal intelligence, the DH children's performance on a variety of tests of ToM and EF failed to better that of hearing children who were, on average, 3–4 years younger. Moreover, they showed no evidence of closing the gap on the hearing controls in terms of ToM on the second test occasion. ToM impairments were apparent even when the tests were presented with pictorial support and notwithstanding participants' excellent performance on questions intended to assess their comprehension and memory of the belief narratives. Although the DH group outdid the hearing controls on the picture-sequencing task, it seems likely that their success reflected capabilities other than ToM. There was a reliable correlation between picture-sequencing accuracy and nonverbal intelligence in the DH group; in contrast, sequencing success for the controls was best predicted by belief understanding. These findings suggest that the DH children were less inclined than the hearing children to think about mental states when attempting to construct a meaningful arrangement of pictures.

Results showed positive correlations in both groups between language ability and belief understanding, between inhibitory control and belief understanding, and between language ability and inhibitory control, all of which remained robust after controlling for current age. The strong involvement of language in the ToM and EF performance of the DH group is consistent with the view that development in these domains is largely driven by social interactions (Figueras-Costa et al., 2008; Peterson & Siegal, 2000). In line with previous research, language ability and inhibitory control were independent forces on belief understanding—a finding that has been taken to implicate an important role of these variables in either the emergence or expression of ToM (Schneider, Lockl, & Fernandez, 2005). Although it is well documented that language predicts

ToM in DH children, the present investigation is the first to reveal an influence of inhibition. Because the same variables underpinned false-belief inferences in the two groups, our data lend weight to the suggestion that—despite being delayed—development of ToM in DH children proceeds in a similar manner as in hearing children (Peterson & Wellman, 2009).

SES and Cognitive Development

In the hearing group, SES was predictive of memory span, inhibitory skills, and implicit references to false belief. While acknowledging the possible involvement of heredity in these associations, it is worth noting that neither household income nor maternal education was related to verbal and nonverbal intelligence. Potentially, the positive relation between maternal education and inhibition could be attributed to scaffolding. Hughes and Ensor (2009) observed that high-SES mothers provided better scaffolding than low-income mothers, with benefits for children's EF.

In the DH group, measures of SES showed positive correlations with memory span, picture-sequencing accuracy, and the frequency of explicit references to false beliefs. Mimicking the hearing children, there were no significant associations with either verbal or nonverbal intelligence. The finding that maternal education predicted children's propensity for explicitly describing false beliefs is in accord with evidence that the responsibility for a deaf child's communication tends to fall on the mother (Jackson & Turnbull, 2004). Although studies with hearing preschoolers have shown that higher-SES mothers make more effort to engage their children in conversation (Hoff, Laursen, & Tardif, 2002), our failure to find a positive association between SES and verbal ability in the DH group suggests that higher-SES mothers did not talk more to their deaf children per se. Rather, they might have tried harder to discuss mental states, possibly due to superior mastery of sign language. Congruent with the latter possibility, Moeller and Schick (2006) reported that maternal sign-language fluency was related to DH children's ToM, as was quality of mind-minded talk but not quantity of talk overall. Alternatively, our measures of SES might have indexed a general influence of the home environment on DH children's cognitive development, including language input from other relatives and economic factors affecting their education.

Siblings and Cognitive Development

Among the hearing children, we found the strongest influences on development from close-in-age siblings and younger siblings, with such impact being limited to the measures of ToM. Specifically, children with a greater number of brothers and sisters who were within 3 years of their own age were more likely to refer to desires when explaining their picture sequences at Time 1 and were more likely to refer explicitly to false beliefs when explaining their picture sequences at Time 2. Children with a greater number of younger siblings were more likely to refer to emotions when explaining their picture sequences at Time 2. To the best of our knowledge, no previous research has examined effects of close-in-age siblings on ToM in hearing preschoolers. Nevertheless, the finding that ToM was influenced most obviously by brothers and sisters who were of nearly the same age as our participants accords with evidence of a greater impact of siblings aged 1–12 years older than all siblings (Peterson, 2000).

Despite such striking effects on mental-state language, sibling numbers were not significantly related to the accuracy of children's *inferences* about beliefs. Our study is not the first that has failed to detect an impact of siblings, either younger or older, on hearing preschoolers' belief inferences in traditional tests (Cole & Mitchell, 2000; Cutting & Dunn, 1999; Hughes & Ensor, 2005). Possibly, siblings have a greater hand in teaching preschoolers how to label concepts about the mind than in developing such concepts in the first place. Our findings suggest that older siblings are inclined to discuss desires and false beliefs, whereas younger siblings focus on emotions. Alternatively, the positive relation between number of younger siblings and participants' referencing of emotions could mean that parents habitually remark on the mood of their infants and toddlers in front of older children in the family.

Importantly, and in contrast with the hearing controls, measures of cognitive functioning in the DH group showed *negative* relations with number of siblings, particularly older siblings aged up to 12 years. Even after controlling for current age, maternal education, and household income, the adverse influence of older siblings was evident for inhibitory control, memory span, belief understanding, picture-sequencing accuracy, and references to emotions in the picture-sequencing task. Additionally, the total number of siblings aged 1–12 years was linked negatively with children's propensity for talking about characters' desires in their picture sequences. There was little impact of number of younger siblings on any of the measures, apart from a positive association with nonverbal intelligence; moreover, the unfavorable effects of older siblings on DH children's cognitive development were attenuated when considering the number of older siblings aged up to 18 years (rather than 12 years). These findings show clearly that later-born DH children were disadvantaged relative to earlier-born DH children in terms of their intellectual growth, independent of overall family size and SES.

The present study is the first in the literature to expose consequences of birth order for the cognitive development of deaf children growing up in hearing families. Consistent with our findings, O'Brien et al. (2011) observed a negative association between number of older siblings and ToM performance in ASD children. They proposed that older siblings might interfere with ToM development in an ASD child by (1) robbing them of opportunities for one-on-one interactions with the primary caregiver and (2) dominating their efforts to communicate and, thus, failing to help them learn. These suggestions seem applicable to our DH sample and could also explain the adverse influence of older siblings on memory span and inhibition. In relation to ToM, DH children with many older siblings might have found it harder to gain their parents' time and attention, thus limiting their access to discourse about mental states. In relation to EF, older siblings might have tended to take responsibility for the younger deaf child—hindering their development of higher-order control processes.

The question of whether typically developing children show birth-order effects has proved controversial, with some researchers concluding that older siblings show a small but significant superiority over younger siblings in terms of IQ and others maintaining that any such effects are an artifact of SES and family size (review by Downey, 2001). Within the former literature, disadvantages attached to being a young sibling have been explained by the concept of *resource dilution*, which supposes that parents have finite resources (time, attention, and material resources such as books and toys) and that younger siblings find it harder to compete for them. It has also been suggested that later-born children are exposed to immature language (from older brothers and sisters) and have fewer opportunities to practice cognitive skills by tutoring younger siblings (Zajonc, 2001). In the present study, failure to detect birth-order effects in the hearing group might reflect their young age. Alternatively, such effects might be *accentuated* in deaf or language-impaired children who depend much more than typically developing children on environmental support for cognitive development.

Of course, an obvious question to be addressed by future research concerns the extent to which our results hold true for more recent cohorts of DH children. The past decade has witnessed major advances in hearing aid technology and its early provision, more widespread neonatal screening for hearing problems, and the introduction of better educational approaches, all of which mean that the prospects for such children have never been brighter. Further to seeking up-to-date information regarding the consequences for DH children's language and cognition of early cochlear implantation and auditory–verbal therapy, future investigations should explore whether the adverse effects of older siblings are diminished relative to those reported here. Additionally, observational studies could provide detailed information regarding the nature and frequency of DH children's communicative interactions with caregivers and siblings as a function of birth order. If the quality of such interactions is shown to be poorer for later-born children, for example, with diminished use of attention-getting strategies and efforts to gain eye contact before speaking, then parents could be educated about the problem. Older siblings, too, could be encouraged to avoid overprotective behaviors and instead interact with the DH child in ways that promote their social and intellectual development.

Conclusion

In conclusion, the present study revealed important family influences on the cognitive development of deaf children born into hearing families, with such children being significantly advantaged by being one of the older siblings. This effect was independent of SES and evident over a range of measures—including nonverbal IQ, memory span, cognitive inhibition, belief understanding, picture-sequencing accuracy, and frequency of mental-state language. We have suggested that the findings can be understood in terms of resource dilution theories of birth-order phenomena, which postulate that earlier-born children profit from increased parental attention and investment. As discussed, further research is needed to ascertain whether our results are relevant to more recent cohorts of DH children.

Conflicts of Interest

No conflicts of interest were reported.

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Appendix

List of questions accompanying the individual tests of belief understanding:

- ***Buzz/Woody Test.*** "Where did Woody put his hat at the beginning of the story?" (control); "Where is the hat now?" (control); "Where will Woody look first for his hat?" (false belief).
- ***Smarties Test.*** "When I first showed you this, before I opened it, what did you think was inside, Smarties or crayons?" (own false belief); "What will *(friend's name)* think is inside, Smarties or crayons?" (others' false belief); "What is in this tube really? Smarties or crayons?" (control).
- ***Appearance/Reality Test.*** "What does this look like?" (control); "What does it feel like?" (control); "What is it really?" (false belief).
- ***What Face?*** "Which face goes here? Please show me the girl's face." (false belief).
- ***Max Picture Strip.*** "Where will Max look first for his chocolate?" (false belief).
- ***Thought Bubbles 1.*** "What does the boy think is on the end of his fishing line?" (false belief); "What is on the end of his line really?" (control).
- ***Thought Bubbles 2.*** "What does the girl think is on the other side of the fence?" (false belief); "What is on the other side of the fence really?" (control).
- ***Thought Bubbles 3.*** "What does the man think is swimming in the sea?" (false belief); "What is swimming in the sea really?" (control).

- *Not Own Belief.* "This is Sam. Sam wants to find his puppy. It might be hiding in the house or in the garden. Where do you think Sam's puppy is hiding? *(Child answers, e.g., "garden").* That's a good guess. Sam thinks his puppy is hiding in the ------ *(opposite location to child's answer, e.g., house).* Where is Sam going to look for his puppy?" (false belief).
- *Explicit False Belief.* "This is Mary. Mary wants to find her kitten. Mary's kitten is really in the bedroom. Mary thinks her kitten is in the kitchen. Where will Mary look for her kitten?" (false belief).
- *Animate False Belief Test.* "Where is Sally's mother now?" (control); "Where did Sally's mother go first?" (control); "Where will Sally look first for her mother?" (false belief).
- *Animate True Belief Test.* "In the beginning of the story, where did Tom's mother think Tom was?" (true belief); "In the beginning of the story, where was Tom?" (control).
- *Second-Order False Belief.* "Where was the ice cream van at the beginning of the story?" (control); "Where is it now?" (control); "Where does Mary think that John will go first to look for the ice cream van?" (false belief).