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Understanding Theory of Mind in Deaf and Hearing College Students

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Abstract

Theory of Mind—the understanding that people have thoughts, wants, and beliefs that influence their interpersonal behavior—is an aspect of social cognition that develops with consistent, increasing complexity across age groups, languages, and cultures. Observed delays in theory of mind development among deaf children and others has led to a conversational account of theory of mind development and its delays in terms of the nature and amount of social communication experienced by children directly (conversationally) and indirectly (via overhearing). The present study explored theory of mind in deaf young adults by evaluating their understanding of sarcasm and advanced false belief (second-order false belief and double bluff), as well as related cognitive abilities. Consistent with previous studies, deaf participants scored significantly below hearing peers on all three theory of mind tasks. Performance was unrelated to their having had early access to social communication via either sign language (from deaf parents) or spoken language (through cochlear implants), suggesting that deaf participants' performance was not solely a function of access to social communication in early childhood. The finding of different predictors of theory of mind performance for deaf and hearing groups is discussed in terms of its language, social, and cognitive foundations.

Theory of Mind (ToM), a key facet of social cognition, has been studied by developmental psychologists for decades (for reviews, see [Wellman, 2011, 2014](#)) and is of broad interest to other disciplines (e.g., cognitive science, philosophy). In their seminal study, [Premack and Woodruff \(1978\)](#) defined ToM as the ability to “impute mental states to self and others” and to cognitively reason about these unobservable states (e.g., belief, knowledge, thinking) to “make predictions about the behavior of self and others” (p. 515). ToM thus involves “meta-representational development” ([Baron-Cohen, Leslie, & Frith, 1985](#)) and is “theory-like” in that it makes empirically testable predictions based on metacognitive reasoning about beliefs. As [Garfield, Peterson, and Perry \(2001\)](#) explained: “theory of mind is the cognitive achievement that enables us to report our propositional

attitudes [thoughts], to attribute such attitudes to others, and to use such postulated or observed mental states in the prediction and explanation of behavior” (p. 494). Defined in that way, it is clear that acquisition of a ToM is a cognitively complex developmental achievement that is distinct both conceptually and empirically from other, simpler social skills and attributes—like general sociability, intent and desire perception, emotion recognition and empathy—that do not require a meta-representation and are already present in some form by late infancy.

ToM typically is assessed using false-belief tasks requiring the prediction of the behavior of protagonists who hold false beliefs that the person being tested does not share. When used with hearing children, false belief tasks normally are spoken by the examiner, sometimes with dolls, puppets, or other props to

ensure comprehension. A meta-analysis of the performance of several thousand typically-developing hearing children on false belief tests by [Wellman, Cross, and Watson \(2001\)](#) revealed a consistent developmental trajectory in ToM performance. Many to most children under age 4 fail these tests. However, between the ages of 5 and 6 years, success on them is found in varied cultures, language communities, and socio-economic circumstances, indicating mastery of meta-representational ToM by the vast majority of children by the time they enter school.

In contrast to the ubiquitous findings with typically-developing hearing children, children who are deaf and whose parents are both hearing often demonstrate delays in ToM acquisition to varying degrees. [Peterson and Siegal \(1995\)](#), for example, found that well over half of the deaf 8- to 13-year-olds from hearing families to whom they administered false belief tasks (using signed and spoken communication) failed them.¹ Subsequently, [Peterson and Siegal \(1999\)](#) compared three groups of children using false belief tasks: (a) deaf children from hearing families, (b) native-signing deaf children of signing deaf parents, and (c) hearing children. The finding that deaf children with deaf parents developed ToM on the same timetable as hearing children, while deaf children from hearing families were seriously delayed, suggested a “conversational account” for both ToM development and for its delays.

Social Communication and Theory of Mind Development in Deaf Children

Children’s understanding of others’ mental states is facilitated by social interaction and conversation (especially about mental states) with peers, siblings, parents, and others, as well as via incidental learning by overhearing others’ spoken communication and/or visually eavesdropping on deaf parents’ signed interactions. Deaf children from hearing families, however, often lack frequent exposure to family conversations, especially about ToM-relevant topics such as people’s thoughts and feelings. That is, the lack of fluency in sign language among most hearing parents, together with children’s hearing losses, preclude full access to parents’ and siblings’ interpersonal communication. This creates a very different conversational environment for deaf children in hearing families compared to hearing children of hearing parents and deaf children of deaf parents, one that seems a likely contributor to the ToM similarities and differences in the three populations.

Even before ToM became a focus for research in the field of child development, a variety of studies had demonstrated that deaf children lag behind hearing peers in tasks requiring the ability to take alternative perspectives, both socially and physically (for review, see [Marschark, 1993](#), Chapters 4 and 7). Such findings suggest that social-behavioral-conversational experiences such as social pretend play and the negotiating of pretend roles and stipulations with playmates—a strong ToM correlate for hearing children ([Jenkins & Astington, 2000](#))—as well as general linguistic-developmental factors are at play in the development of ToM for deaf and hearing children alike.

A social-conversational account of ToM development in deaf children was supported by [Courtin \(2000\)](#), who examined false belief performance in 5- to 8-year-old deaf children of deaf parents, deaf children of hearing parents, and hearing children of hearing parents. He found that compared to hearing children of hearing parents, over twice as many deaf children of deaf parents—who had full and effective access to language and social communication through sign language from birth—passed the false belief tasks. Further, almost twice as many deaf children

whose hearing parents communicated with them via sign language passed the false belief tasks compared to deaf children whose hearing parents communicated with them only via spoken language. Together with clear effects of age, these results led Courtin to emphasize the importance to ToM development of early exposure to language and the potential of sign language to provide deaf children and their parents an effective, shared mode of increasingly complex social communication as children grow up. Similar results and conclusions now have been extended from the early preschool years (e.g., [Meristo et al., 2012](#)) through primary school (e.g., [Jackson, 2001](#); [Peterson, Wellman, & Slaughter, 2012](#)).

[Morgan and Kegl \(2006\)](#) examined performance in a false belief task and a mental state narrative task among a group of deaf individuals aged 7–39 years who acquired Nicaraguan Sign Language at different ages. They found that individuals who had acquired sign language by 10 years of age were more likely to pass a false belief task than those who learned it later, but those who had learned to sign later did use mental state terms in the narrative task. A recent study involving deaf and hearing 15- to 28-year-olds by [Lecciso, Levante, Baruffaldi, and Petrocchi \(2016\)](#) similarly found that deaf individuals who learned to sign later performed more poorly than native signers on a second-order false belief task (requiring recursive understanding of A’s false belief about B’s belief) as compared to hearing peers matched for age and nonverbal intelligence. They also found differences between the groups in understanding why someone might say something not literally true (e.g., a white lie).

The above findings are consistent with reviews by [Peterson \(2009\)](#) and [Peterson and Siegal \(2000\)](#) concluding that with false belief tasks as the metric for ToM, children who are exposed to sign language relatively late generally experience significant ToM delays relative to hearing children and deaf native signers who, from birth, have access to a shared language in which to converse with family members. [Marschark, Green, Hindmarsh, and Walker \(2000\)](#), however, obtained results like [Morgan and Kegl’s \(2006\)](#) finding of mental state terms (e.g., *think*, *know*, *guess*) being used spontaneously by late signers in a narrative task. The Marschark et al. study involved deaf and hearing 9- to 15-year-olds in an open-ended narrative task in which the children made up stories on selected fantasy themes. All of the deaf children had hearing parents; none were native signers. The deaf children were found to use just as many mental state words and expressions as the age-matched hearing peers, suggesting that predicting others’ behavior on the basis of a ToM in false belief tasks is more complicated than simply recognizing that others have minds of their own. Children—deaf or hearing—thus might have ToM and use mental state terms even if they do not succeed in false belief tasks that require metacognitive predictions of how others would act in particular situations where beliefs and reality are at odds. [Peterson and Slaughter \(2006\)](#) and [Peters, Remmel, and Richards \(2009\)](#) obtained similar findings. Peterson and Slaughter tested a sample of late-signing deaf children aged 6–11 years. Many of the children who failed standard, first-order false belief tests nevertheless included mental state terms appropriately when creating spontaneous narratives in response to pictures. Peters et al. investigated ToM in children with cochlear implants (CIs), aged 3–12 years. They found the children were far more likely to use mental state terms when narrating a wordless children’s picture book than when explaining characters’ anomalous actions (based on false beliefs) in a series of video clips.

In short, ToM development clearly is related to language, both in terms of children’s levels of language development and

the extent of current and previous access to language-based interactions (signed or spoken), especially in social settings. Early access to sign language among deaf children of deaf parents thus is associated with better ToM performance both when false belief tasks are used as indicators and when the concept is defined more broadly and developmentally as a sequence of conceptual milestones on a Theory-of-Mind Scale (Peterson, Wellman, & Liu, 2005; Wellman & Liu, 2004) that includes understanding false belief as an intermediate step. Differences between deaf children of deaf parents and deaf children of hearing parents are complex, however, and go beyond simple access to fluent language and active participation in conversation. Deaf children who have limited access to effective communication either because they learn to sign later or because their hearing parents are less skilled and/or less comfortable with sign language likely will benefit less from direct and indirect (i.e., incidental) communicative interactions.

Even when social communication is facilitated through parents' and deaf children's mutual use of sign language, in either deaf or hearing families, the incidental acquisition of such information may be more limited because it depends on relatively unidirectional observation as opposed omnidirectional overhearing of spoken conversations among others. As a result, ToM development among deaf children of deaf parents (or signing hearing parents) may be more variable than among hearing children of hearing parents or perhaps limited in terms of benefits being associated with earlier stages of development but not later, more advanced aspects of ToM (e.g., second-order false belief). Such limitations, in turn, may affect cognitive development in addition to social and language development, as well as further interactions among all three. These issues largely remain empirical questions, however, given the relatively few studies that have explored the long-term impact on advanced ToM of early access to social conversation. Deaf children's having increasingly greater access to auditory input through the use of CIs and digital hearing aids thus offers another perspective on—and perhaps another facilitator of—their ToM development.

Theory of Mind and Cochlear Implant Use

The demonstrated advantage on false belief tasks for deaf children who acquire sign language early on from their deaf parents as compared to deaf children of deaf or hearing parents who use spoken language (Courtin, 2000; Meristo et al., 2012) does not necessarily indicate any a priori advantage to ToM development from language in the visual-gestural modality over the aural-oral modality (but see Peterson & Siegal, 2000, p. 139). Anecdotally, deaf signers frequently suggest that they are more aware than hearing individuals of facial expression and "body language" in their conversation partners, but there does not appear to be any empirical evidence in that regard. For hearing preschoolers, both general language ability (e.g., Milligan, Astington, & Dack, 2007) and executive function skills (e.g., working memory, sequential processing, visual-spatial organization) are frequent correlates of false-belief test success (e.g., Carlson, Claxton, & Moses, 2015; Holmer, Heimann, & Rudner, 2016). However, these domain-general cognitive abilities do not fully explain ToM differences between deaf native and late signers. Woolfe, Want, and Siegal (2002), for example, found that even after controlling statistically for the influence of language ability and executive functioning, deaf native signers who had grown up in signing deaf families significantly outperformed deaf children with hearing parents on false belief tasks. Their use of the Wisconsin Card Sorting Task as an executive function measure is particularly interesting in that

performance on it depends on both working memory and inhibition, both aspects of executive function which not only are related to ToM, but also are abilities in which deaf children and young adults, with and without CIs, typically lag behind hearing peers (Kronenberger, Colson, Henning, & Pisoni, 2014; Marschark, Sarchet, & Trani, 2016).

Accessing spoken language through listening can be improved through the use of CIs, potentially providing young CI users with access to effective social communication with their parents and others, as well as to spoken language about emotions and other mental states. However, even deaf individuals who use CIs have lesser access to the prosody and other nuances of spoken language associated with emotion (e.g., Most, Ingber, & Heled-Ariam, 2012). Most and Aviner (2009), for example, obtained evidence suggesting that the enhanced auditory access provided to CI users may not be sufficient to offer advantages in social communication. They presented small samples of deaf 10- to 17-year-olds with stimuli that consisted of a single neutral sentence ("I am going out now and I'll be back later") but varied in auditory (intonation contours) and visual (nonverbal) cues that communicated the emotions of happiness, sadness, anger, and fear. There was no difference between CI users and peers who used hearing aids in their ability to identify the emotions, with both groups performing significantly below hearing peers.

Peterson (2004) compared false belief performance between small groups of 4- to 12-year-old CI users and hearing aid users who primarily used spoken language (although some were reported to have basic sign language skills) and who did not differ on measures of language development. There was no difference in the two groups' performance on false belief tasks, with both groups performing significantly below hearing peers. Wellman, Fang, and Peterson (2011) obtained similar results in their longitudinal study of performance on five ToM tasks administered to hearing children in China and the United States and deaf children in Australia. The 31 Australian children, who ranged from 4 to 12 years old at first testing, were described as late signers who used sign language in school, but 19 of the 31 also used CIs. Wellman et al. found no differences between the Australian CI users and peers who did not use CIs (henceforth "nonusers") at the time of the first testing, the only point at which the two groups were distinguished.

Sundqvist, Lyxell, Jönsson, and Heimann (2014) investigated ToM among 16 CI users, aged 4–9 years. Half of the children received their CIs prior to 27 months of age, and half received them after that age, but the two groups did not differ in their length of CI use or on measures of language or nonverbal intelligence. The ToM tasks included both a "cognitive" measure, the frequently-used Sally-Anne (unexpected location) false belief task (Baron-Cohen et al., 1985) and a "social-emotional" measure in which children had to recognize emotions and feelings experienced by individuals in a set of six stories depicting everyday situations. Sundqvist et al. reported that, as a group, the children with CIs performed at levels significantly below a hearing comparison group on both ToM tasks. Considering the earlier- and later-implanted CI users separately, Sundqvist et al. found that the earlier-implanted children performed as well as their hearing peers and significantly better than the later-implanted children on the social-emotional measure. Both the early- and late-implanted groups scored significantly lower than the hearing comparison group on the Sally-Anne task and did not differ from each other.

Ketelaar, Rieffe, Wiefferink, and Frijns (2012) conducted a large study involving a sample of 72 deaf CI users aged 1–5 years, all of whom had received their implants very early (mean =

16 months). An age-matched, hearing comparison group also was included ($n = 69$). Three different kinds of tasks were used to assess (1) nonverbal intention-perception skills, (2) the ToM concept of diverse desires (Wellman & Liu, 2004), and (3) ToM-based false-belief understanding. The CI users performed as well as the hearing children on the intention-perception tasks. However, intention-perception tasks do not require the mental representation that defines ToM but can instead be passed more simply by perceptually discriminating between deliberate and accidental actions (e.g., the sight of a hand/arm reaching purposefully for an object, picking it up, then dropping it versus a randomly waving hand/arm bumping an object that then falls over). Furthermore, such simple, non-representational intention perception tasks are routinely passed by some non-human species and by hearing infants from as young as 9 months of age (Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998), so the CI children's adept performance was not surprising. By contrast, Ketelaar et al. found the CI users' performance to fall significantly behind hearing peers on the false belief and diverse desire tasks, the latter requiring meta-representational understanding that desire (e.g., for chocolate) is a state of mind and not an inherent property of the food itself. A majority (62%) of the hearing control children passed the diverse desire task, and 31% passed the false belief task, but none of the CI users passed the latter and only 20% passed the former. Thus despite early implantation, the deaf children were significantly delayed on both of these standard ToM tasks requiring them to predict others' behaviors on the basis of desires or false beliefs.

Meristo, Strid, and Hjelmquist (2016) used two false belief tasks in another study examining potential benefits of CI use to ToM. They administered a nonverbal unexpected location task and the Sally-Anne task to eight, 4- to 8-year-old Estonian CI users; seven, 4- to 8-year-old Estonian hearing aid users; and 15, 4- to 9-year-old Swedish hearing children. The groups were comparable on nonverbal intelligence, but the CI users and hearing children scored higher than the hearing aid users on the Peabody Picture Vocabulary Test-4 (PPVT), used as a measure of language development. On the Sally-Anne task, the hearing children outperformed the hearing aid users but not the CI users. Performance on the nonverbal task was assessed via eye tracking, determining where children were looking and for how long (see Meristo et al., 2016). Results indicated significantly better performance by the hearing children than either group of deaf children. Performance on both tasks was significantly related to "language development" as measured by the PPVT, even when age and nonverbal intelligence were controlled.

Taken together, these findings are mixed but indicate that there might be some ToM benefits of using CIs to aspects of early ToM development. However, such benefits may be task dependent. That is, CI users, at least those who receive their CIs early, may develop certain ToM concepts earlier than deaf children who do not use CIs and do not have early access to sign language. Nevertheless, that level of understanding does not appear sufficient to enable them to predict others' behaviors based on their inferred emotional states or false beliefs (e.g., Ketelaar et al., 2012; Marschark et al., 2000; Sundqvist et al., 2014). Such findings suggest a need for further research, especially with older groups of deaf children and youth, both CI users and nonusers. While CIs may well facilitate ToM development by providing greater opportunities for overhearing the conversations of others (or at least to hear that conversations are occurring), the extent of any related benefits could be less than expected, because CIs do not provide users with "normal" hearing. Even if hearing among CI users is far less variable than among hearing aid users, CIs are most effective in one-on-one

situations and situations with minimal background noise. These situations are perhaps of limited value with regard to ToM development, especially for school-aged children whose conversations with peers on the playground and could, but for these limitations of CIs, have provided a rich source of ToM-relevant mental-state input (e.g., Peterson & Wellman, *in press*).

The presumed impact of CI use on ToM also is confounded naturally with age as well as increasing language abilities (which are confounded with each other). Studies involving high school and college-aged CI users have indicated that early benefits of CI use due to improved access to spoken language are attenuated or absent by that age in vocabulary and world knowledge (Convertino, Borgna, Marschark, & Durkin, 2014), reading (Geers, Tobey, Moog, & Brenner, 2008), and achievement across the academic curriculum (Crowe, Marschark, Dammeyer, & Lehane, 2017; Marschark, Shaver, Nagle, & Newman, 2015). Such findings have been attributed to the more advanced and complex linguistic, cognitive, and academic demands at secondary school and college levels relative to those involved at the primary school level (see Marschark & Knoors, 2019). It remains to be determined whether social-emotional functioning—tapped, for example, by ToM tasks—similarly will fail to show long-term benefits from CI use, or whether young adults' longer CI use might provide advantages in that domain.

Theory of Mind Becomes More Complex

As deaf (or hearing) children get older, one would expect that more frequent and more diverse social experience and increasing cognitive and language abilities would facilitate their understanding of more advanced meta-representational aspects of ToM beyond those, like first-order false belief, that typically become accessible to hearing children by the time they reach the early grades of primary school. In their pioneering elaboration of ToM as a meta-representational conceptualization of the mind, Premack and Woodruff (1978) hinted at one of the more advanced aspects of ToM: second-order false belief. Second-order false belief builds on and goes beyond the primary focus on language in ToM research. Investigations in that domain, however, largely have neglected the role of increasing cognitive mediation of ToM with increasing age. Indeed, while the ease of social-conversational access to mentalistic conversational input and discussion is a likely contributing factor to ToM development and its delay for deaf children, it is not necessarily the only one.

Beyond conversation and language ability at large, deaf children's ToM abilities would be expected to be associated with various cognitive abilities. In particular, hearing children's performance on false belief tasks has been found to correlate with their performance on a number of executive function tasks such as working memory, inhibitory control, and reasoning/problem solving. Carlson et al. (2015), for example, found evidence that, among hearing preschoolers, "executive skills are implicated in the acquisition of mental-state concepts" (p. 186). Consistent with that finding, Marcovitch et al. (2015) reported that executive function ability at age 3 years predicted ToM at age 4, with the same finding between ages 4 and 5 years, but over neither time period was the reverse relationship found. McAlister and Peterson (2013), in contrast, found that hearing children's executive functioning skills at age 4 failed to predict ToM skills at age 5, whereas ToM skills at age 4 did significantly predict executive functioning skills at age 5. Further, among slightly older children, aged 5.22–6.98 years at the outset of their study, Devine, White, Ensor, and Hughes (2016) found no longitudinal link between executive function and ToM over a four

year period, although there were associations between these abilities at each of the times of testing. Like other domain-general cognitive skills (including the ones addressed in the present study), however, executive functions including memory, sequential processing, and reasoning have developmental trajectories in deaf children, adolescents, and young adults that may differ from those in hearing children (e.g., Edwards, Khan, Broxholme, & Langdon, 2006; Harris et al., 2011; Kronenberger, Pisoni, Henning, & Colson, 2013; Marschark et al., 2017).

When considering the developmental progression of ToM understanding, there is clear evidence that certain, more advanced forms of meta-representational understanding are intrinsically connected with first-order false-belief understanding while also reflecting a clear developmental progression beyond it. As included in the present study, the more developmentally-advanced ToM concept of second-order false belief requires first-order false belief (predicting Person A's behavior based on a false belief) but also recursively requires a more advanced level of metacognitive reasoning (predicting Person B's false belief about Person A's belief). Thus, whereas a majority of hearing children pass first-order false belief by age 5–6, second-order false belief is rarely fully mastered before the age of 8–10 years (e.g., Perner & Wimmer, 1985). Another ToM concept that builds upon yet goes beyond first-order false belief is sarcasm. Extending Wellman and Liu's (2004) five-item developmental scale of social cognition milestones, Peterson et al. (2012) tested the appreciation of nonliteral communicative intent such as sarcasm, irony, and humor—abilities that also do not emerge among hearing children until about 8–10 years of age. That study included a group of late-signing deaf children, aged 6–12 years, who were found to lag significantly behind hearing age-mates in their understanding of sarcasm even when age and language ability were controlled. The sarcasm task proved difficult even for typically developing hearing children up to age 11, indicating it to be a useful task for tapping ToM at later ages.

O'Reilly, Peterson, and Wellman (2014) examined advanced ToM among deaf adults as well as children in experiments involving native signers, late deaf signers, and age-matched hearing individuals. Their first study involved 5- to 12-year old deaf children, some of whom were native-signers and some of whom did not enter a signing environment until 4–5 years of age but were deemed to be “skilled signers.” They were administered tasks that assessed understanding of first-order false belief (e.g., “Where will she look?”), second-order false belief (e.g., “Where does the boy think Mum will go to look for the present?”), and sarcasm (“That’s what I call good manners” said to a child who had been rude). On first-order false belief tasks, the hearing children significantly outperformed both groups of deaf children, while the deaf native signers significantly outperformed the deaf late signers. On both second-order false belief and sarcasm tasks, the hearing children outperformed both groups of deaf children, which did not differ from each other, although floor effects were apparent (O'Reilly et al., 2014, p. 1866). Seventeen (40%) of the children had CIs, but analyses indicated no significant differences between them and the 25 children without CIs on any of the ToM or language measures. First-order false belief, second-order false belief, and sarcasm also were assessed in O'Reilly et al.'s (2014) second study, involving deaf native-signing and late-signing adults (aged 18–69 years) and a hearing comparison group. On all three tasks, the native-signing deaf participants did not differ significantly from the hearing participants, and both groups outperformed the late sign language learners. No information was provided

on possible CI use among the adult deaf participants, nor were possible effects of age discussed.

Hao, Su, and Chan (2010) studied mental state language in four groups of Chinese college students: deaf native-signers, deaf late signers from hearing families who became deaf before acquiring spoken language, deaf late signers from hearing families who became deaf after acquiring spoken language, and a hearing comparison group. CI use among the deaf students was not reported. The hearing group outperformed all the deaf groups in use of mental state terms during recall of a story containing embedded false beliefs, but performance of the postlingually deaf group equaled that of the hearing group and surpassed the other two deaf groups in implicit use of mental state language during story comprehension. Thus, consistent with O'Reilly et al. (2014), the deaf individuals who had grown up from birth with full access to either signed language (i.e., native signers) or spoken language (i.e., hearing and postlingually-deafened adults) displayed advantages over late signers whose prelingual hearing losses would have limited early access to conversation in their hearing families.

The Present Study

The limited research concerning ToM among deaf adults relative to that involving deaf children leaves open questions of the extent to which early access to social communication either through CIs (i.e., spoken language) or sign language is associated with advanced ToM skills and the extent to which it might be mediated by various cognitive abilities different from those involved for deaf (or hearing) children. The present study therefore was designed to extend previous research by investigating these issues among deaf and hearing college students, as indicated by their understanding of sarcasm, second-order false belief, and double bluff (O'Reilly et al., 2014; Peterson et al., 2012). The deaf participants included both CI users and nonusers. Studies reviewed above concerning potential benefits to performance on ToM tasks from deaf children's use of CIs indicated that CI users and nonusers rarely differ significantly, with both groups usually performing below hearing peers. It is possible that longer CI use might result in individuals becoming more attuned to the nuances of spoken language that reflect emotional states, and thus we might expect a divergence in ToM performance among young adult CI users and deaf nonusers, in favor of the former.

As noted earlier, studies involving older deaf learners have found that early academic benefits associated with CI use and usually attributed to access to spoken language are diminished or absent by high school age (Convertino et al., 2014; Crowe et al., 2017; Geers et al., 2008; Marschark, Shaver, et al., 2015). What limited evidence is available also suggests no differences in social participation among young adults as a function of CI use (Kushalnagar et al., 2011; Marschark, Machmer, et al., 2018). A primary question in the present study thus was whether CI use or duration of use would be significantly associated with performance on advanced ToM tasks. The study also included consideration of deaf participants' language abilities and two cognitive factors potentially related to ToM, visual-spatial processing and sequential processing, both aspects of executive function that have been explored with college-age CI users and nonusers (e.g., Beer et al., 2014; Kronenberger et al., 2014; Marschark, Spencer, et al., 2015).

Because most false belief tasks, including the second-order false belief tasks used here, encourage if not require visual-spatial imagery of task content, participants' visual-spatial

abilities were assessed using a well-documented assessment tool for that domain. Deaf individuals, and particularly those who use sign language, frequently are assumed to be advantaged in the visual-spatial domain, at least when tasks require significant allocation of attention (e.g., Bavelier, Dye, & Hauser, 2006; Hauser, Lukomski, & Hillman, 2008). A number of recent studies, however, have failed to find advantages on visual-spatial tasks among deaf learners from preschooler into early adulthood, including those with CIs (AuBuchon, Pisoni, & Kronenberger, 2015; Beer et al., 2014; Edwards & Anderson, 2014; Kronenberger et al., 2014; Marschark, Spencer, et al., 2015). It nevertheless remains an empirical question whether visual-spatial ability might benefit deaf individuals and/or deaf signers on ToM tasks relative to hearing individuals and/or deaf individuals who use spoken language. To the extent that the understanding of sarcasm might be facilitated by mental imagery associated with either task content or likely facial expressions (Most & Aviner, 2009), visual-spatial ability might be of significant benefit on the sarcasm task as well.

Both first-order and second-order false belief tasks also involve sequential processing, as performance depends on recognition and retention of sequences of events. Several studies have suggested that hearing individuals generally outperform deaf individuals, both CI users and nonusers, on tasks requiring sequential processing, such as recall of sequentially-presented verbal or nonverbal information (Dawson, Busby, McKay, & Clark, 2002; Kronenberger et al., 2014; Marshall et al., 2015), although here again, findings are inconsistent (e.g., Edwards & Anderson, 2014; Marschark, Walton, Crowe, Borgna, & Kronenberger, 2018). The extent to which sequential processing skill is associated with performance on ToM tasks apparently has not been investigated previously with either deaf or hearing individuals. It was examined in the present study through use of a nonverbal (visual-spatial) sequential processing task (Woolfe et al., 2002).

Finally, the present study considered deaf participants' communication skills and preferences. A well-documented communication questionnaire was administered to deaf CI users and nonusers concerning spoken language skills and sign language skills as well as information about CI and hearing aid use.

In summary, the present study compared performance of deaf and hearing college students on three kinds of advanced ToM tasks: sarcasm, second-order false belief, and double bluff. Within the deaf sample, performance was examined in terms of self-rated sign language and spoken language abilities as well as CI and hearing aid use. Possible links between ToM performance and participants' visual-spatial and sequential processing abilities also were explored. In principle, visual-spatial and sequential executive functioning could provide advantages for all participants. However, the influence of visual-spatial abilities on ToM performance would be expected to be most pronounced among deaf individuals, who generally are visually oriented (Bavelier et al., 2006; Hauser et al., 2008; Woolfe et al., 2002), while the influence of sequential problem solving abilities should be most pronounced among hearing individuals, who typically evidence better sequential abilities (Marschark & Knoors, 2012). On the basis of previous findings involving deaf children, the impact of sign language should be particularly apparent among deaf participants in the present study who report being native signers. Although only about 3–5% of deaf children in the United States have a deaf parent (Mitchell & Karchmer, 2004), previous studies involving the student population from which the present sample was drawn found that native signers comprised about 10% of the research samples.

Method

Participants

All participants were volunteers recruited through posted advertisements or personal contact and paid for their time. They included 94 deaf² students (42 females, 52 males) and 41 hearing students (26 females, 15 males) attending a university in the northeastern United States. Forty-six of the deaf participants were active CI users (mean age of first/only implantation = 6.62 years, $SD = 4.84$); 14 of them reported using two CIs (mean age of second implantation = 14.79 years, $SD = 2.94$). These ages are relatively late by current standards, but they accurately represent the present college-age cohort in the United States. Forty-three of the deaf participants, including six CI users, reported being active hearing aid users. Eleven of the deaf students reported using neither CIs nor hearing aids.

Four deaf students (two CI users, two nonusers) reported knowing no sign language. Nine of the 90 deaf participants who reported knowing sign language reported being native signers (i.e., signing since birth). This number is relatively high in the population at large but, as noted earlier, the proportion is consistent with previous studies involving students at this university. The 81 "late signers" reported learning sign language between 5 and 22 years of age (mean = 6.91, $SD = 5.85$). Hearing students were not asked about possible sign language skills. Collection and analyses of self-report language measures are described below.

Materials and Procedure

Testing was conducted in a laboratory setting, individually or in small groups, depending on student schedules. Testing was conducted by one of two investigators who also were sign language interpreters very familiar with student communication skills through more than 15 years' experience each interpreting at the university. They communicated with participants using sign language, spoken language, or both depending on participant preference.

Deaf participants first completed the short communication questionnaire. They were asked to rate their overall sign language skill using a 5-point Likert scale from "I don't know sign language" to "excellent." They rated their spoken language skills on two dimensions: how well they understand spoken language on a 5-point scale from "nothing" to "everything people say" and how much they thought others understand their speech on a 5-point scale from "nothing" to "everything I say." Those two ratings were averaged to yield an overall measure of spoken language skill comparable to the rating of overall sign language skill. Deaf participants also were asked to indicate which language modality was their "best form of communication" (signed or spoken), the age at which they learned sign language, whether they used hearing aids, whether they used CIs and, if so, the age(s) at which they had received them. Finally, if participants used hearing aids or CIs, they were asked to rate how often they used them on a four-point Likert scale from "not often" to "all the time." The use of these language self-ratings have a long history with this population (e.g., McKee, Stinson, & Blake, 1984). Although Likert scales run the risk of individuals' inflating self-assessments (and perhaps avoiding the end points), they have proven consistent with objective assessments of sign language and spoken language abilities among deaf university students with and without CIs in previous studies (e.g., Marschark, Machmer et al., 2018; Spencer et al., 2018) as

well as behavioral outcomes in a variety of studies conducted with this population (e.g., [Convertino, Marschark, Sapere, Sarchet, & Zupan, 2009](#); [Marschark et al., 2017](#)). Further, for the purposes of analyses reported below, only relative differences in self-reported language skills are relevant here, and thus absolute differences with objective assessments are not at issue. Participants' responses to the communication questions are summarized in Table 1.

Participants' visual-spatial skills were assessed using the Spatial Relations task of the Woodcock-Johnson III Tests of Cognitive Abilities (WJ-III; [Woodcock, McGrew, & Mather, 2001](#)). This 33-item task requires individuals to identify two or three shapes (out of six) that can be combined to form a complex target shape, tapping visual feature detection, manipulation of mental images, visual-spatial matching, and visual-spatial construction skills. After reading the instructions and viewing the practice items, participants were given 8 min to complete as many of the test items as they could. Each participant's score was simply the proportion of the 33 items correctly completed.

Next, participants' sequential processing skill was evaluated using the 20 items on the Sequences subtest of the *General Ability Measure for Adults* (GAMA; [Naglieri & Bardos, 1997](#)). Use of that task here follows [Woolfe et al.'s \(2002\)](#) suggestion that non-verbal sequential processing tasks are most appropriate for assessing executive function in deaf children (early and late signers, in their case). The GAMA sequential items require selection of one of six figures that completes a logical sequence of geometric designs that vary in shape, color, and location. Naglieri and Bardos described this subtest as requiring analysis of interrelationships among designs, emphasizing attention to spatial and sequential arrangements of the geometric figures. After reading the instructions and viewing practice items, participants were given 6 min to complete as many test items as they could. Each participant's score was the proportion of the 20 items correctly completed.

The untimed ToM tasks involved eight short stories tapping advanced ToM. Two tested recognition of second-order false beliefs, two tested double-bluff understanding, and four tested understanding of sarcasm (see [Appendix](#)). The second-order false belief stories were modified versions of stories used by [Coull, Leekam, and Bennett \(2006\)](#) and [O'Reilly et al. \(2014\)](#). Modifications in both cases were very minor. For example, our "Postcard" story (see [Appendix](#)) had the same test questions, control question and overall narrative structure as Coull et al.'s Study 2 "New Story" but to make it more suitable for adults we replaced the toy robot in their story with a postcard. Double bluff stories came from [Happé \(1994\)](#). The sarcasm stories were

versions of stories used by [O'Reilly et al. \(2014\)](#), slightly modified to be appropriate for North American deaf adults. As the participants were all college students, and Flesch-Kincaid reading grade levels of the eight stories ranged from 1.9 to 4.6 (mean = 3.04, $SD = 1.03$), they read the stories rather than having them presented in any other format. Participants were given the stories and told "Here are several short stories with questions after each. Please read the stories and answer the questions as best you can." The task was untimed.

Performance for each story was evaluated based on participants' responses to a single control question that checked for comprehension of factual information (for example, "Where is the present now?") and a single test question that assessed ToM understanding (a "why" question in each case). The two second-order false belief tasks involving unexpected locations required grounding questions to set up the "why" test questions. These were not scored, both for consistency with the corresponding sarcasm and double bluff items and because the vast majority of participants got both grounding questions correct. Scoring of test questions was closely based on the detailed descriptions provided by [O'Reilly et al. \(2014, Appendix A\)](#) and [Coull et al. \(2006, Appendix B\)](#).

Results

Performance Scores

Preliminary analyses examined possible differences among the three participant groups (CI users, $n = 46$; nonusers, $n = 48$; hearing, $n = 41$) in the frequencies with which they passed the control questions associated with the sarcasm items and the advanced false belief (second-order and double bluff) items. A one-way analysis of variance with sarcasm control question scores as the dependent variable yielded a significant effect of group, $F(2, 132) = 9.04, p < .001$. Bonferroni-adjusted post hoc tests indicated that the hearing participants passed significantly more control questions than either group of deaf participants, $ps < .01$, which did not differ significantly from each other (see [Table 2](#)). A similar analysis with second-order false belief control question scores as the dependent variable also yielded a significant effect of group, $F(2, 132) = 9.07, p < .001$. Bonferroni-adjusted post hoc tests again indicated that the hearing participants passed significantly more control questions than either group of deaf participants, $ps < .01$, which did not differ significantly from each other. Analysis of the control question scores for the double bluff items did not yield a significant effect, $F(2, 132) < 1.0$, as all groups were near ceiling (see [Table 2](#)).

Table 1. Mean scores on communication variables for deaf cochlear implant (CI) users ($n = 46$) and deaf nonusers ($n = 48$)

	CI users		Deaf nonusers	
	Mean	SD	Mean	SD
Age at cochlear implantation (years)	6.62	4.84	—	—
Age at sign language acquisition (years)	7.10	6.02	5.38	5.77
Frequency of cochlear implant use	3.33	0.79	—	—
Spoken language ability	2.73	0.66	2.08	0.99
Sign language ability	2.91	1.07	3.06	1.16
Hearing aid use	$n = 6$		$n = 37$	
Frequency of hearing aid use	0.30	0.87	2.38	1.62
Best form of communication				
Sign language	$n = 27$		$n = 31$	
Spoken language	$n = 19$		$n = 16$	

Table 2. Mean theory of mind, sequential processing, and visual-spatial processing scores

	CI ^a users n = 46		Deaf nonusers n = 48		Hearing n = 41	
	Mean	SD	Mean	SD	Mean	SD
Sarcasm control	0.83	0.21	0.85	0.21	0.98	0.06
Sarcasm test	0.61	0.32	0.58	0.35	0.89	0.18
Second-order false belief control	0.72	0.34	0.69	0.38	0.95	0.15
Second-order false belief test	0.35	0.33	0.45	0.42	0.89	0.21
Double bluff control	0.98	0.10	0.99	0.07	1.0	0.00
Double bluff test	0.59	0.35	0.60	0.38	0.91	0.22
GAMA ^b Sequences score	0.53	0.14	0.54	0.16	0.64	0.13
Spatial Relations score	0.75	0.13	0.76	0.14	0.85	0.10

^aCochlear implant.^bGeneral Abilities Measure for Adults.

Analyses of sarcasm and advanced false belief test scores for the three groups also involved one-way analyses of variance, but included individuals' scores only for those items for which they had passed the corresponding control questions (see Table 2). A one-way analysis of variance for the sarcasm test questions yielded a significant effect of group, $F(2, 132) = 13.99$, $p < .001$. Bonferroni-adjusted post hoc tests indicated that the hearing participants passed significantly more test questions than either group of deaf participants, $p < .001$, which did not differ significantly from each other. A similar analysis for the second-order false belief test questions yielded a significant effect of group $F(2, 132) = 31.76$, $p < .001$, as scores increased from the CI users to the nonusers to the hearing participants. Bonferroni-adjusted post hoc tests indicated that the hearing participants passed significantly more test questions than either group of deaf participants, $p < .001$, which did not differ significantly from each other. Analysis of the double bluff test questions also yielded a significant effect of group $F(2, 132) = 13.17$, $p < .001$, and Bonferroni-adjusted post hoc tests indicated again that the hearing participants passed significantly more test questions than either group of deaf participants, $p < .001$, which did not differ significantly from each other.

Participants' performance on the GAMA Sequences subtest was analyzed using a one-way analysis of variance for the three groups in which the proportion of items correct was the dependent variable. That analysis yielded a significant main effect of group, $F(2, 132) = 7.79$, $p < .001$. Bonferroni-adjusted post hoc tests indicated that the hearing participants scored higher than either group of deaf participants, $p < .01$; the deaf groups did not differ significantly from each other (see Table 2). A similar analysis of WJ-III Spatial Relations scores also yielded a significant main effect of group, $F(2, 132) = 7.91$, $p < .001$, and the post hoc tests indicated that the hearing participants demonstrated significantly greater visual-spatial performance than either group of deaf participants, $p < .001$, which did not differ significantly from each other.

In short, participants' performance in both the ToM tasks (both control questions and test questions) and the cognitive/executive function tasks (both visual-spatial and sequential) yielded essentially the same results: Hearing participants outperformed both CI users and deaf nonusers, who did not differ. Despite this consistency in the results, it may well be that ToM performance within the three groups was associated with differing cognitive/executive function abilities.

Predicting Advanced Theory of Mind Abilities

As indicated earlier, language, visual-spatial, and sequential processing abilities all appear potentially involved in correctly responding to advanced ToM questions. That possibility was evaluated here through the use of separate stepwise multiple regressions. Because the CI users and nonusers did not differ significantly either on the ToM tasks or the sequential and visual-spatial tasks, they were treated as a single group, although CI use and age at implantation were used as predictor variables together with extent of hearing aid use, sign language and spoken language self-ratings, age of sign language acquisition, reported best form of communication, GAMA Sequences scores, and Spatial Relations scores. A separate analysis was conducted for the hearing participants using the last two scores as predictor variables. For both deaf and hearing groups, sarcasm test scores, second-order false belief test scores, and double bluff test scores consecutively were used as criterion variables.

Analysis of the deaf participants' sarcasm scores yielded only self-rated spoken language ability as a significant predictor, $R^2 = .09$, $\beta = .30$, $F(1, 45) = 4.34$, $p < .05$, as better self-rated spoken language ability predicted better understanding of sarcasm. Analysis of the hearing participants' sarcasm scores yielded Spatial Relations scores as the only significant predictor, $R^2 = .18$, $\beta = .41$, $F(1, 40) = 8.40$, $p < .01$, as better visual-spatial skill was associated with better understanding of sarcasm. Analysis of the deaf participants' second-order false belief scores yielded only GAMA Sequences scores as a significant predictor, $R^2 = .12$, $\beta = .35$, $F(1, 45) = 6.07$, $p < .05$, as greater demonstrated sequencing ability was associated with better understanding of second-order false belief. Analysis of the hearing participants' second-order false belief scores yielded no significant predictors. Analyses using double bluff scores as the criterion variable failed to yield significant predictors for either deaf or hearing participants.

Importantly for the present purposes, neither CI use nor sign language ability was a significant predictor of deaf participants' performance in any of the ToM tasks, nor was the length of CI use or the age of sign language acquisition. Further, sarcasm, second-order false belief, and double bluff scores of the small group of nine deaf participants who indicated that they were native signers did not differ significantly from those of deaf participants who indicated that they learned to sign later, all $t_s(88) \leq 1.35$.

Discussion

The primary aim of this study was to determine whether the delays in ToM development seen in many deaf children continue into adulthood. In this regard, the study produced results that, though largely consistent with past research, extended and clarified previous findings in novel and important ways. In addition, the study explored possible links of advanced understanding of ToM, visual-spatial and sequential executive function abilities, and individual differences among deaf individuals in their use of CIs and hearing aids as well as their reported use of sign language and spoken language.

Previous research involving deaf preschool and school-aged children has found ToM delays that, at least in some respects, can remain substantial up to age 12 or 13 years (Gray, Hosie, Russell, & Ormel, 2001; O'Reilly et al., 2014; Peterson, 2009). Delays in the development of some aspects of ToM have even been found to persist into adulthood (Hao et al., 2010; Peterson & Wellman, *in press*). Extrapolating from earlier research, it appeared plausible that such delays might be reduced or eliminated for young adult CI users owing to greater early access to conversational, social (spoken) language. Some previous data, though limited to very small samples, also had suggested a possible advantage for adult native signers, again owing to greater early access to conversational, social (sign) language. Results of the present study, however, indicated that neither having a CI nor duration of CI use was significantly associated with advanced ToM performance. Similarly, although the sample of native signers in our study was very small, results indicated that they did not differ from other deaf signers in their ToM performance, and reported age of sign language acquisition was not significantly associated with ToM performance.

In the present study, the lack of benefits to ToM performance for the CI users compared with the deaf nonusers can be interpreted as providing further support for the conversational account of ToM development, with exposure to social-emotional communicative interactions early in life being of particular importance. In this student cohort, the age at which the CI users received their (first) implant was late by current standards, at an average over 6 years of age. Therefore in this group, like their counterparts without CIs, full access to rich and varied communicative interactions generally, and in particular social communication, is likely to have been severely limited during the early years crucial for the development of false-belief and mental state understanding (Wellman et al., 2001). It is plausible that if this developmental "window" for the acquisition of early ToM abilities is missed, early hearing loss continues to have a detrimental impact that precludes deaf individuals catching up with their hearing counterparts, even after many years of implant use (Kral, Kronenberger, Pisoni, & O'Donoghue, 2016). It remains to be seen whether the deficit is ameliorated by direct access to spoken language and indirect exposure to conversations about others' mental states in children receiving CIs in their first or second year of life, as is current practice.

While the results with regard to the CI users are disappointing with respect to the role of technology in facilitating the development of ToM among deaf children and youth, there are three factors in addition to age at implantation that suggest that such findings should not be totally unexpected. First, as noted earlier, several studies have demonstrated that despite the benefits to hearing afforded by CIs, the degraded speech signals they provide—particularly in less than quiet environments such as classrooms and social groups where conversations about others' thoughts and feelings often take place—may limit

access to the nuances of spoken language necessary for recognition of its emotional qualities. This can prove especially problematic when it comes to accessing intonation, vocal emphasis, and other prosodic cues necessary for recognition of the emotional qualities of spoken conversation (e.g., Most & Aviner, 2009; Most et al., 2012). In this regard, it might be expected that with longer CI use and exposure to diverse spoken language models, individuals could gain greater expertise in decoding the nuances of spoken language. The lack of significant associations between duration of CI use and ToM performance here suggests that is unlikely to be the case. However, it was noted earlier that the mean age at implantation in the present university student sample was quite high (6.62 years), consistent with characteristics of this U.S. age cohort. As ages of implantation continue to decline, it may be that individuals who receive CIs within the first year or so of life will develop language proficiencies and speech reception skills of sufficient sensitivity to support greater ToM acuity by the age of participants in this study. At least in the United States, such individuals have not yet reached young adulthood, so the matter will have to be left to future research.

A second reason why the present findings perhaps should not have been totally unexpected is that although both earlier cochlear implantation and early access to sign language have been found to provide young deaf children with significant advantages in vocabulary development and academic achievement, a number of studies have found those advantages to be diminished or absent by secondary school age (e.g., Crowe et al., 2017; Geers et al., 2008; Marschark, Shaver, et al., 2015; for a review, see Marschark & Knoors, 2019). Finally, although sign language can provide deaf children with access to social conversation and its emotional qualities, the necessity of direct observation—as opposed to the possibility of overhearing—limits its potential benefits for incidental learning (Marschark & Knoors, 2012).

Undoubtedly, all of these factors are interrelated, as many deaf children fail to keep pace with hearing peers in linguistic, cognitive, and academic domains as they get older (Knoors & Marschark, 2014). Moreover, neither the use of CIs nor sign language provides deaf children with the full range of language input available to typically-developing hearing children, a situation likely to be exacerbated as they need to transition from basic interpersonal communication skills to cognitive academic language proficiencies. Related limitations in linguistic knowledge (e.g., vocabulary), abilities (e.g., comprehension and repair strategies), and interest in reading will negatively impact learning from text even further. The ever-increasing interplay among these factors thus appears to create quantitative and qualitative differences between deaf and hearing individuals in cognitive and social-emotional functioning, including ToM.

Deaf participants in the present study have abundant opportunities to engage in social interactions with deaf (and hearing) peers from diverse communication backgrounds. These conversational contacts provide exposure to rich signing and/or speaking opportunities, at least in the students' current college environment, in which deaf students make up almost 10% of the student body. Such a setting affords access to varied social situations and experiences that could support and enhance students' understanding of other's mental states while also exposing them to the potential complexities of social situations of the sort examined in the present study. A limiting factor, however, might be the fact that deaf youth frequently choose friends who are deaf and may socialize more with peers who have communication and language abilities similar to their own (Kersting,

1997; Punch & Hyde, 2011). While facilitating their everyday social-conversational interactions, this could result in reduced exposure to situations that could challenge and extend ToM understanding, especially the understanding of socially-complex situations like those addressed in the advanced ToM tasks employed here. Future studies might evaluate this suggestion by exploring possible links between deaf students' ToM scores and their naturalistically-observed conversational patterns (e.g., frequency of discussion of cognitive mental states, use of sarcasm) and the similarity of ToM performance between friends.

While it may be that some aspects of social competency, such as social maturity and social confidence, do not differ between deaf young adults as a function of sign language or CI use (e.g., Antia & Kreimeyer, 2015; Marschark et al., 2017; Marschark, Walton, et al., 2018), these attributes may rely less on advanced cognitive skills than does ToM understanding. For social maturity and social confidence, the incidental learning from interactions with family, peers, and others to whom deaf children and young adults have had access may be sufficient to facilitate typically-developing social skills in early childhood, even if not at an equivalent pace to that of hearing peers. Advanced ToM tasks, in contrast, test the individual's ability to use basic ToM reasoning (i.e., understanding mental states such as belief, desire or intention) in a more flexible, pragmatic, context-sensitive manner and in application to puzzling "real life" social contexts that are inevitably more complex in adulthood than those encountered in childhood.

An additional factor contributing to apparent delays in ToM among the deaf college students in this study is the likely reduction (or possible absence) of explicit teaching of ToM understanding and skills after primary school age. Coping with social exclusion, emotion regulation, and empathy also can prove problematic, reducing opportunities for the kinds of social interactions that foster more advanced ToM functioning (see Antia & Kreimeyer, 2015). As a result, there has been an increase in school-based interventions focusing on these skills in the preschool and primary years. Antia and Kreimeyer (2015, Chapter 11), for example, described interventions teachers of deaf children can use to promote the development and use of social interaction skills such as conversational language and turn-taking, recognizing and responding to peer emotions, and social problem-solving through scaffolding of interactions, group work, role-play, and coaching of social routines. All of these could be expected to have at least an indirect impact on the development of ToM skills. Morgan (2015) described a possible intervention for social cognitive learning and ToM based on Wellman and Liu's (2004) five-stage framework of development of ToM. However, Morgan's intervention, which tackles ToM reasoning explicitly, is designed for use with deaf children from infancy (aimed at optimizing early communication in the family) to a school intervention for 3- to 5-year-olds. The PATHS curriculum (Greenberg & Kusché, 1998) also has been suggested as an effective intervention strategy for social interaction and communication (Antia & Kreimeyer, 2015), but it is aimed at deaf children only of primary-school age. As such, we still are in need of research into interventions designed to support ToM understanding or development for teens and young adults.

Thus far, the present findings have been considered primarily within a social-conversational framework for conceptualizing the development of ToM understanding and the delays or deficits in its acquisition created by deaf children's early social-linguistic environments. A full explanation of ToM functioning, however, also needs to take into account known differences between deaf

and hearing children (as well as adolescents and young adults) in language and cognitive abilities. In particular, this study used two nonverbal executive function tasks to evaluate the potential contributions of visual-spatial ability and sequential processing ability to advanced ToM understanding. Results indicated poorer performance on both the WJ-III Spatial Relations task and GAMA Sequences task among the deaf college students compared with hearing peers. The lack of differences between CI users and nonusers on either task parallels the pattern observed on both control and test questions in the ToM task, emphasizing that advanced ToM performance depends on more than language skills alone. Although significantly better performance on the Spatial Relations task by the hearing participants may appear counterintuitive given some previous findings regarding visual-spatial cognition in deaf individuals (e.g., Bavelier et al., 2006; Hauser et al., 2008), that finding is consistent with findings from several studies, some of which have been used to establish equivalence of deaf and hearing participants in terms of nonverbal intelligence or academic ability (e.g., Beer et al., 2014; Kronenberger et al., 2014; Marschark, Spencer, et al., 2015).

The demands of the present ToM tasks on executive function and other cognitive abilities are likely to have been considerable (Kronenberger et al., 2014), and therefore may have placed deaf participants at a disadvantage, contributing to their poorer scores on both the second-order false belief and sarcasm tasks. Higher-order ToM tasks of this sort, which embed basic ToM concepts (such as what someone believes or thinks) in hierarchical structures (such as what someone thinks a third person thinks or believes), require high-level working memory and problem-solving abilities. Holmer et al. (2016) thus found ToM performance associated with working memory ability but not sign language ability among deaf 7- to 14-year-olds. In fact, they observed delays in ToM development despite the children having age-appropriate sign language skills.

The present findings indicate a relationship between ToM and hearing loss among deaf young adults largely uninfluenced by CI use or use of signed versus spoken language. The picture becomes more complex, however, when the precise roles of visual-spatial and sequential processing and self-reported communication skills are examined in more detail. Considering first the deaf participants (CI users and nonusers combined), the only significant predictor of understanding of sarcasm among these deaf college students was self-rated spoken language skills. Sarcasm is one aspect of nonliteral communicative intent that has been proposed to reflect a more sophisticated, advanced understanding of mental states. Empirical evidence shows it to develop after first-order false belief understanding in both deaf and hearing children (Peterson et al., 2012). Sarcasm understanding may reasonably be hypothesized to require a more advanced level of language competency than first-order false belief tests and may possibly benefit from written as well as spoken language skills. Since use of spoken (English) language among deaf secondary and college students is associated with better English and reading comprehension test scores (Crowe et al., 2017; Marschark, Shaver, et al., 2015), the deaf students in this study who were more proficient in the use of spoken language may have had a fuller understanding of the stimulus stories. Those deaf students also may have had greater access to the intonation and prosody of spoken language that frequently indicate sarcasm, either as a consequence of lesser degrees of hearing loss or the use of CIs and hearing aids. While the self-report measures of spoken language and sign language abilities used here are only proxies for formal tests of students' language skills and their hearing thresholds

were not available, the self-report measures used here have been validated in recent studies (e.g., Marschark et al., 2018; Spencer et al., 2018).

Still considering the deaf students, superior performance on the second-order false belief tasks was predicted by higher GAMA Sequences scores. This is not surprising given the highly sequential nature of the information in each story: Comprehension of the stories is dependent on the ability to process successive pieces of information, holding them in mind, then making a judgment based all the information available. This interpretation is consistent with findings of Botting et al. (2017) and Edwards and Anderson (2104) indicating that nonverbal executive function abilities are predicted by various language skills.

There was no evidence that sequential or visual-spatial abilities or factors relating to communication played a role in deaf students' understanding of the double-bluff scenarios presented in this study. Unlike the second-order false belief stories, those stories only require the individual to recognize that another person wishes to deceive a listener and that this intention can be implemented by speaking the literal truth. They do not necessarily entail further steps like recursive belief understanding or predicting behavior based on those beliefs (Ketelaar et al., 2012; Marschark et al., 2000; Peterson & Slaughter, 2006). Thus, they are less complex and hence potentially less dependent on cognitive processes such as reasoning or working memory.

Considering now the hearing participants, this study found no evidence for an association between either second-order false belief or double bluff understanding and either visual-spatial or sequential processing ability. However, in this group, higher scores on the sarcasm stories were predicted by superior performance on the WJ-III Spatial Relations test. While the reasons for this dissociation are unclear, several other studies involving deaf and hearing college students engaged in cognitive tasks have found different predictors for the two groups (e.g., Borgna et al., 2018; Marschark et al., 2017; Marschark, Spencer, et al., 2015). The extent to which such differences derive from hearing status, language ability, educational background, or some other factor(s) remains to be determined.

Implications and Conclusions

Educational interventions aimed at encouraging the development of mental state understanding and at establishing the skills needed for deaf children to function appropriately in social interactions with their peers and adults are already routinely implemented in many schools. These interventions often are not aimed specifically at deaf children, and while they may prove to be beneficial to them (or subgroups of deaf children), particular interventions may not address the specific difficulties or build on the strengths of all deaf children. In contrast to these generic approaches, Wellman and Peterson (2013) described a 6-week ToM training program, tested on 43 5–13 year old deaf children of hearing parents, using thought-bubbles to represent and elicit talk about mental states such as thinking, knowing, wanting, and seeing. They concluded that delays in ToM development are not intractable, and that intensive training can lead to dramatic improvements on a range of standard ToM tasks. Such programming usefully could be extended, using age-appropriate materials and teaching methods, to older deaf students. Marschark and Knoors (2019) also pointed out that early interventions for deaf and hard-of-hearing learners focusing on

language and academic achievement may not be sufficient, as many if not most students would continue to benefit from relevant interventions throughout the school years. In light of the results of the present study, we would argue that such interventions should extend to explicitly developing mental state understanding and social competency throughout the secondary school years and perhaps even beyond.

In the absence of any evidence to date that there is some specific cognitive impediment to deaf individuals acquiring ToM and related abilities, the present findings provide support for extending to young adults a social-conversational account of mental state understanding. At the same time, insofar as the present participants were young adults with language skills appropriate for university entrance, it appears unlikely that the differences in ToM performance observed in the present study can be attributed to linguistic ability per se. Previous studies have demonstrated that early access to sign language is associated with better ToM performance, at least among children. The present findings, in contrast, indicate that neither being a native signer nor having access to spoken language via a CI at an earlier age is associated with ToM performance among college students. These findings thus raise questions about the long-term impact of early access to language (see Marschark & Knoors, 2019) and suggest the need for future studies to advance understanding of the issues involved. For example, beyond examining ToM performance and young adults who receive CIs as infants, it would be worthwhile to examine how ToM acquisition and behavior are related to other aspects of social-emotional functioning such as social maturity, prosocial and antisocial behavior, and social dominance.

In terms of the cognitive processes that are likely involved in ToM abilities, working memory is a main contender. Relative difficulties in working memory, both verbal and visual-spatial, have been found among deaf individuals from early childhood through adulthood (Edwards & Isquith, in press; Marschark & Knoors, 2012; Rudner, Toscano, & Holmer, 2015), and these are largely independent of CI use or (signed or spoken) communication mode (Marschark et al., 2016; Marschark, Spencer, et al., 2015). Such difficulties may hinder the development and expression of ToM understanding, especially when it comes to recalling and integrating complex social information needed both in everyday adult social interactions and in order to pass advanced ToM tasks such as those used in this study. Similarly, executive control processes such as response inhibition may be critical in allowing the individual to resist the pre-potent response of viewing a social situation from their own perspective. Even as adults, whether deaf or hearing, such “egocentric” failures to perceive or appreciate someone else’s point of view can limit the quality of a person’s social participation and close relationships as well as their ToM test performance.

The present findings suggest the importance of future research into the potential of interventions based on executive function and other higher-level cognitive skills likely involved in higher-level ToM to boost advanced social cognition in real-life situations as well as in test performance. Targeted training for those who fail advanced ToM tests like those used here could ameliorate some of the social and conversational difficulties that at least some deaf adolescents and young adults encounter, including everyday problems in communicating with conversational partners who use subtle conversational devices like sarcasm or double bluffing. Resulting gains in conversational skill may then have follow-on benefits for further linguistic and cognitive growth as well as academic achievement.

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Conflicts of interest

No conflicts of interest were reported.

Notes

1. In studies with deaf children (including all those cited here unless noted otherwise), false-belief tasks are spoken and/or signed by the experimenter, depending on the child's mode of communication.
2. Participants in such studies typically are referred to as "deaf," "deaf and hard of hearing," or "having a hearing loss." Detailed audiological information is rarely available, but no studies to date have reported degree of hearing loss being associated with ToM development or performance. Participants in the present study varied in their hearing losses, but all were sufficient to qualify for related support services (i.e., sign language interpreting or real-time text). Neither current hearing thresholds nor other demographic information was available for the purposes of this study.

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Appendix

Theory of mind materials based on Coull et al. (2006), Happé (1994), and O'Reilly et al. (2014)

Sarcasm Stories

The Park

Sara and Tom are good friends. They are going to have lunch outside in the park for Sara's birthday. It is Tom's idea. He says it will be a lovely sunny day, a perfect day for a picnic in the

park. But just as they unpack the food, it starts raining. Soon both Sara and Tom are all wet. The birthday cake is soggy and ruined. Sara is mad! She tells Tom, "Oh yes, it's a lovely day for lunch in the park. Yes, indeed." *Control question:* Was Sara happy about the rain? (yes or no) *Test question:* Why did she say to Tom "Oh, yes, it's a lovely day for lunch in the park"?

Party Food

A girl and a boy are at a party. There is a big table covered with delicious food: cake, pies, ice cream, chocolates, lollipops, and chips. The boy rushes over to the table and fills his plate with food. He eats it all up and rushes back to the table again. He fills his plate again and has finished his second plateful before the girl can even get to the front of the line to get any food. When the boy goes back a third time to fill his plate again, the girl still hasn't had anything. She sees the big pile of food on the boy's plate and says, "Are you sure you have enough food? You're not eating enough. You must not have been hungry. You are just too polite." *Control question:* Does the girl think the boy did not eat enough food? (yes or no) *Test question:* Why did she say "You're not eating enough food"?

The Goalie

Matt and Joe are good friends. They love to play soccer and are on the same team. At the last soccer game, Joe was playing goalkeeper. That day, Joe was not trying. He was slow and lazy and did not pay attention to the ball. He missed a lot of easy saves. Because of this, their team lost the game. Matt was unhappy about losing. Matt said to Joe, "You sure are a great goalkeeper, Joe! You played really well today!" *Control question:* Did Matt think Joe had played well? (yes or no) *Test question:* Why did Matt say that Joe played really well in the game?

The Beach

It's Saturday and the girl and boy want to go swimming. The girl says, "Let's go to the indoor pool so we won't get caught in the rain." But the boy says "No, let's go to the beach instead. The sun is shining, and it is going to be a perfect day for the beach." The girl says "Okay," and they get on the bus for the beach. But just as they arrive at the beach, there is a big storm. There is so much thunder, rain, and wind that they can't even get off the bus. They go straight back home with no swimming. Now it is too late for the pool. The girl says to the boy, "You were right, it was a perfect day for the beach!" *Control question:* Does the girl think the boy was right about the weather? (yes or no) *Test question:* Why did the girl say it was perfect weather for the beach?

Second-order false belief stories

The Birthday Gift

The boy and his mom are in the bedroom wrapping Dad's birthday present. It's supposed to be a surprise for Dad. Mom says, "Let's hide the present under the blue bed so Dad doesn't see it." She does that and then she says, "I am going shopping now."

Mom leaves the room and closes the door. But then she sneaks back and peeks into the bedroom through the window. The boy can't see her. The boy wants to play a trick on his mom. He moves the present. He takes it out from under the blue bed and puts it under the pink bed. *Control question:* Where is the present now? (under the blue bed or under the pink bed). More: Then Mom comes back. She says "I bought a birthday card. I'll get the present and put the card on it." *Grounding question:* Where does the boy think his mom will go to look for the present? *Test question:* Why does he think that?

The Postcard

Jason and his big sister are playing in Jason's room. Jason just got a postcard from a friend, and he doesn't want his sister to read it. Their mom calls Jason. He hides the card under his blanket and goes downstairs. His sister takes the card out and reads it. Then she puts the card in Jason's desk. Jason finishes with their mom. Before coming back into his bedroom he peeks around the door and sees his sister moving the card from his bed to his desk drawer. He watches her but she does not see him. *Control question:* Does Jason know that she moved the card? (yes or no). More: Then Jason returns. He says to his sister "Okay, I will show you the postcard." *Grounding question:* Where does his sister think Jason will go to get the card? (the bed or the desk) *Test question:* Why does she think that?

Double Bluff stories

The Baseball Bat

Mary is always teasing her little brother Joe and telling him lies. Joe knows this. He thinks Mary never tells him the truth. Now Mary has hidden Joe's baseball bat somewhere. Joe can't find it. He knows Mary hid it. Joe says, "Where is my bat, Mary? You must have hidden it either in the cupboard or under your bed, because I've looked everywhere else. Is it in the cupboard or under your bed?" Mary answers, "The bat is under the bed." *Control question:* Where does Joe go to look for his bat? (the cupboard or the bed). More: Actually the bat is under Mary's bed. *Test question:* Why did Mary tell Joe that the bat is under the bed?

The Soldier

During the war between the Orange army and the Blue army, the Orange army captures a Blue army officer. They want him to tell them where the Blue army is hiding. They say, "We know your Blue army is either up in the hills or in the trees beside the lake. You must tell us where it is." The Orange army men know the Blue officer will not want to tell them the truth. The Blue officer is brave and wants to help his Blue army. Really, the Blue army is hiding in the hills. But remember, the Blue prisoner does not want the Orange army to know this. He says, "My army is in the hills." *Control question:* Does the Blue prisoner know the Blue army is in the hills? (yes or no). *Test question:* Why did the Blue prisoner tell his enemies the truth?