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Do deaf adults with limited language have advanced theory of mind?

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ABSTRACT

Previous studies show that deaf children have deficits in false belief understanding due to their language impairment. However, it is not clear whether deaf adults still have problems in advanced theory of mind (ToM). The present study examined deaf adults' performance on three aspects of advanced ToM. All of the deaf groups lacking mental state language tended to perform worse than the hearing group on explicit mental state understanding. Deaf groups with either vocabulary skill or interpersonal experience from early years were similar to the hearing group in implicit mental state reasoning. Individuals frequently using syntactic complements or having interpersonal experience with hearing people from early years tended to use ToM better. Moreover, language ability was the only predictor for explicit rather than implicit mental state understanding. Sufficient language is not necessary for all aspects of advanced ToM. Rich interpersonal experience as a substitute for language may facilitate deaf adults' advanced ToM.

1. Introduction

Theory of mind (ToM) refers to the ability to ascribe mental states to oneself and others and to predict others' behavior, using knowledge in the mental domain (Premack & Woodruff, 1978). Although the term is originally proposed for studying social cognition in chimpanzees, it has stimulated a lot of research into human skills. With this skill, one can react appropriately to others' thoughts and feelings in social interaction. The false belief task (Wimmer & Perner, 1983) is conventionally used as a classic assessment of ToM, because success in this task strongly confirms that understanding of mental subjectivity is achieved. For typically developing children, performance on false belief tasks has been significantly above the chance level by the age of four (Wellman, Cross, & Watson, 2001). Furthermore, their ToM performance is affected by many factors such as language (e.g., Ruffman, Slade, Rowlandson, Rumsey, & Garnham, 2003; Slade & Ruffman, 2005), executive functions (e.g., Carlson, Moses, & Claxton, 2004; Gordon & Olson, 1998), and social experience (e.g., Garfield, Peterson, & Perry, 2001; McAlister & Peterson, 2007).

A significant relationship between language ability and false belief understanding has been documented in typically developing children (see Milligan, Astington, & Dack, 2007 for a review). Moreover, deaf children have also been investigated in this respect. Deaf children show a specific delay in language skill but normal development in many other respects. First, they have no neurological abnormality, which seems responsible for ToM impairment in children with autism (e.g., Frith, Morton, & Leslie, 1991). Second, they are not delayed in executive function (Jackson, 2001; Meristo & Hjelmquist, 2009; Woolfe, Want, & Siegal, 2002). As a result, the role of language in ToM can be better illustrated through studies on deaf individuals. Furthermore, such studies will provide practical suggestions for ToM development in deaf individuals.

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Altogether numerous studies have demonstrated that deaf children of hearing families, regardless of their language modality, have difficulties in false belief understanding (Courtin & Melot, 2005; Jackson, 2001; Moeller & Schick, 2006; Peterson, 2002, 2004; Peterson & Siegal, 1995; Peterson, Wellman, & Liu, 2005; Russell et al., 1998; Schick, de Villiers, de Villiers, & Hoffmeister, 2007; Steeds, Rowe, & Dowker, 1997). At the same time, significant language impairment has been found in these children. They show deficits in vocabulary skill (Schick et al., 2007) rather than syntax comprehension (Schick et al., 2007). Their vocabulary skill can predict their performance on false belief tasks (Schick et al., 2007). Mental state language (Peterson & Slaughter, 2006) and use of syntactic complement (Schick et al., 2007) were also related to their false belief understanding. In sum, language impairment is probably the main cause of ToM deficits in deaf children of hearing families.

Other evidence is accumulating that language ability is even a prerequisite for false belief understanding. For example, Pyers and Senghas (2009) compared the performance of two groups of deaf adults on false belief tasks. These adults had learned a recently emerging language—Nicaraguan Sign Language. The older group was exposed to the early form of this language, whereas the younger one gained access to the more developed form of this language. As would be expected, the older group had lower language ability and performed worse than the younger group on false belief tasks. More importantly, group difference in false belief understanding disappeared when the two groups were comparable in language ability two years later. Therefore, this study has further indicated that false belief understanding cannot develop independently without corresponding language ability.

Nevertheless, one critical issue remains to be clarified. Do deaf adults with limited language still have problems in advanced ToM? It is not clear whether advanced ToM also depends crucially on language ability. Advanced ToM, usually assessed by the strange stories task (Happé, 1994), involves an understanding of complex mental states such as those in irony, metaphor and complex narratives (Wellman & Liu, 2004). Children seem unable to reason perfectly about these complex mental states (e.g., O'Hare, Bremner, Nash, Happé, & Pettigrew, 2009), whereas adults have shown good performance (e.g., Happé, 1994; White, Hill, Happé, & Frith, 2009). Thus, individuals cannot acquire advanced ToM until they enter adulthood. As regards the relationship between language and advanced ToM, there may be two possibilities. On the one hand, given that advanced ToM involves complicated mental state processing, correspondingly sufficient language seems indispensable. On the other hand, adults have broadened in social experience after many years' interacting with others. This experience is likely to assist advanced ToM, just as language does. In that case, perhaps sufficient language is not necessary for advanced ToM.

Few studies have provided empirical data on the role of language in advanced ToM, and consequently, we lack a definitive answer. We know of one related study that investigated adults with developmental language disorders in childhood (Clegg, Hollis, Mawhood, & Rutter, 2005). The results showed that these individuals still displayed language impairment in their mid-thirties and performed poorly on the strange stories task. Simultaneously, they had a limited range of acquaintances and friends in their daily life. Therefore, perhaps it is not merely limited language that causes their deficits in advanced ToM. Rather, insufficient social experience may also prevent them from developing advanced ToM. Thus, it is essential to separate the effect of language from that of social experience.

Apart from this, different aspects of advanced ToM need to be defined, because language may be particularly important for some aspects rather than others. To address the developmental sequence of basic ToM in preschoolers, Wellman and Liu (2004) constructed a ToM scale that described children's developmental progression from an understanding of diverse desire to real-apparent emotion. A similar developmental sequence was found in deaf children (Peterson & Wellman, 2009; Peterson et al., 2005). As Wellman and Liu (2004) argued, their ToM scale reflected children's advancements in the understanding of mental subjectivity. Real-apparent emotions are more difficult to understand than diverse desires, because the former emphasize "internal–external contrast" (Wellman & Liu, 2004, p. 536), whereas the latter just focus on "subjective-subjective individuation" (Wellman & Liu, 2004, p. 536). As a result, only with deep understanding of mental subjectivity can children pass real-apparent emotion tasks. However, mental states to be understood in Wellman and Liu's tasks (2004) differed not only in mental subjectivity but also in whether they were expressed. For instance, the desires were explicit mental states clearly expressed in the story context, while the emotions were implicit ones that must be inferred from the context. Consequently, great difficulty in real-apparent emotion tasks is also probably due to the implicit feature of the emotions.

Although basic ToM focuses on the understanding of mental subjectivity, we propose that it is the increasing insight into the implicit mental states that characterizes progression in advanced ToM. Successful detection of the implicit mental states requires a great deal of cognitive effort and is the real challenge for adults. Thus, we will consider three aspects of advanced ToM in terms of the implicit feature of mind: explicit mental state understanding, implicit mental state reasoning, and ToM use.

Taken together, the present study aimed to investigate deaf adults' advanced ToM, and understand the relationship between language and advanced ToM. Deaf adults were delayed in language skill and were in the process of developing advanced ToM. More importantly, they also differed in social experience, especially interpersonal experience. Therefore, the effect of language on advanced ToM could be separated from that of interpersonal experience.

In the present study, three tasks were used to tap different aspects of advanced ToM. First, the story recall task assessed explicit mental state understanding. The target mental states were clearly expressed and explained in the story. Participants were asked to recall the story content, including these explicit mental states. Second, the story comprehension task assessed implicit mental state reasoning. The target mental states were hidden in the story, and participants were required to infer these implicit mental states from the background information. Finally, the referential communication task was used to assess ToM use in real interaction. The target mental states involved in the interaction were unexpressed. Moreover, they were not directly asked. Participants must spontaneously use these inferred mental states to give correct responses to others' instructions. In a sense, these mental states were apt to be ignored and thus more implicit.

In addition, we also attempted to examine different aspects of language ability, including vocabulary skill, mental state language, and syntactic complement use. Previous studies usually elicit participants' mental state language by asking them to describe the photographs, wordless storybooks, video clips and so on. However, the results from this procedure may reflect mental state understanding rather than isolated language ability. Furthermore, it is not clear whether participants really know what mental state words are. To evaluate the purely mental state concepts, we directly required participants to produce as many mental state words as possible. For the use of a syntactic complement, our preliminary results have found that adults, including the deaf, had no problems in mastering this important syntax (such as "think that ..."). The key issue is whether they can spontaneously use the syntactic complement. Therefore, participants were asked to construct sentences with mental state words, and their spontaneous use of syntactic complements was assessed.

It was hypothesized that the importance of language might be different for the three aspects of advanced ToM. Explicit mental state understanding necessarily calls for corresponding language ability, because these complex mental states are directly expressed through language. Nevertheless, implicit mental state understanding and ToM use might be achieved in spite of limited language. Predictably, interpersonal experience as a substitute for language may enable deaf adults to gain insight into the hidden mind.

2. Method

2.1. Participants

Fifty-three deaf college students participated in the study. They were recruited from the Deaf Institute in a regular university in China where a considerable proportion of the students were typically hearing people. Thus, deaf students in this study were similar to hearing students in terms of educational experience.

These deaf adults comprised four groups. There were 10 postlingually deaf bilinguals of hearing families (PoBH), 15 prelingually deaf bilinguals of hearing families (PrBH), 20 prelingually deaf signers of hearing families (PrSH), and 8 prelingually deaf adults of deaf families (PrDD). All of the postlingually deaf adults experienced their hearing loss after the age of four. Forty-one prelingually deaf adults experienced their hearing loss when they were one year old or younger. One adult in PrBH group became deaf at the age of two. One adult in the PrDD group became deaf at the age of three but had not completely acquired language.

The control group of hearing adults (HA) consisted of 32 hearing college students from another regular university in China. PoBH, PrDD and HA had a shared communication mode with their parents from their early years, and thus had interpersonal experience from early years. PoBH, PrBH and HA could communicate with hearing people, and thus had interpersonal experience with hearing people. The characteristics of each group are shown in Table 1.

To compare directly the groups' performance on experimental tasks, task instructions were presented through written language, and participants were required to write down their answers. Because deaf participants used written language as one of the main communication modes in their daily interaction, they could understand and complete tasks in written language very well.

Table 1
Characteristics of adults in each group.

	Postlingually deaf bilinguals of hearing families (PoBH)	Prelingually deaf bilinguals of hearing families (PrBH)	Prelingually deaf signers of hearing families (PrSH)	Prelingually deaf adults of deaf families (PrDD)	Hearing adults (HA)
No. of adults	10	15	20	8	32
Mean age (SD)	21.65 (2.51)	21.41 (1.66)	22.52 (1.36)	20.73 (2.02)	21.11 (1.20)
Range of unaided-hearing loss of the better ear	95–120 dB	71–120 dB	71–120 dB	80 dB-tone deaf	
Ratio of males:females	5:5	7:8	10:10	4:4	15:17
Shared communication mode with parents from early years	Oral language	No	No	Sign language	Oral language
Communication mode	Sign and oral language	Sign and oral language	Sign language	Sign language (4); sign and oral language (4)	Oral language
Interpersonal experience from early years	Yes	No	No	Yes	Yes
Interpersonal experience with hearing people	Yes	Yes	No	No	Yes

Note: Interpersonal experience from early years is derived from shared communication mode with parents from early years. Interpersonal experience with hearing people is derived from communication mode.

2.2. Measures and scoring

2.2.1. Measures of language ability and nonverbal IQ

Three aspects of language ability were assessed. Vocabulary skill was assessed by the vocabulary subtest in the Wechsler Adult Intelligence Scale-Revised (Chinese revised version) (Gong, 1992). Participants were asked to write down the meaning of each word. The vocabulary score was calculated by combining the scores of all items, ranging from 0 to 80. Another rater who did not know the purpose of the experiment rated answers of 22% of the participants, and the inter-rater reliability was good (Kappa = 0.90). For the following rating, the reliabilities were obtained using the same procedure.

Mental state language was assessed by production of mental state words. Participants were required to write down as many mental state words as possible that they knew. The mental state word score was derived from the total number of mental state words they wrote. According to Peterson and Slaughter's (2006) coding categories of mental state terms, each word that participants produced was judged as either a mental state word or a non-mental state word. Kappa for coding of mental state words was 0.89.

Syntactic complement use was assessed by constructing sentences with mental state words. Eight mental state words (know, think, pretend, imagine, see, surprised, wish, intend) based on Peterson and Slaughter's (2006) coding categories of mental terms were provided to participants. They were asked to construct a sentence using each word. The total number of sentences with syntactic complements produced the syntactic complement use score, ranging from 0 to 8. For coding of the syntactic complement under the given word, Kappa was 0.95.

Participants' nonverbal IQ scores were obtained from the performance scale in the Wechsler Adult Intelligence Scale-Revised (Chinese revised version) (Gong, 1992).

2.2.2. Measures of advanced ToM

2.2.2.1. Story recall task. The fourth story in Rutherford's (2004) embedded false belief tests was used to examine explicit mental state understanding. The story involved various complex mental states of story characters. Their mental states were clearly expressed, and reasons why they held these mental states were explained. Each sentence in the story was divided into sentence units in which one verb described one fact. This resulted in 17 mental state sentence units and 17 behavior sentence units.

Participants were told to read the story at their own pace so that they had enough time to finish the whole story. They were instructed not to write down the content of the story until they finished reading. Therefore, the information they recalled would reflect their understanding of the story.

Each sentence participants wrote down was first divided into sentence units (Kappa = 1.00), and then each sentence unit was judged as either a mental state or a behavior sentence unit (Kappa = 1.00). Finally, the correctness of mental state and behavior sentence units was further determined. If the contents of the sentence unit were consistent with the original story or derived from the story, it was rated as correct. The inter-rater reliabilities were good for the correct mental state sentence unit (Kappa = 0.98) and the correct behavior sentence unit (Kappa = 0.98). The mental state sentence unit score was calculated by subtracting the incorrect mental state sentence units from the correct ones and represented explicit mental state understanding. The behavior sentence unit score was calculated in the similar way and represented explicit behavior understanding.

2.2.2.2. Story comprehension task. Eight ToM stories – two irony stories, two white lies stories, two double bluff stories, one mistake story, and one persuasion story – were adopted to measure implicit mental state reasoning. Irony stories were based on Langdon and Coltheart (2004). The other six stories were based on Happé, Brownell, and Winner (1999). In addition, four control stories (Happé et al., 1999) were also used to tap non-mental reasoning.

Participants were allowed to spend as long as necessary reading to guarantee their memory for background information in the stories. Next, they answered questions about why story characters acted in certain ways or said something, without referring back to the stories. This procedure was intended to prevent them from just copying out sentences in the stories and instead to reveal their real reasoning.

Scoring was based on Happé, Winner, and Brownell (1998). A score of 2 was given if participants definitely referred to the exact mental states; 1 was given if they answered more generally; and 0 was given for unrelated answers. Thus, ToM story score ranged from 0 to 16 and represented implicit mental state reasoning. The control story score ranged from 0 to 8 and represented non-mental reasoning. The inter-rater reliability was good for ToM stories (Kappa = 0.97) and control stories (Kappa = 0.98).

2.2.2.3. Referential communication task. A referential communication task adapted from Keysar, Lin, and Barr (2003) was used to assess ToM use in real interactions. Our task only used cards with different colors and shapes; thus, the adapted version was easier to understand and carry out. Each array included three cards of different colors and sizes. Two were visible and the other was under an opaque piece of paper (see Fig. 1).

The participants sat opposite an experimental confederate with the array in-between them on the table. They were asked to take a card according to the confederate's instructions when a baffle was placed between them, for example, "take the dark triangle" (false belief use question). In the experimental condition, participants knew privately that the covered cards (e.g., a

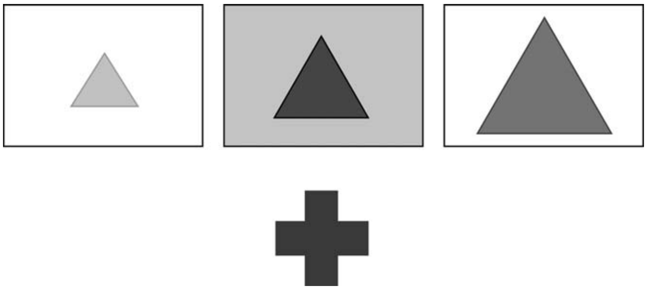

Fig. 1. An array used in an experimental trial in the referential communication task. The four instructions in this trial: take the big triangle; take the light triangle; take the small triangle; take the dark triangle (critical instruction).

darker triangle) were more compatible with the critical instructions. However, they saw that something else as the covered card (e.g., a cross) was being indicated to the confederate. In the control condition, the covered cards were unrelated to the critical instructions. After each trial, control questions were asked to confirm participants' understanding of the interactional context: "Which card was under the opaque paper? Which card did the confederate think was under this paper (false belief reasoning question)?".

There were four trials with different arrays in each condition and four instructions, including a critical one, in each trial. In each trial, a correct choice for the critical instruction with correct answers for control questions was scored as 1. Therefore, participants' critical instruction scores in both conditions ranged from 0 to 4. The critical instruction score in the experimental condition reflected the degree of ToM use. If participants spontaneously consider the confederate's mental states, they can make the correct choice just by choosing from the visible cards.

2.3. Procedure

Testing occurred across two sessions in a quiet room. In the first session, participants' language ability and nonverbal IQ were assessed individually. In the second session, held one week later, advanced ToM tasks were administered to them individually. At the end of the experiment, each participant received a beautiful gift for having participated in the experiment.

2.4. Data analyses

Data analysis was performed with two main statistical procedures. First, ANOVAs were conducted to show group differences in language ability, nonverbal IQ, and the three aspects of advanced ToM. Regression analyses were then carried out, exploring the relationship between language ability and advanced ToM. Deafness per se was not the reason for ToM delay (Peterson, 2004; Peterson et al., 2005; Schick et al., 2007). Therefore, deaf and hearing groups were combined in the regression analyses. In addition, the two variables of interpersonal experience (interpersonal experience from early years; interpersonal experience with hearing people) were dummy coded as 1 = with the interpersonal experience, and 0 = without the interpersonal experience. They were separately entered into the regression models to avoid collinearity problems.

3. Results

3.1. Performance of different groups on language and nonverbal IQ measures

There were significant differences between groups in the vocabulary score, $F(4, 80) = 12.14$, $p < 0.001$, $\eta^2 = 0.378$. A post hoc Bonferroni test indicated that PrBH, PrSH and PrDD had significantly lower scores than did HA, $ps < 0.05$, but PoBH performed similarly to HA, $p > 0.05$. In addition, PoBH had a higher score than did the other deaf groups, $ps < 0.05$. Significant differences between groups were also observed in the mental state word score, $F(4, 80) = 8.85$, $p < 0.001$, $\eta^2 = 0.307$. A post hoc Bonferroni test demonstrated that all of the deaf groups produced fewer mental state words than did HA, $ps < 0.05$. Furthermore, group differences in the syntactic complement use score only approached significance, $F(4, 80) = 2.06$, $p = 0.094$, $\eta^2 = 0.093$.

In nonverbal IQ, group differences were not significant, $F(4, 80) = 1.02$, $p = 0.400$, $\eta^2 = 0.049$. Means and standard deviations for scores for each language measure and nonverbal IQ are displayed in Table 2.

3.2. Performance of different groups on advanced ToM measures

In the story recall task, the mental state and behavior unit scores of each group were compared (see Fig. 2). A 5 (group) × 2 (sentence unit type) repeated measure ANOVA was conducted. It yielded a significant interaction effect, $F(4, 80) = 5.27$, $p = 0.001$, $\eta^2 = 0.209$. The main effect for group was also significant, $F(4, 80) = 2.57$, $p = 0.044$, $\eta^2 = 0.114$. There was no

Table 2
Descriptive statistics for language and nonverbal IQ measures for each group.

	Postlingually deaf bilinguals of hearing families (PoBH)	Prelingually deaf bilinguals of hearing families (PrBH)	Prelingually deaf signers of hearing families (PrSH)	Prelingually deaf adults of deaf families (PrDD)	Hearing adults (HA)
Mean vocabulary score (SD)	56.60 (9.83)	44.93 (8.22)	39.15 (10.57)	42.00 (15.08)	55.25 (7.41)
Mean mental state word score (SD)	10.70 (6.43)	11.00 (6.46)	10.85 (5.60)	8.50 (4.75)	20.09 (9.02)
Mean syntactic complement use score (SD)	3.50 (0.71)	3.80 (1.27)	3.85 (1.04)	3.25 (1.17)	3.09 (1.06)
Mean nonverbal IQ (SD)	105.70 (9.60)	110.00 (11.04)	112.80 (10.69)	108.13 (10.68)	111.47 (9.16)

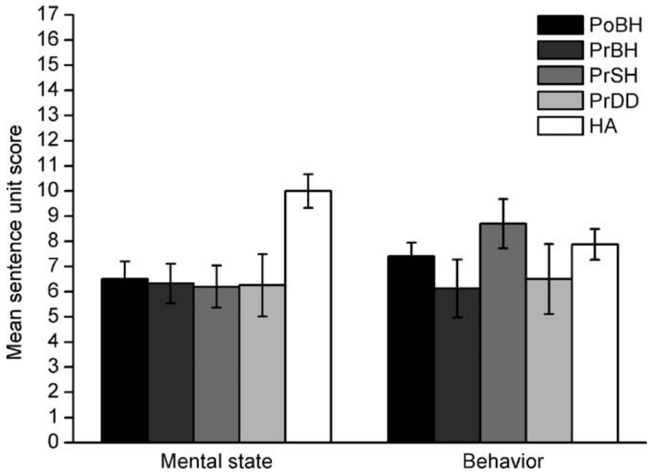

Fig. 2. Mean mental state sentence unit score and mean behavior sentence unit score of each group on the story recall task. Error bars represent the standard error. *Note*: PoBH = postlingually deaf bilinguals of hearing families; PrBH = prelingually deaf bilinguals of hearing families; PrSH = prelingually deaf signers of hearing families; PrDD = prelingually deaf adults of deaf families; HA = hearing adults.

significant main effect for sentence unit type, $F(1, 80) = 0.36$, $p = 0.552$, $\eta^2 = 0.004$. To explain this interaction effect, separate ANOVAs were carried out for mental state and behavior sentence unit scores. Significant differences between groups in the mental state sentence unit score were found, $F(4, 80) = 5.67$, $p < 0.001$, $\eta^2 = 0.221$. A post hoc Bonferroni test showed that the difference between HA and any deaf group was significant or marginally significant, HA versus PoBH, $p = 0.067$; HA versus PrBH, $p = 0.011$; HA versus PrSH, $p = 0.002$; HA versus PrDD, $p = 0.077$. However, there were no significant group differences in the behavior sentence unit score, $F(4, 80) = 1.20$, $p = 0.316$, $\eta^2 = 0.057$. Thus, the results showed that all of the deaf groups tended to perform worse than the hearing group on explicit mental state understanding. As all of the deaf groups had limited mental state language, sufficient mental state language seemed to be necessary for explicit mental state understanding.

As for performance on the story comprehension task, significant group differences existed in the ToM story score, $F(4, 80) = 8.00$, $p < 0.001$, $\eta^2 = 0.286$. A post hoc Bonferroni test indicated that PrBH and PrSH performed worse than did HA, $ps < 0.001$, while PoBH and PrDD performed similarly to HA, $ps > 0.05$. In the control story score, there were also significant differences between groups, $F(4, 80) = 6.34$, $p < 0.001$, $\eta^2 = 0.241$. A post hoc Bonferroni test indicated that PrSH had a lower score than did HA, $p = 0.001$. In addition, PrSH also had a lower score than did PoBH, $p = 0.003$. The difference between PrBH and PoBH approached significance, $p = 0.073$. Means and standard deviations for ToM story and control story scores are shown in Table 3. The results indicated that with either vocabulary skill or interpersonal experience from early years, PoBH and PrDD had no problems in implicit mental state reasoning, thus implying that sufficient language ability was not necessary for this aspect of advanced ToM.

Table 3
Descriptive statistics for the ToM story score and the control story score for each group.

	Postlingually deaf bilinguals of hearing families (PoBH)	Prelingually deaf bilinguals of hearing families (PrBH)	Prelingually deaf signers of hearing families (PrSH)	Prelingually deaf adults of deaf families (PrDD)	Hearing adults (HA)
Mean ToM story score (SD)	8.23 (2.30)	6.13 (2.72)	6.10 (1.92)	7.00 (3.34)	9.41 (2.34)
Mean control story score (SD)	6.20 (1.48)	4.00 (2.36)	3.35 (2.03)	3.88 (2.59)	5.59 (1.64)

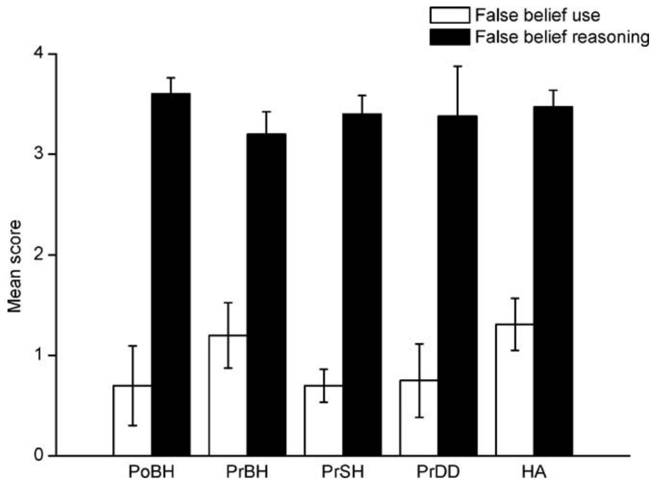

Fig. 3. Mean false belief use score and mean false belief reasoning score of each group on the referential communication task. Error bars represent the standard error. *Note*: PoBH = postlingually deaf bilinguals of hearing families; PrBH = prelingually deaf bilinguals of hearing families; PrSH = prelingually deaf signers of hearing families; PrDD = prelingually deaf adults of deaf families; HA = hearing adults.

Finally, participants' performance on referential communication tasks was compared. A 5 (group) $\times$ 2 (condition) repeated measure ANOVA showed only a main effect of the condition, $F\,(1, 80) = 259.74$, $p < 0.001$, $\eta^2 = 0.765$. All of the groups had lower critical instruction scores in the experimental condition than in the control condition, which meant that they were not spontaneously able to use ToM in real interaction. In addition, there was no significant effect for group, $F\,(4, 80) = 0.82$, $p = 0.519$, $\eta^2 = 0.039$. The interaction effect was not significant, $F\,(4, 80) = 1.22$, $p = 0.331$, $\eta^2 = 0.057$. Another 5 (group) $\times$ 2 (question type) repeated measure ANOVA found only the main effect for the question type (see Fig. 3), $F\,(1, 80) = 196.69$, $p < 0.001$, $\eta^2 = 0.711$. All of the groups performed better on false belief reasoning questions than on false belief use questions. The main effect for group was not significant, $F\,(4, 80) = 0.67$, $p = 0.613$, $\eta^2 = 0.003$. There was also no significant interaction effect, $F\,(4, 80) = 1.08$, $p = 0.374$, $\eta^2 = 0.051$. These results thus confirmed that each group's failure in ToM use was not due to their difficulties in inferring others' mental states.

3.3. Predictors of advanced ToM

Hierarchy regressions were conducted using the mental state sentence unit score as the dependent variable (see Table 4). For both hierarchy regressions, the set of language measures were entered at Step 1. Next, the two variables of interpersonal experience were separately entered at Step 2. In the first hierarchy regression, the model with the set of language measures was significant, $F\,(3, 81) = 6.71$, $p < 0.001$, $R^2 = 0.199$. When interpersonal experience from early years was entered next, it did not account for additional variance, $\Delta R^2 = 0.018$, $F\,(\text{change}) = 1.87$, $p = 0.175$. More importantly, at this final step, only the mental state word score still predicted the mental state sentence unit score, $\beta = 0.32$, $t = 2.99$, $p = 0.004$. The second hierarchy regression found similar results, with interpersonal experience with hearing people entered instead. Interpersonal experience with hearing people did not account for additional variance, $\Delta R^2 = 0.005$, $F\,(\text{change}) = 0.46$, $p = 0.498$. At the final step, mental state word score still predicted the mental state sentence unit score, $\beta = 0.33$, $t = 3.11$, $p = 0.003$. Therefore, the results were consistent with those from the ANOVAs, suggesting that explicit mental state understanding necessarily required sufficient language ability, especially mental state language.

Table 4
Hierarchy regressions predicting the mental state sentence unit score.

	β	t	p
Regression 1			
Step 1: Vocabulary score	0.21	1.96	0.053
Mental state word score	0.34	3.29	0.001
Syntactic complement use score	0.03	0.28	0.781
Step 2: Interpersonal experience from early years	0.16	1.37	0.175
Regression 2			
Step 1: Vocabulary score	0.21	1.96	0.053
Mental state word score	0.34	3.29	0.001
Syntactic complement use score	0.03	0.28	0.781
Step 2: Interpersonal experience with hearing people	0.09	0.68	0.498

Table 5
Hierarchy regressions predicting the ToM story score.

	β	t	p
Regression 1			
Step 1: Vocabulary score	0.48	5.16	0.000
Mental state word score	0.28	3.02	0.003
Syntactic complement use score	0.04	0.44	0.662
Step 2: Interpersonal experience from early years	0.23	2.24	0.028
Regression 2			
Step 1: Vocabulary score	0.48	5.16	0.000
Mental state word score	0.28	3.02	0.003
Syntactic complement use score	0.04	0.44	0.662
Step 2: Interpersonal experience with hearing people	0.07	0.67	0.502

To determine predictors for implicit mental state reasoning, hierarchy regressions were carried out with the ToM story score as the dependent variable (see Table 5). In the first hierarchy regression, the model with the set of language measures was significant, F (3, 81) = 16.33, $p < 0.001$, $R^2 = 0.377$. More importantly, interpersonal experience from early years significantly explained additional variance, $\Delta R^2 = 0.037$, F (change) = 5.00, $p = 0.028$. At the same time, the vocabulary score and the mental state word score still predicted the ToM story score at this final step, $ps < 0.05$. Similar results were obtained from the second hierarchy regression, except that interpersonal experience with hearing people did not have an independent contribution, $\Delta R^2 = 0.004$, F (change) = 0.45, $p = 0.502$. Moreover, the vocabulary score and the mental state word score still predicted the ToM story score at this final step, $ps < 0.05$. In sum, either language ability or interpersonal experience from early years could enable one to infer the implicit mental states.

In addition, hierarchy regressions were also conducted for control story scores (see Table 6). In the first hierarchy regression, the model with the set of language measures was significant, $F(3, 81) = 12.00$, $p < 0.001$, $R^2 = 0.308$. Nevertheless, interpersonal experience from early years did not account for additional variance, $\Delta R^2 = 0.018$, F (change) = 2.12, $p = 0.150$. At the final step, the vocabulary score still predicted the control story score, $p = 0.001$; and the mental state word score marginally predicted the control story score, $p = 0.078$. For the second hierarchy regression, similar results were obtained. Interpersonal experience with hearing people did not explain additional variance, $\Delta R^2 = 0.001$, F (change) = 1.28, $p = 0.262$. However, at this final step, the vocabulary score still predicted the control story score, $p = 0.001$; and the mental state word score marginally predicted the control story score, $p = 0.068$. The results thus showed that compared to interpersonal experience, language ability seemed more important for non-mental reasoning.

Because each group had low critical instruction scores in the experimental condition of the referential communication task, we focused on participants' individual performance. Participants who had a critical instruction score of 4 in the experiment condition were distinguished from those who did not, because the group with high critical instruction score was competent in using ToM consistently. In the following logistic regression, the dependent variable was whether one could consistently use ToM.

The group with high critical instruction scores primarily consisted of hearing adults, suggesting that richer interpersonal experience was important for ToM use. The richer interpersonal experience involved both interpersonal experience from early years and that with hearing people. As a result, whether one had interpersonal experience with hearing people from early years was considered in the regression model. PoBH and HA had this richer interpersonal experience.

For the logistic regression, the best-fitting model included the syntactic complement use score and interpersonal experience with hearing people from early years as independent variables, χ^2 (2, $N = 85$) = 12.17, $p = 0.002$. Specifically, the syntactic complement use score predicted whether one could consistently use ToM, $B = 1.66$, Wald = 6.22, $p = 0.013$. Moreover, interpersonal experience with hearing people from early years also had a significant effect, $B = 3.19$, Wald = 5.05, $p = 0.025$. Therefore, individuals frequently using syntactic complements or having interpersonal experience with hearing people from early years were more likely to use ToM better when interacting with others.

Table 6
Hierarchy regressions predicting the control story score.

	β	t	p
Regression 1			
Step 1: Vocabulary score	0.45	4.62	0.000
Mental state word score	0.20	2.08	0.040
Syntactic complement use score	−0.04	−0.40	0.688
Step 2: Interpersonal experience from early years	0.16	1.45	0.150
Regression 2			
Step 1: Vocabulary score	0.45	4.62	0.000
Mental state word score	0.20	2.08	0.040
Syntactic complement use score	−0.04	−0.40	0.688
Step 2: Interpersonal experience with hearing people	0.13	1.13	0.262

4. Discussion

Previous studies have shown that false belief understanding cannot mature independently without corresponding language ability (Pyers & Senghas, 2009; Schick et al., 2007). The present study was the first to further explore whether a similarly close relationship still existed between language and advanced ToM. Based on the performance of deaf adults, our results clearly indicated that sufficient language ability was not necessary for all aspects of advanced ToM, except for explicit mental state understanding.

Explicit mental state understanding is a basic mentalizing ability for adults. It involved understanding of the clearly expressed mental states. In other words, what people think and feel has been directly told; participants only need to hold them in mind. Unexpectedly, our results found that all of the deaf groups appeared not to be competent in this mentalizing skill. Notably, deaf adults' failure was not due to their poor memory for linguistic information. Recall that their behavior sentence unit scores approximated those of the hearing adults. Thus, they have no difficulties in understanding linguistic information about behavior. Rather, a low mental state sentence unit score reflects their fundamental problems in understanding the explicit mental states per se. Morgan and Kegl (2006) showed that deaf individuals could describe the expressed mental states in a nonverbal cartoon, no matter when they learned language. However, their participants might have benefited from visual information concerning mental states.

What then are the critical factors for an understanding of the linguistically explicit mental states? All of the deaf groups produced fewer mental state words than did the hearing group. Consistent with this result, only mental state language predicted participants' performance on explicit mental state understanding. It is thus obvious that this aspect of advanced ToM necessarily calls for rich mental state language. The Vygotskian concept of internalization (Vygotsky, 1978, 1986) may give reasonable explanations. Within his framework, the internalization of external mental state language plays an important part in ToM development (Symons, Peterson, Slaughter, Roche, & Doyle, 2005). Specifically, external mental state language from discourse increases individuals' inner mental state language. Using these mental words is then internalizated into the individual's conception of the mind (Symons, 2004). Consequently, mental state language fosters ToM. Furthermore, most linguistically explicit mental states must be expressed through mental terms such as "believe", "wish", and so forth. Thus, they seem unlikely to be comprehended without a corresponding language specific to the mental domain.

Different from explicit mental state understanding, implicit mental state reasoning emphasizes the process of reasoning. This aspect of advanced ToM involves more sophisticated mentalizing skill. However, it was problematic only for the two prelingually deaf groups of hearing families in the present study. Relevant to our findings, previous studies also reveal that deaf children of hearing families are delayed in false belief reasoning (e.g., Moeller & Schick, 2006; Peterson, 2004; Peterson & Siegal, 1995; Russell et al., 1998). In addition, our results found that the performance of deaf adults of deaf families approximated that of hearing adults. It is consistent with the well-developed false belief reasoning in deaf children of deaf families (e.g., Courtin & Melot, 2005; Schick et al., 2007). Similarly, postlingually deaf adults of hearing families who were seldom investigated were also comparable with hearing adults in this sophisticated mentalizing skill. To summarize, better performance of PrDD and PoBH may arise from their internal resources—either vocabulary skill or interpersonal experience from early years. The paucity of these resources inhibits implicit mental state reasoning in prelingually deaf adults of hearing families. This explanation also received support from the regression analysis. Either vocabulary skill or interpersonal experience from early years could predict performance on implicit mental state reasoning.

Vocabulary skill as general language ability (Schick et al., 2007) affects ToM in many ways. Cheung (2006) mentions two important aspects of general language: the symbolic aspect and the social aspect. The symbolic aspect focuses on the representational link between words and their referents and may increase one's awareness about the representational mental states. Consistent with this view, understanding of synonyms is found to be related to false belief understanding (e.g., Doherty & Perner, 1998). The social aspect emphasizes the use of language in social interaction. Hence, its effect may be manifested in talking about mental states. Peterson and Siegal (1995) also claim that access to conversation facilitates ToM development. What one learns from the conversations may be some "general ToM principles" (Apperly, 2008, p. 269) concerning the causal relationships between mental states or mental states and behavior. Taken together, vocabulary skill assists reasoning in the mental domain. Moreover, language is also considered useful for inference (Clark, 1998). At the same time, our results indicated that vocabulary skill predicted performance on non-mental reasoning. Perhaps vocabulary skill is beneficial to general reasoning ability, and general reasoning ability helps mental state reasoning in turn. With regard to the role of mental state language in implicit mental state reasoning, our results are consistent with previous studies (e.g., Ruffman, Slade, & Crowe, 2002; Symons et al., 2005).

Apart from language ability, interpersonal experience from early years was predictive of implicit mental state reasoning. Previous studies also find the effects of particular interpersonal experience on advanced ToM. For example, Rutherford (2004) showed that the "loser" with low status in an experimental task performed better than did the "winner" with high status on ToM tasks. It is possible that subordinates develop sophisticated ToM through careful observation and reflection in interacting with superiors. More importantly, in the present study, deaf adults' interpersonal experience even compensated for their poor language ability, sustaining the advanced ToM. However, without corresponding language ability, social experience such as having siblings (e.g., McAlister & Peterson, 2007; Ruffman, Perner, Naito, Parkin, & Clements, 1998) or many years' interaction with others seems of no use for individuals who are developing basic ToM. Compelling evidence for this argument came from the recent study (Pyers & Senghas, 2009). Their deaf adults with limited language ability in the developmental period of basic ToM still showed deficits in false belief understanding, even if they had more than 20 years' social experiences. To form the association between current and previous interactional contexts concerning people's mind, one must first realized that both of them are related to certain types of mental states. It hence requires some basic conceptions of the mind. Therefore, one cannot form an association between current context and previous experiences before development of basic ToM. Instead, only for individuals who have undergone a basic conceptual change in the mental domain does social experience become helpful, assisting their advanced ToM development. Consequently, implicit mental state reasoning does not necessarily require sufficient language ability.

Interpersonal experience as a substitute for language is also evidenced in ToM use. This aspect is the most difficult one, because participants must be sensitive to the interactional contexts where mental state should be considered. Similar to the results from Keysar et al. (2003), we found that all of the groups had difficulties in using ToM in real interaction with others. Nevertheless, participants' failure was not due to their inability to detect false beliefs, because they performed well on the false belief reasoning question. Therefore, the spontaneous use of mental state was the key point. Syntactic complement use predicted the performance on ToM use. This special syntax involves an embedded sentence under a verb and enables the representation of mental states. With frequent use of this syntax, one may be more aware that everyone has an inner state of his own that is manifested in the embedded proposition. Thus, he/she is inclined to solve problems from others' perspective. In addition, interpersonal experience with hearing people from early years also significantly predicted performance in ToM use. Taken together, sufficient language ability is not necessary for ToM use, because richer interpersonal experience can compensate for limited language.

In sum, the present study has made valuable contributions to our theoretical thinking about language and ToM. It is clear that the relationship between language and advanced ToM is quite different from that between language and basic ToM. Sufficient language ability is not necessary for all aspects of advanced ToM, because interpersonal experience begin to play a compensative role. Relevant to practical applications, the present study is also fruitful in providing suggestions for ToM development in deaf individuals. First, deaf individuals should increase their mental state vocabulary, to understand others' explicit mental states. Second, upon learning some sign language, parents of deaf individuals may interact with their children from early years. At the same time, deaf individuals themselves may expand their social interaction with others. With this rich interpersonal experience, advanced ToM can be eventually acquired even if language ability is limited.

Despite the theoretical and practical significance, there remain some limitations in the present study. Although the make-up of the groups is well representative of the small population of deaf adults, the sample sizes of some deaf groups are relatively modest. Moreover, the present study focuses on group differences with cross-sectional design, whereas future studies may further use longitudinal design to confirm the causal roles of language and interpersonal experience in advanced ToM.

In conclusion, the present study showed that deaf adults with limited language had problems in explicit mental state understanding, but did not necessarily have difficulties in implicit mental state reasoning. Therefore, sufficient language ability is not necessary for all aspects of advanced ToM. Rich interpersonal experience may be an alternative route to advanced ToM for deaf adults.

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