frontiers | Frontiers in Communication

TYPE Brief Research Report
PUBLISHED 10 June 2024
DOI 10.3389/fcomm.2024.1401576

OPEN ACCESS

EDITED BY
Victoria Marrero-Aguiar,
National University of Distance Education (UNED), Spain

REVIEWED BY
Pedro Alfaro-Faccio,
Pontificia Universidad Católica de Valparaíso, Chile
Jesús Valero,
Ramon Llull University, Spain

*CORRESPONDENCE
Elisabet Serrat
✉ elisabet.serrat@udg.edu
Francesc Sidera
✉ francesc.sidera@udg.edu

RECEIVED 15 March 2024
ACCEPTED 21 May 2024
PUBLISHED 10 June 2024

CITATION
Serrat E, Amadó A, Durrleman S, Intxaustegi A and Sidera F (2024) Expressive syntax matters for second-order false belief: a study with hearing-impaired children. *Front. Commun.* 9:1401576. doi: 10.3389/fcomm.2024.1401576

Expressive syntax matters for second-order false belief: a study with hearing-impaired children

Elisabet Serrat[1]*, Anna Amadó[2], Stephanie Durrleman[3], Alaitz Intxaustegi[1] and Francesc Sidera[1]*

[1]Department of Psychology, Universitat de Girona, Girona, Spain, [2]Department of Psychology, Sociology and Social Work, Universitat de Lleida, Lleida, Spain, [3]Department of Neuroscience and Movement Science, Faculty of Medicine, University of Fribourg, Fribourg, Switzerland

While children with typical language development may capitalize on general language skills to grasp the content of others' minds, those with challenges in mind-reading could rather rely more specifically on complementation structures. However, most studies investigating mind-reading have focused on first-order false-belief reasoning, while much less is known about second-order false-belief, particularly for children that may present language difficulties, such as children with hearing impairment. This study aims to explore the link between language development and second-order false-belief in hearing-impaired children compared to their hearing counterparts. It seeks to ascertain whether mastering second-order false-belief requires the comprehension of complements or other language skills in hearing-impaired children, and if a distinct pattern emerges in their hearing peers. Children with hearing-impairment ($n = 22$) and a chronological age-matched control group ($n = 25$), ages 8–12, were administered a second-order false-belief task (carefully avoiding use of complements and highly visual). Alongside this, they completed assessments of expressive vocabulary, receptive and expressive syntax, recalling sentences, and a recursive sentential complements task. Correlational analysis revealed that in the control group only productive syntax was related to performance on the second-order false-belief task, while in the hearing-impaired group, expressive vocabulary, recalling sentences and sentential complements were related to second-order false-belief performance. These results show that vocabulary, recursive complements and expressive syntax are particularly important aspects for second-order false-belief success in children with hearing-impairment as compared to their hearing peers. These results shed light on how language and second-order false-belief understanding are related in their development.

KEYWORDS

second-order false-belief, language, hearing-impairment, recursive complements, syntax, theory of mind, children

1 Introduction

The study of the relationship between Theory of Mind (hereafter ToM) and language is fundamental to understanding the complexity of human interactions. ToM, or the ability to attribute mental states to others (Yu and Wellman, 2023), together with the mastery of language, allow us to communicate effectively, establish meaningful relationships and resolve conflicts. It is currently assumed that language and ToM are related (Astington and Baird, 2005). However, they are not monolithic concepts and do not develop in one fell swoop, and can moreover emerge differently across groups. Thus, it becomes relevant to ask: Which subcomponents of language are related to which ToM skills, and in what way do these relationships manifest themselves throughout development in different populations? In this study, we will delve into these issues by focusing on an advanced ToM ability that is rarely examined, 'second-order false belief' (SOFB), and its link to different language abilities in middle childhood (lexical and syntactic), in both hearing children and children with hearing impairment. The aim of this study is to expand our understanding of how these communicative and socio-cognitive skills relate to one another in hearing and hearing-impaired children.

Most studies that have reported links between language skills and ToM have focused on studying linguistic influences on first-order mentalistic skills (i.e., those that involve understanding, for example, other people's false beliefs) and have found that various language skills are important for its development, such as vocabulary (Schick et al., 2007), language referring to mental states (Ornaghi et al., 2015), grammatical skills (Farrar et al., 2009), conversational experience (Ornaghi et al., 2017), epistemic verbs (San Juan and Astington, 2017) or general language comprehension (Cheung et al., 2004). There is also evidence to suggest that children with language difficulties (Rieffe and Wiefferink, 2017) or hearing deficits (Woolfe et al., 2002; Schick et al., 2007; Slaughter and Peterson, 2011; Walker et al., 2017) have less difficulties in first-order false belief.

The literature on this topic has suggested different theoretical explanations for the influence of language on first-order ToM. One suggests that the mastery of the syntax of complementation (or comprehension of sentential complements) is an ideal tool to represent people's false beliefs. Specifically, it is argued that this type of complement with cognitive and communicative verbs (as in "Gabriel thinks/says that his brother ate the cake") can be true or false regardless of whether the subordinate sentence is true or false (i.e., Gabriel can say the brother ate the cake despite the brother having not eaten it), a fact that would make mastery of these sentences important for children's understanding that people can have false beliefs about reality (de Villiers, 2018). On the one hand, some studies have shown that comprehension of sentential complements is related to comprehension of first-order false beliefs, both in typically developing children (de Villiers and de Villiers, 2012) and in deaf and hard of hearing (hereafter DHH) children with slow linguistic development and no sign language (de Villiers and de Villiers, 2000). On the other hand, linguistic training with sentential complements can improve children's ability to understand first-order false beliefs, including in DHH children (Lohmann and Tomasello, 2003; Durrleman et al., 2019, 2021; Durrleman and Delage, 2020), suggesting that language does indeed help with this ToM ability.

There is an extensive literature on how children develop the capacity to understand first-order false beliefs. Such understanding is useful in a wide range of situations in which we need to anticipate or explain the behavior of others based on the consideration that their beliefs may not coincide with reality (e.g., the shop is closed, but Maria believes that the shop is open; Wimmer and Perner, 1983). However, a less explored aspect of ToM is the recursivity of belief attribution (Peloquin et al., 2023). When we attend to beliefs that refer not to the state of the world, but to *another's* belief about the state of the world (e.g., "*John believes* not that the shop is open/closed but *that Mary believes that* the shop is open/closed"), we perform a recursive mental state attribution commonly referred to as second-order false belief (SOFB) understanding (Perner and Wimmer, 1985; Perner, 1988). Developmentally, while first-order false-belief comprehension is achieved at around 4 years of age, the more complex operation of SOFB is usually achieved between 7 and 9 years of age in typically developing children (Miller, 2009, 2012). However, this SOFB skill has been studied to a lesser extent in the ToM literature (Miller, 2012), and even less is in DHH children. One example of such is the study by Walker et al. (2017) with 5-, 6- and 8-year-old DHH children, which included a measure of SOFB at 8 years. In their study, no differences were found between the hearing group and the DHH group in terms of SOFB resolution, which may be due to the age of the participants or the degree of hearing loss.

Along the lines outlined above, some authors hypothesize that in order to understand this type of recursive mentalistic reasoning (SOFB), mastery of recursive complement sentences is necessary, because it is precisely the subcomponent of language that allows us to construct sentences referring to the beliefs that one person has about another person's beliefs (e.g., "Peter's mother believes that Peter thinks…") (see de Villiers et al., 2014). In support of this view, Polyanskaya et al. (2018) found that mastery of recursive complements was a significant predictor of SOFB comprehension, even after controlling for variables such as age, grammatical comprehension, and working memory. On the other hand, the study by Hollebrandse et al. (2014) compared SOFB comprehension tasks (verbal and low verbal) and found that children aged 7–9 years performed worse on the low verbal version, arguing that language might help second-order belief reasoning by helping to keep track of the different beliefs of the people involved. However, this study does not allow us to draw conclusions about whether it was the syntactic, semantic, or pragmatic aspects of language that helped to perform better on the verbal SOFB tasks than on the low verbal version of these tasks.

Moreover, it is relevant to study the relationship between language and SOFB in children with language impairment because it has been suggested that ToM milestones may have a differential order of acquisition in DHH children (Peterson and Wellman, 2009; Yu et al., 2021). Such results suggest that ToM acquisition in these groups is not merely delayed, but develops differently. So the relationships between mentalistic skills and language may be different in children with language impairment compared to hearing children, as suggested by preliminary findings in children with autism (Polyanskaya et al., 2022). Furthermore, it has been observed that the difficulties of children with language impairment or auditory deficits in understanding the mental states of others may persist even into adulthood (Clegg et al., 2005; O'Reilly et al., 2014; Marschark et al., 2019), and they may also be present in children with early hearing provisions (Yu et al., 2021). Identifying the potential links between these abilities and language in DHH children may hint at possible remediation avenues (Durrleman et al., 2021) and thus contribute to minimizing challenges of this group before reaching adulthood.

1.1 Present study

Given that the link between the various components of language and SOFB has not been sufficiently elucidated, the aim of the present study is to shed light on the link between different components of language development and SOFB in DHH children compared to hearing peers. First, we will analyze whether the link between ToM and language is similar in the two groups of participants and secondly whether SOFBs require global language skills or rather the specific recursive mastery of sentential complements.

Thus, two exploratory research questions emerge:

1 Which language components (vocabulary, general syntax or sentential complements) will show the strongest relationship with SOFB in hearing and DHH children, and are the patterns similar or different in these groups?
2 Is mastery of recursive sentential complements a necessary condition for hearing and DHH children to pass SOFB?

2 Methods

Participants were part of a larger study about the relations between language components and ToM in primary school children.

2.1 Participants

Forty-seven children participated in this study. They were divided in two groups: DHH children ($n = 22$; 9 females) and hearing children ($n = 25$; 14 females), ages 8–12. The DHH group included 22 non-signing children ($M_{age} = 9.92$ years; range 8.05–12.61 years; SD: 1.37), diagnosed with permanent bilateral hearing loss by a certified audiologist. The average age of first audiological devices was 43.8 months (SD: 28.7). The degree of hearing loss ranged from mild–moderate to profound. All of them needed audiological aids: 11 used 2 hearing aids, 7 had two cochlear implants (CI), 2 had 1 CI, and two had a CI and a hearing aid.

All of the children of the DHH group wore audiological devices and were assisted by Language-therapists. A total of 10 children had a profound loss, 2 a severe one, 9 a moderate loss, and one a mild/moderate loss. Due to the heterogeneity of the sample in terms of the degree of hearing loss, two groups were created to assess possible differences in terms of study variables: a subgroup of children with profound/severe hearing loss ($n = 12$) and a subgroup of children with moderate/mild hearing loss ($n = 10$). The analysis found no significant differences in study variables between the groups ($p > 0.05$).

The 25 hearing children had a mean age of 10.24 years (range 8.32–12.17 years; SD: 1.07). There were no significant age differences between the two groups ($F = -2.325$; $p = 0.134$), and no differences either in the non-verbal IQ ($F = 1.099$; $p = 0.403$).

2.2 Measures

The following tasks were individually administered in the following order.

2.2.1 Expressive vocabulary

The Part A of the vocabulary sub-test of the K-Bit test (Kaufman and Kaufman, 2000) was administered to assess children's expressive vocabulary. In this test, children are shown black and white drawings and they are asked to name the picture. The raw score of this part was used.

2.2.2 Non-verbal intelligence

The matrices subtest of the K-BIT test (Kaufman and Kaufman, 2000) was used to ensure that the non-verbal intelligence of the two groups was similar. The items of the test require to understand the existent relationships between different items by pointing or naming the correct response in a multiple-choice question. The standard score of this sub-test was calculated.

2.2.3 Comprehension of first- and second-order complements

We designed a task to evaluate children's comprehension of first- and second-order sentential complements with communication verbs. It was based on the task used by Hollebrandse et al. (2008). In this task, children were told 2 stories, with the support of 2 colored drawings for each.

In each story a first character said something to a second character in direct speech (while showing the first drawing). After that, the second character reported the same information to a third character, but this information contradicted what was seen in the drawing 2. After that, two test questions were asked: The first-order complement question asked about what the first character said to the second character (e.g., "What did the mother say?"). The second-order complement question asked about what the second character had said to a third character (e.g., "What has Gabriel said to Marta?").

Children were awarded one point if they replied correctly to the first question using a first-order sentential complement (e.g., "She said that it was sunny"), and they were awarded another point to the second-question if they responded correctly by using a second-order sentential complement (e.g., "He said that the mother had said that it was sunny"). Since there were two tasks and they scored 0–2 each, the range of total scores was 0–4.

2.2.4 Understanding first- and second-order false belief

An adaptation from the Sally-Anne task used by Braüner et al. (2020) was designed for this study. In this adaptation we created two tasks with low verbal content, and we avoided the use of second-order sentential complements. Each story was told with 6 colored drawings, presented in pairs. The tasks contained questions about the understanding of first and second-order false beliefs in addition to control questions. In each task children were awarded 1 point for responding correctly to the control and SOFB questions, and another point for justifying their answer to the latter (if they explained that one of the characters did not see or did not know that the other character had seen or known where the object really was). The description of one of the tasks can be found in Supplementary material.

2.2.5 Sentence repetition

The sentence repetition subtest of the Clinical Evaluation of Language Fundamentals (CELF-V; Wiig et al., 2013), a standardized test designed to assess language in children from 5 to 15 years, was used. The sub-test measures the child's ability to listen to sentences of increasing length and complexity and repeat them without changing the meaning, content or structure. It has 26 items with different starting points, and items are valued from 0 to 3 according to the mistakes made by children. The raw score of the test was used.

2.2.6 Receptive grammar

The Comprehension of Grammatical Structures (CEG) test (Mendoza Lara et al., 2005) was administered to evaluate receptive grammar. It was designed to evaluate children from 4 to 11 years of age. In this test children are shown four drawings and they have to choose which of them corresponds to a sentence read by the examiner. It does not require any type of verbal response, so it is an appropriate measure to evaluate language comprehension in children who may have expressive language difficulties. The CEG has 80 evaluation items, we only included a selection of 16 items that were mostly linked to the aims of our research, with the following grammatical structures: 2 items of predicative non-reversible SVO sentences; 2 items of attributive sentences; 2 items of pronominalized predicative sentences; 2 items of predicative sentences SVO with plural subject; 4 items of relative sentences from the type SO; 2 items of OVS sentences with a focused object; 2 items of relative sentences of the type SS.

2.2.7 Expressive syntax

In order to evaluate the expressive syntax of the participants, we administered the syntax subtest of the BLOC-SR (Puyuelo et al., 2007), a standardized test designed for evaluating the language of children from 5 to 12 years. This test uses practice items for children to understand which type of sentences they are expected to produce. The syntax subtest has 35 items plus 10 items of practice. However, for the interests of the present study, only 12 items of the syntax subtest were administered to the children (plus 3 practice items), corresponded to the following parts of the sub-test: (a) 4 items of simple sentences of the type S-V-adverbial of place; (b) 4 items of simple sentences of the type (S-V-DO-IO); (c) 4 items of adverbial clauses of cause and condition.

2.2.8 Other measures

In addition to the tests administered to the children, the following questionnaires were administered to the parents or speech therapists of the participants:

a Sociodemographic data questionnaire: A brief questionnaire was administered to the parents to ask for: gender, date of birth, date of schooling, language used by the parents to address their children, language used between the child's parents, existence of learning difficulties, and existence of medical problems or disorders.
b Hearing loss questionnaire: A brief questionnaire was administered to the speech therapists to gather information about the following variables: age of onset and cause of the hearing loss, age of detection, level of loss in each ear, types and age of onset of hearing devices, and relatives with hearing loss.

2.3 Procedure

First, permission to conduct the study was obtained by the ethical committee of the institution where the first author works. Parents of the participants were asked to sign a consent form.

DHH children were contacted through public services attended by children with hearing loss and/or linguistic difficulties. The speech therapists working in this service visit children at the child's school on a weekly basis. This service contacted the families and schools. Speech therapists were present to the sessions as listeners but did not participate in them. Hearing children were contacted through a public school.

Tasks were administered in 2 sessions, lasting about 25 to 40 min each, in a quiet room in the child's school.

Due to the relatively small size of the sample and the fact that three of the study variables, including the dependent variable, did not meet the assumptions of parametric analysis, the Mann–Whitney U group comparison test and Spearman's correlation analysis were applied.

3 Results

Descriptive statistics of language measures and SOFB comprehension are shown in Table 1.

Between-group comparisons showed no differences in the acquisition of recursive complements between the hearing and DHH groups ($Z = -0.393$; $p = 0.694$), nor in the receptive grammar ($Z = -1.356$; $p = 0.175$), or expressive syntax ($Z = -1.766$; $p = 0.077$); however, significant group differences were found in the level of vocabulary ($Z = -4.159$; $p < 0.001$), in sentence repetition ($Z = -3.565$; $p < 0.001$), and in the understanding of SOFB ($Z = -2.169$; $p = 0.030$).

Correlational analysis (see Table 2) revealed that in the control group only general expressive syntax was related to performance on the SOFB task while in the hearing-impaired group, vocabulary, sentential complements and expressive syntax were related to SOFB performance.

We then specifically studied the relationship between second-order sentential complements and SOFB understanding. Most children (95.6%) who passed the second-order complements task also passed the SOFB task (22 out of 23). Conversely, among those who failed the second-order complements task, 62.5% passed the SOFB task (15 out of 24). Fisher's Exact Test indicated a significant

TABLE 1 Means (and standard deviations) of the variables in the study, comparing DHH and hearing children.

	Hearing children	DHH children	Comparison (Mann–Whitney)
SOFB	3.48 (1,26)	2.86 (1.49)	$Z = -2.169$
			$p = 0.030$
			$r = 0.32$
Vocabulary	38,84 (3.36)	32.09 (5.63)	$Z = -4.159$
			$p < 0.001$
			$r = 0.61$
Sentence repetition	8.9 (2.82)	5.05 (3.42)	$Z = -3.565$
			$p < 0.001$
			$r = 0.53$
Sentential Complements	3.24 (0.93)	3.18 (0.79)	$Z = -0.393$
			$p = 0.694$
Receptive grammar	12.64 (2.29)	11.82 (2.11)	$Z = -1.356$
			$p = 0.175$
Expressive syntax	9.84 (1.79)	8.50 (2.61)	$Z = -1.766$
			$p = 0.077$

The effect size estimate r was calculated using the formula $r = |Z|/\sqrt{n}$ (see Rosenthal, 1991; cited in Field, 2018).

TABLE 2 Spearman correlations between SOFB and other variables in the DHH and hearing groups.

		Vocabulary	Sentential complements	Sentence repetition	Receptive grammar	Expressive syntax
SOFB	Hearing children	$r_s = 0.167$	$r_s = 0.314$	$r_s = 0.278$	$r_s = 0.077$	$r_s = 0.501$*
		$p = 0.424$	$p = 0.126$	$p = 0.179$	$p = 0.713$	$p = 0.011$
	DHH children	$r_s = 0.432$*	$r_s = 0.448$*	$r_s = 0.435$	$r_s = 0.203$	$r_s = 0.523$*
		$p = 0.045$	$p = 0.048$	$p = 0.055$	$p = 0.364$	$p = 0.013$

*Correlation is significant at the 0.05 level (2-tailed).

TABLE 3 Crosstabs showing the relationship between children's performance in SOFB tasks and their performance in second-order complements task.

		Pass SOFB tasks	Fail SOFB tasks	Total
Hearing children	Pass second-order complements task	13	1	14
	Fail second-order complements task	8	3	11
Total		21	4	25
DHH children	Pass second-order complements task	9	0	9
	Fail second-order complements task	7	6	13
Total		16	6	22

In this table, children were considered as passing SOFB tasks if they responded correctly to the question about SOFB in each task; also, children were considered as passing the second-order complements if they responded correctly to the second-order complements question in both tasks.

relationship ($p = 0.010$). Further analysis for each group separately (see Table 3) showed significance for DHH children ($p = 0.046$) but not for hearing children ($p = 0.288$). Notably, 53.8% of DHH children passed the SOFB task without mastering second-order complements task, compared to 72.7% for hearing children.

4 Discussion

Similarly to prior studies, comparative results between hearing and DHH groups showed differences in SOFB understanding in favor of the hearing children (Jones et al., 2015; but see Walker et al., 2017). In relation to the linguistic variables, differences were observed too in terms of expressive vocabulary and sentence repetition. However, no such differences were observed in expressive syntax or receptive grammar, nor in understanding sentential complements.

With regard to our first research question, the relationship between SOFB and language was observable in both groups for expressive syntax, with a correlation of moderate-high intensity. For hearing children, this more advanced component of ToM (SOFB) was not related to some of the language components to which simpler, first-order belief performance had been linked in prior studies, such as vocabulary (Schick et al., 2007) or grammar (Farrar et al., 2009). These results are partially in line with those obtained by other scholars focusing on SOFB, namely Filip et al. (2023), who reported that in 5–6-year-olds, neither syntactic comprehension nor vocabulary production explained SOFB understanding, whereas syntactic recursion and pragmatics did. In another study, Bigelow et al. (2021) found that vocabulary was associated with advanced ToM in both young and old children. However, their results are not entirely comparable with ours, as their study included different types of ToM tasks (including first- and second-order FB tasks). Moreover, their vocabulary task consisted of defining vocabulary, which requires syntactic skills. Taken together and bridging the differences between the tasks, the results of the abovementioned studies and ours point to a greater importance of expressive syntactic skills (through syntactic recursion, pragmatics or vocabulary definition) in explaining SOFB understanding. Of course, it can be suggested that syntactic expression (of simple and complex sentences) requires a higher level of morphosyntactic mastery than the necessary for syntactic comprehension. The results show, therefore, a relationship between the mastery of complex linguistic skills and SOFB. Unfortunately, our study does not allow us to explore the relationship with the pragmatic and discursive skills that are in full development in the ages of the children in our sample, which should be the subject of future studies.

While the SOFB-language link emerged in both groups for expressive syntax, the group of hearing children nevertheless had a differential pattern to that observed in the group of DHH children, in which sentential complements, sentence repetition, vocabulary and syntactic expression showed a clear relationship with SOFB. In the DHH group, therefore, a more global relationship between language and SOFB was observed, with several linguistic components involved. The intensity of this relationship was also stronger than the one reported for hearing children by Osterhaus and Bosacki's (2022) meta-analysis between the linguistic measures and advanced SOFB. Prior studies also have found that ToM skills were more strongly related to language in DHH children as compared to hearing children (see Sidera et al., 2017, 2020).

In short, although we observed that language was associated with SOFB both in hearing and DHH children, it should be emphasized that not all components were associated to the same extent in both groups. It is possible that these differences in the relationship between language and SOFB are due to variations in their developmental progress. This may be due to a different progress in global language development, which affects the domain of the SOFB, or the differences may even stem from the specific mastery of some of the components of the language, such as that of the recursive complement sentences.

In relation to our second research question, we did not observe that mastery of recursive complement sentences was necessary for SOFB understanding, neither in DHH or hearing children. While we found that almost all children who mastered second-order sentential complements were successful in understanding SOFB, many children who did not pass the second-order sentential complements task still passed the SOFB task. However, these variables were significantly associated in DHH children and not in hearing children, which means that mastering second-order complements was more important for passing 2OFB for DHH children than for hearing children. In sum, understanding sentential complements may not be a necessary condition for understanding the SOFB task, but it seems to help, as previously found for first-order FB understanding (de Villiers and Pyers, 2002). Nevertheless, the sentential complements task that we used, despite the fact that it had visual aids, required from syntactic expression and thus may be more demanding than the syntactic comprehension questions involved in SOFB comprehension tasks. In this sense, the results of the study by Guan et al. (2018), with complementation and first-order FB tasks, suggest that the two tasks involve interacting but separate neural networks. Precisely these authors pointed out that the complementation task is potentially more demanding than the FB task. In this regard, future studies could study the link between SOFB understanding and recursive sentential complements understanding using also receptive and not only expressive tasks of sentential complements.

The results of this study, although exploratory, showed that beyond first-order FB, the relationship between language and advanced aspects of ToM, such as SOFB, continues to be observed. In this sense, improving language abilities can help the development of mentalistic skills. In particular, we observed the relevance of the mastery of complex aspects of linguistic ability, such as the syntactic component in its expressive aspect. In this regard, at an educational level, fostering the development of syntactic skills in conversations about people's beliefs, including sentential complements, might be beneficial for fostering SOFB, as interventions with sentential complements may be useful for developing FB understanding in DHH children (Durrleman et al., 2021). Finally, our study shows that the relationship between SOFB and language was different in hearing and DHH children, as authors such as Farrar et al. (2017) have already suggested, both in relation to the syntax of complementation and other aspects of linguistic competence. Future studies should study this differential development in more detail.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Comitè d'Ètica i Bioseguretat de la Recerca, University of Girona, Spain. This study was conducted in accordance with the local legislation and institutional requirements (reference for this study CEBRU0014-2018). Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

ES: Conceptualization, Formal analysis, Funding acquisition, Investigation, Writing – original draft, Writing – review & editing, Methodology, Project administration, Resources, Supervision. AA: Investigation, Resources, Writing – review & editing, Methodology. SD: Conceptualization, Methodology, Writing – review & editing, Supervision. AI: Investigation, Resources, Writing – review & editing. FS: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Writing – review & editing, Data curation, Project administration, Supervision.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This work was funded by MICIU, Ministerio de Ciencia, Innovación y Universidades, Spain (ref PID2020-118419GB-I00).

Acknowledgments

We are very thankful to the educational services called CREDA (centres attending students with hearing impairment and language disorders). Specifically, to thank the participation of CREDA Narcís Masó, CREDA Maresme-Vallès Oriental, CREDA Jordi Perelló, and CREDA Catalunya Central, as well as their speech therapists and directing teams.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomm.2024.1401576/full#supplementary-material

References

Astington, J. W., and Baird, J. A. (2005). *Why language matters for theory of mind.* Oxford: Oxford University Press.

Bigelow, F. J., Clark, G. M., Lum, J. A. G., and Enticott, P. G. (2021). The mediating effect of language on the development of cognitive and affective theory of mind. *J. Exp. Child Psychol.* 209:105158. doi: 10.1016/j.jecp.2021.105158

Braüner, T., Blackburn, P., and Polyanskaya, I. (2020). Being deceived: information asymmetry in second-order false belief tasks. *Top. Cogn. Sci.* 12, 504–534. doi: 10.1111/tops.12422

Cheung, H., Hsuan-Chih, C., Creed, N., Ng, L., Ping Wang, S., and Mo, L. (2004). Relative roles of general and complementation language in theory-of-mind development:

evidence from Cantonese and English. *Child Dev.* 75, 1155–1170. doi: 10.1111/j.1467-8624.2004.00731.x

Clegg, J., Hollis, C., Mawhood, L., and Rutter, M. (2005). Developmental language disorders--a follow-up in later adult life. Cognitive, language and psychosocial outcomes. *J. Child Psychol. Psychiatry* 46, 128–149. doi: 10.1111/j.1469-7610.2004.00342.x

de Villiers, J. G. (2018). "Perspectives on truth: the case of language and false belief reasoning" in *Semantics in language acquisition, for the John Benjamins series trends in language acquisition*. eds. K. Syrett and S. Arunachalam (Amsterdam: John Benjamins), 222–245.

de Villiers, J. G., and de Villiers, P. A. (2000). "Linguistic determinism and the understanding of false beliefs" in *Children's reasoning and the mind*. eds. P. Mitchell and K. Riggs (Hove, UK: Psychology Press), 191–228.

de Villiers, P. A., and de Villiers, J. G. (2012). Deception dissociates from false belief reasoning in deaf children: implications for the implicit versus explicit theory of mind distinction. *Br. J. Dev. Psychol.* 30, 188–209. doi: 10.1111/j.2044-835X.2011.02072.x

de Villiers, J. G., Hollebrandse, B., and Hobbs, K. (2014). "Recursive complements and propositional attitudes" in *Recursion*. eds. T. Roeper and P. Speas (Cham: Springer Verlag).

de Villiers, J. G., and Pyers, J. E. (2002). Complements to cognition: a longitudinal study of the relationship between complex syntax and false-belief-understanding. *Cogn. Dev.* 17, 1037–1060. doi: 10.1016/S0885-2014(02)00073-4

Durrleman, S., Burnel, M., De Villiers, J. G., Thommen, E., and Delage, H. (2019). The impact of grammar on mentalizing: a training study including children with autism Spectrum disorder and developmental language disorder. *Front. Psychol.* 10:2478. doi: 10.3389/fpsyg.2019.02478

Durrleman, S., and Delage, H. (2020). Training complements for belief reasoning in developmental language disorder. *J. Speech Lang. Hear. Res.* 63, 1861–1877. doi: 10.1044/2020_JSLHR-19-00075

Durrleman, S., Dumont, A., and Delage, H. (2021). Syntactic strategy training for theory of mind in deaf children. *J. Deaf Stud. Deaf Educ.* 27, 89–100. doi: 10.1093/deafed/enab034

Farrar, M. J., Guan, Y., and Erhardt, K. (2017). "Theory of mind and communication in health and risk messaging" in *Oxford Research Encyclopedia of Communication*. ed. R. Parrott (New York: Oxford University Press).

Farrar, M. J., Johnson, B., Tompkins, V., Easters, M., Zilisi-Medus, A., and Bengino, J. P. (2009). Language and theory of mind in preschool children with specific language impairment. *J. Commun. Disord.* 42, 428–441. doi: 10.1016/j.jcomdis.2009.07.001

Field, A. (2018). *Discovering statistics using IBM SPSS statistics*. Los Angeles: SAGE Publications Ltd.

Filip, A., Białek, A., and Białecka-Pikul, M. (2023). Both syntactic and pragmatic sentence adequacy matters for recursive theory of mind in 5-year-olds. *Cogn. Dev.* 66:101297. doi: 10.1016/j.cogdev.2023.101297

Guan, Y., Farrar, M. J., and Keil, A. (2018). Oscillatory brain activity differentially reflects false belief understanding and complementation syntax processing. *Cogn. Affect. Behav. Neurosci.* 18, 189–201. doi: 10.3758/s13415-018-0565-9

Hollebrandse, B., Hobbs, K., de Villiers, J. G., and Roeper, T. (2008). "Second order embedding and second order false belief" in *Language acquisition and development: Proceedings of GALA 2007 (pp. 270–280)*. eds. A. Gavarró and M. J. Freitas (Cambridge: Cambridge Scholar Press).

Hollebrandse, B., van Hout, A., and Hendriks, P. (2014). Children's first and second-order false-belief reasoning in a verbal and a low-verbal task. *Synthese* 191, 321–333. doi: 10.1007/s11229-012-0169-9

Jones, A. C., Gutierrez, R., and Ludlow, A. K. (2015). Confronting the language barrier: theory of mind in deaf children. *J. Commun. Disord.* 56, 47–58. doi: 10.1016/j.jcomdis.2015.06.005

Kaufman, A. S., and Kaufman, N. L. (2000). *K-Bit, Test breve de inteligencia de Kaufman*. Madrid: TEA Ediciones.

Lohmann, H., and Tomasello, M. (2003). The role of language in the development of false belief understanding: a training study. *Child Dev.* 74, 1130–1144. doi: 10.1111/1467-8624.00597

Marschark, M., Edwards, L., Peterson, C., Crowe, K., and Walton, D. (2019). Understanding theory of mind in deaf and hearing college students. *J. Deaf Stud. Deaf Educ.* 24, 104–118. doi: 10.1093/deafed/eny039

Mendoza Lara, E., Carballo García, G., Muñoz López, J., and Fresneda, M. D. (2005). *Test de Comprensión de Estructuras Gramaticales (CEG)*. Madrid: TEA Ediciones.

Miller, S. A. (2009). Children's understanding of second-order mental states. *Psychol. Bull.* 135, 749–773. doi: 10.1037/a0016854

Miller, S. A. (2012). *Theory of mind: Beyond the preschool years*. New York, NY: Psychology Press.

O'Reilly, K., Peterson, C. C., and Wellman, H. M. (2014). Sarcasm and advanced theory of mind understanding in children and adults with prelingual deafness. *Dev. Psychol.* 50, 1862–1877. doi: 10.1037/a0036654

Ornaghi, V., Brazzelli, E., Grazzani, I., Agliati, A., and Lucarelli, M. (2017). Does training toddlers in emotion knowledge lead to changes in their prosocial and aggressive behavior toward peers at nursery? *Early Educ. Dev.* 28, 396–414. doi: 10.1080/10409289.2016.1238674

Ornaghi, V., Grazzani, I., Cherubin, E., Conte, E., and Piralli, F. (2015). 'Let's talk about emotions'. The effect of conversational training on preschoolers' emotion comprehension and prosocial orientation. *Soc. Dev.* 24, 166–183. doi: 10.1111/sode.12091

Osterhaus, C., and Bosacki, S. L. (2022). Looking for the lighthouse: a systematic review of advanced theory-of-mind tests beyond preschool. *Dev. Rev.* 64:101021. doi: 10.1016/j.dr.2022.101021

Peloquin, C. M., McDermott, C. H., and Moses, L. J. (2023). Individual differences in second-order false-belief understanding and executive abilities: a meta-analytic review of evidence from school-age children and adults. *Cogn. Dev.* 68:101367. doi: 10.1016/j.cogdev.2023.101367

Perner, J. (1988). "Developing semantics for theories of mind: from propositional attitudes to mental representation" in *Developing theories of mind*. eds. J. W. Astington, P. L. Harris and D. R. Olson (New York, NY: Cambridge University Press), 141–172.

Perner, J., and Wimmer, H. (1985). "John thinks that Mary thinks that…" attribution of second-order beliefs by 5-to 10-year-old children. *J. Exp. Child Psychol.* 39, 437–471. doi: 10.1016/0022-0965(85)90051-7

Peterson, C. C., and Wellman, H. M. (2009). From fancy to reason: scaling deaf and hearing children's understanding of theory of mind and pretence. *Br. J. Dev. Psychol.* 27, 297–310. doi: 10.1348/026151008X299728

Polyanskaya, I., Braüner, T., and Blackburn, P. (2018). Second-order false beliefs and recursive complements in children with ASD. In: *Proceedings of the 42nd annual Boston University Conference on Language Development*.

Polyanskaya, L., Manrique, H. M., Marín, A., García-Palacios, A., and Ordin, M. (2022). Typological differences influence the bilingual advantage in metacognitive processing. *J. Exp. Psychol. Gen.* 151, 2706–2719. doi: 10.1037/xge0001225

Puyuelo, M., Renom, J., Solanas, A., and Wiig, E. (2007). *Evaluación del lenguaje: BLOC (Screening-R)*. Barcelona: Elsevier Masson.

Rieffe, C., and Wiefferink, C. H. (2017). Happy faces, sad faces: emotion understanding in toddlers and preschoolers with language impairments. *Res. Dev. Disabil.* 62, 40–49. doi: 10.1016/j.ridd.2016.12.018

Rosenthal, R. (1991). *Meta-analytic procedures for social research (2nd ed.)*. Newbury Park, CA: Sage.

San Juan, V., and Astington, J. W. (2017). Does language matter for implicit theory of mind? The effects of epistemic verb training on implicit and explicit false-belief understanding. *Cogn. Dev.* 41, 19–32. doi: 10.1016/j.cogdev.2016.12.003

Schick, B., de Villiers, P., de Villiers, J., and Hoffmeister, R. (2007). Language and theory of mind: a study of deaf children. *Child Dev.* 78, 376–396. doi: 10.1111/j.1467-8624.2007.01004.x

Sidera, F., Amadó, A., and Martínez, L. (2017). Influences on facial emotion recognition in deaf children. *J. Deaf Stud. Deaf Educ.* 22, 164–177. doi: 10.1093/deafed/enw072

Sidera, F., Morgan, G., and Serrat, E. (2020). Understanding pretend emotions in children who are deaf and hard of hearing. *J. Deaf Stud. Deaf Educ.* 25, 141–152. doi: 10.1093/deafed/enz040

Slaughter, V., and Peterson, C. C. (2011). "How conversational input shapes theory of mind development in infancy and early childhood" in *Access to language and cognitive development*. eds. M. Siegal and L. Surian (New York, NY: Oxford University Press), 3–22.

Walker, E. A., Ambrose, S. E., Oleson, J., and Moeller, M. P. (2017). False belief development in children who are hard of hearing compared with peers with normal hearing. *J. Speech Lang. Hear. Res.* 60, 3487–3506. doi: 10.1044/2017_JSLHR-L-17-0121

Wiig, E. H., Semel, E., and Secord, W. A. (2013). *Clinical evaluation of language fundamentals. 5th* Edn. Madrid: Psychological Corporation.

Wimmer, H., and Perner, J. (1983). Beliefs about beliefs: representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition* 13, 103–128. doi: 10.1016/0010-0277(83)90004-5

Woolfe, T., Want, S. C., and Siegal, M. (2002). Signposts to development: theory of mind in deaf children. *Child Dev.* 73, 768–778. doi: 10.1111/1467-8624.00437

Yu, C.-L., Stanzione, C. M., Wellman, H. M., and Lederberg, A. R. (2021). Theory-of-mind development in young deaf children with early hearing provisions. *Psychol. Sci.* 32, 109–119. doi: 10.1177/0956797620960389

Yu, C. L., and Wellman, H. M. (2023). All humans have a 'theory of mind'. *J. Autism Dev. Disord.* 53, 2531–2534. doi: 10.1007/s10803-022-05584-1