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REVIEW ARTICLE

On the Relationship between Theory of Mind and Syntax in Clinical and Non-Clinical Populations: State of the Art and Implications for Research

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Abstract:

Background:

Over the years, different explanations have been given on the relationship between syntax and Theory of Mind, *i.e.*, the ability to attribute mental states to others and predict, describe, and explain behavior based on such mental states. In the present study, we focus on the relationship between false-belief understanding as a crucial aspect of Theory of Mind, and on the ability to master the syntax of complementation, *i.e.*, the ability to produce and comprehend sentences in a recursive way.

Objective:

Our purpose is to test two main hypotheses on the relationship between false-belief understanding and the ability to master the syntax of complementation: the dependence and the independence of false-belief understanding on syntactic complementation.

Method:

We analyze studies on children with typical development, deaf children with deaf signing or hearing parents, children with specific language impairment, children diagnosed with autism spectrum disorder, longitudinal and training studies, and studies on adults with neuropsychological disorders.

Conclusion:

Strengths and weaknesses of the two hypotheses are discussed and limitations of the current state of knowledge are presented. A lifespan approach taking into account both the emergence and maintenance of false-belief understanding and using both implicit and explicit false-belief tasks is proposed to face the issue discussed.

Keywords: Aphasia, Atypical development, Syntactic complementation, False-belief understanding, Syntax, Theory of Mind.

1. INTRODUCTION

Theory of Mind (ToM) is the ability to attribute mental states to others and predict, describe, and explain behavior based on such mental states [1 - 4]. ToM is thought to be at the core of any successful social interactions and communication process [5, 6], and one of its key components is the False Belief (FB) understanding, *i.e.*, the understanding of another person's wrong belief in relation to one's own knowledge of the real state of affairs [7]. Accordingly, ToM is generally tested through classic FB tasks: these tests provide evidence that children can or cannot

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distinguish between the thoughts and feelings they themselves currently have with those that can be possibly held by others [8] (but see [9, 10] for critical reviews on FB tasks). Although we know much about ToM and, in particular, about FB understanding, it is still not entirely clear which factors are involved in its development and maintenance. It is very complex to study social skills as separate from other abilities as the language, considering also that they develop around the same life-period [11 - 13]. Over the years, different explanations on ToM development have been given, but one of the most interesting is the relationship between FB understanding, and syntactic complementation, *i.e.*, the embedding of one propositional argument under another proposition, as is needed for the expression of propositional attitudes such as beliefs and states of knowledge [14]. Syntax is a mechanism that allows humans to understand and construct an infinite number of sentences from a finite number of elements and complementation is the scaffolding of this mechanism [15, 16].

Here we discuss the state of the art of the field and propose an interpretative structure presenting two main hypotheses on the relationship between FB understanding, as a key ability of ToM, and complementation, as a crucial aspect of syntax. To this end, studies on both children with typical or atypical development, longitudinal and training studies, and studies on adults with neuropsychological disorders are presented and discussed. The different samples mentioned above allow us also to refer to different dimensions, such as the development, maintenance and deficit of one or both the abilities taken in to account (FB and/or syntactic complementation)

2. THE TWO INTERPRETATIVE HYPOTHESES: THEORY OF MIND DEPENDENCE OR INDEPENDENCE UPON SYNTAX

A debated idea is whether we need syntax for the development of the ability to understand FB tasks. According to the literature, there are two main interpretative hypotheses on the relationship between ToM and syntax, *i.e.*, that ToM depends on syntax or that ToM and syntax are independent.

As pointed out by the hypothesis of ToM development dependence upon syntax, FB understanding owes its development to a previously developed linguistic base (*e.g.*, [14, 17]). The proponents of this hypothesis argue that syntax and, more specifically, mastery in complementation, support the crucial processes for FB understanding. According to the linguistic determinism theory proposed by Jill and Peter De Villiers, the acquisition of the ability to master the syntax of complementation in childhood provides the representative structure necessary for the understanding of FBs by converting them into propositional attitudes [14, 18]. When we talk about mental states (*e.g.*, “I think that Sally is afraid”), we use a rather complex construction, which consists of the main clause (“I think that...”) and subordinate clause embedded into the first (“Sally is afraid”). An important stage in development occurs when children understand that the sentential complements, which depend on the verb *think*, may be false after careful comparison with the world. In this syntactical structure, the content can, therefore, have an independent truth value: sentential complements promote an explicit representation of an embedded subordinate clause with a true-or-false truth value [19, 20]. From this viewpoint, syntactic complementation is a necessary precursor to the acquisition of FB understanding, offering the means to debate about mental states and reality.

On the other hand, the hypothesis of ToM development as independent of syntax, syntax and ToM are related but separate skills. As the hypothesis of dependence previously described proposed syntactic complementation as a key component for FB understanding, we expect that a lack of this ability leads to the collapse of the FB component of ToM, also when ToM is already acquired. The proponents of this hypothesis argue that mastery in complementation is not a scaffolding ability for FB understanding, even if these two skills develop in the same life-period. To support the hypothesis of independence, some researchers conducted studies on adult participants with syntactic deficits to explore this issue and found contrasting results. Case studies on aphasic patients, who pass ToM tasks despite their severe linguistic deficit, have contributed to a different way to conceptualize the relationship between ToM and syntax. Siegal and Varley [21] proposed that grammar is marginally important for ToM, although it is an important source for the mediation of conversation. Evidence on patients with aphasia indicates that explicit knowledge of grammar is not necessary to scaffold ToM reasoning.

The hypothesis of independence was further supported by studies on ToM reasoning in adult patients with right hemisphere damage suggesting a double dissociation between grammar on one hand, and ToM and pragmatics, on the other [22].

The proponents of this hypothesis do not totally deny the utility of syntactic functions in the comprehension of others' mental states. Complementation could facilitate ToM when the system fails but it is not essential when

everything is operating optimally. According to Siegal *et al.* [23], syntax plays a critical role in reducing mistakes in the transmission of knowledge but its presence alone cannot guarantee understanding social relationships and communication.

3. THE TWO INTERPRETATIVE HYPOTHESES: STUDIES FOR DIFFERENT SAMPLES

The studies in the domain under consideration have been conducted at different stages of development (children, adolescents, and adults) and in samples presenting both typical and atypical development.

3.1. Longitudinal and Training Studies in Typical Development

To understand the relationship between FB understanding and syntactic complementation, various longitudinal and training studies have been conducted. Longitudinal studies analyzed the development of an ability across the lifespan. Astington and Jenkins [24] assessed ToM and language development in 3-year-old children over a period of 7 months at approximately 3.5-month intervals and their results seem to support the hypothesis that the syntactic subcomponent of language is involved in promoting the development of FB understanding. In a subsequent study on typically developing 3-5-year-old children tested in four sessions over the course of 1 year, De Villiers and Pyers [25] found that the mastery of syntax for sentential complements was the best predictor of success in FB tasks. The authors conclude that complementation is necessary to enable children to represent the correct syntactic form of others' belief states in their own mind.

Training studies attempted to verify the effect of experience. Hale and Tager-Flusberg [26] pre-tested children (ages 36–58 months) with FB and sentential complement tasks to ensure that they had not yet acquired FB understanding or sentential complements, and with relative clause tasks to assess their ability to include the relative clause information in their speech. The children were divided into three different groups and assigned to three different training types: the first was set up on the development of FBs, the second on sentential complements, and the third on relative clauses. The training was scheduled in two training sessions within one week of each other. After the second training session, all children were post-tested with tasks similar to those from the pre-test session. The results supported the hypothesis of linguistic influence on the development of ToM: the training on complementation and the acquisition of sentential complements as specific linguistic constructions led to improved performance on FB tasks, in contrast to relative clause training that did not yield improved FB understanding (see also [27]). Mo *et al.* [28], in a study involving Mandarin-speaking children (ages 40–55 months), showed that training on sentential complements depending on communication verbs (*e.g.*, say) significantly improved FB understanding. The children were divided into four training groups and each training was scheduled in two 25-minute-training sessions within two weeks of each other and 7-day-interval between sessions. Interestingly, they also found that FB training only (*i.e.*, without sentential complement training) improved FB performance but not sentential complement understanding, suggesting that explicit FB understanding can emerge even when children have little competence with sentential complement constructions.

These studies give a controversial support to the hypotheses: longitudinal studies on typical development seem to support the hypothesis of dependence, but training studies highlight that also FB training and not only complementation improve FB understanding.

3.2. Studies of People with Hearing Loss (Deaf and Hard-of-Hearing)

In deaf children born in families with hearing parents, both language ability [29, 30] and FB understanding [31, 32] are acquired later than in children with typical development. On the contrary, studies on deaf children with signing parents show that children who learn sign language at an age comparable to those with typical development can fluently master syntax and display ToM skills comparable to age-matched hearing peers [33]. De Villiers and De Villiers [34] found that FB understanding in orally taught deaf children is independent from general vocabulary skills but is dependent upon the ability to manage false sentential complements.

Interesting findings come from hearing-impaired children with cochlear implants. Rimmel and Peters [35] pointed out that in both linguistic-syntactic and FB tasks, these children performed comparably to deaf children born into signing families, with both groups showing better results in verbal than non-verbal ToM tasks. These findings do not guarantee the predictive ability to master the complementation but merely attest to the importance of previous conversations about mental states. Holding conversations using meta-representative skills increases the development of ToM reasoning, and vice versa, an environment lacking interpersonal and communication possibilities often leads to difficulties in ToM reasoning in deaf children ([31]; on the importance of conversation, see also [36]).

3.3. Studies of People with Autism Spectrum Disorders

Children with Autism Spectrum Disorders (ASD) face a delay in the acquisition of syntax and significant difficulties in FB tasks [37 - 40]. Tager-Flusberg and Sullivan [41] reported that language ability predicted FB performance with an accuracy of 90% in children with ASD and that syntactic comprehension was the best predictor. Tager-Flusberg [38] noted that children with ASD, who fail in ToM reasoning tasks, could not deduce the sentential complementation in phrases depending on communication verbs. The syntax of complementation seems to be significant for the development of the representational mind especially in ASD. Similarly, Durrleman *et al.* [40] set up an experimental study on children with ASD (ages 6.9 to 14.4 years) and found that non-verbal ToM was significantly correlated with the understanding of complement clauses. More specifically, by using regression analyses, they highlighted that morphosyntax played an important role to determine ToM success (for similar results, see also [42]).

Lind and Bowler [43] noted that the syntax of complementation and performance in FB tasks were significantly related in children with ASD matched in age and verbal ability with the comparison group, but neither the bivariate nor the partial correlations between the two abilities differed between the groups. Whereas, in this study, correlational analyses have been carried out, based on these results, it is not possible to identify the direction of causality, but it is possible to observe a simple correlation between ToM competence and syntax of complementation. Other studies adopted a similar position: syntax could facilitate ToM reasoning without implying that this ability is necessary for ToM development (*e.g.*, [44]).

The studies on People with ASD seem to support mainly the hypothesis of dependence but, as it is pointed out by some studies, the results could be interpreted as the influence of reasoning rather than the cause of the development of the FB understanding

3.4. Studies of Children with Specific Language Impairment

Children with Specific Language Impairment (SLI) experience significant syntactic difficulties. Thus, several studies investigated children with SLI to better understand the relationship between syntax and ToM development [45 - 48].

Farrar *et al.* [47] observed that in preschool children with SLI, general grammar and vocabulary contributed to ToM reasoning, whereas sentential complementation abilities did not contribute independently. These findings not only emphasize the generic syntactic ability for overcoming FB tasks but they also display that the ability in syntactic complementation should be less relevant than general language abilities.

Miller [49] pointed out that the mastery of embedded sentential complementation was related to ToM but there was no evidence of causality. Miller compared three groups of children: children with SLI, age-matched children with typical development, and younger typically developed children with linguistic abilities similar to those of SLI children. The experiment consisted of four conditions applied to FB tasks. Children with SLI had linguistic abilities that are below age expectations but they showed intact other cognitive skills including ToM abilities (see also [50]). This study showed that children with SLI performed like younger children in the linguistically demanding “think” and “pretend” conditions, but they were more similar to their age-matched peers in the “look” and “show” conditions. These results emphasize that FB understanding and complementation are not causally related, even if they are required for the linguistic demands of some ToM tasks (see also [46, 51]).

The main studies on children with SLI maintain a more cautious position in the interpretation of the results: the data presented do not allow one to lean for one or the other hypothesis, even if they detect some kind of influence between the two components in analysis.

3.5. Studies of Patients with Aphasia

In order to analyse the relationship between ToM and syntax, here we discuss three case reports of patients who became aphasic following damage to the left hemisphere.

Varley and Siegal [52] were the first to systematically investigate the relation between grammar and ToM by studying patients with aphasia. They reported the case of S.A., a patient with severe agrammatic aphasia but with preserved ToM reasoning. S.A. had a large left hemisphere lesion that affected his linguistic abilities, except for sentence comprehension mediated by a more general preserved pragmatic competence. His spontaneous writing consisted of article-noun, adjective-noun, and quantifier-noun combinations without grammatical structure. Despite

these impairments, preserved ToM understanding tested with FB tasks and executive functioning was observed. This dissociation was also noted in two other cases: M.R., reported by Varley *et al.* [53], revealed impaired performance in executive functioning and linguistic tasks but retained ToM reasoning in a picture-based task. P.H., a patient investigated by Apperly *et al.* [54], showed severe agrammatical aphasia, similar to S.A. and M.R., with specific impairment in embedded complement sentences and relative clauses. Despite these difficulties, ToM reasoning tested on non-verbal first-order and second-order FB tasks was above chance. Similar findings were reported by Ramachandra and Mikajlo [55] (see also [56]; for a brief overview see [21]). In sum, case studies of patients with aphasia are presented by researchers advocating the independence of ToM from grammatical abilities, proposing that ToM reasoning is possible even when specific grammatical constructions are impaired.

DISCUSSION AND CONCLUSION

The role of language in ToM is well recognized, but the relative contribution of different language aspects remains debated [57 - 60]. In the present work, we have focused on the relationship between FB understanding and syntactic complementation with a controversial emerging picture.

First, the linguistic determinism theory has had a strong influence but has not been without criticisms. Studies in line with this theory mainly come from longitudinal and training studies and from studies with deaf children born into hearing families. However, contrasting results were observed as well. For example, Lohmann and Tomasello [27] found in their training study that sentential complement syntax is sufficient for FB understanding in experimental settings, but it might not be a necessary condition in FB comprehension in ecological conditions. Studies on children speaking non-English languages did not support the effectiveness of training on ToM performance. In a study on Swedish preschoolers, Clausen-Bruun [61] found no evidence supporting the role of active production of tensed complements (*i.e.*, full propositions embedded within sentences) in ToM development. A study by Perner *et al.* [62] reported that German children understand desires earlier than beliefs, although both verb types take compliments with a similar structure. Cheung [63] and Tardif *et al.* [64] found that in Cantonese-speaking children, general language comprehension, rather than specific language structure *per se*, accounted for FB understanding. Tompkins [65] proposed that an important aspect for the prediction of children's FB understanding could be the mother's use of contrastives (*i.e.*, the complement syntax that directly contrasted thought and reality). Comparing mothers' cognitive state talk assessed during shared book reading with 3- to 5-year-olds in relation to children's FB understanding six months later, the authors found that, in opposition to the mother's use of contrastives, nor the total use of cognitive state vocabulary neither the complement syntax using the verb "think" predicted children's FB understanding. In their interesting review, Farrar and colleagues [66] analyze different studies and suggest that it seems that syntactic complementation has an influence only on atypical development and not also in typically developing children, where general language seems to have a more relevant effect.

Second, to understand why studies investigating the relationship between syntax and ToM yielded mixed results, it is important to pay attention to the nature of the experimental tasks. Many ToM tasks are not cognitively equivalent and might draw on divergent mental abilities, which is a first limitation of the current literature. As emphasized by Apperly *et al.* [67], there is no definitive evidence for the domain specificity of ToM, especially belief understanding assessed with FB tasks. FB tasks are not well suited to study the relationship between ToM and syntactic complementation, because just passing these tasks requires abilities other than ToM, such as attention and memory [68]. Furthermore, it is important to keep in mind that FB tasks normally used in literature vary for the kind of FB understanding assessed, explicit or implicit [69]. In the former kind of assessment the participant is asked to predict a behavior explicitly by means of a verbal answer consciously controlled, while in the latter kind of assessment procedural non-verbal behaviors such as anticipatory looking or eye gaze are used as an indirect measure of FB understanding. The difference between implicit and explicit ToM was firstly addressed by Clements and Perner [70] who analyzed eye movements and distinguished a period of implicit understanding of FB preceding the onset of explicit understanding. In their experiment, children ages 2 years 11 months were able to look at the correct solution in a FB scenario although they verbally answered incorrectly. Subsequently, Baillargeon [9, 71, 72], using a violation-of-expectation method, reported that 15-month-old infants already show some implicit understanding of FB when tested with an entirely non-verbal task (although explanations of these results not invoking FB understanding have been proposed, see [73, 74]).

Explicit and implicit FB understanding may dissociate during development and in atypical populations [75] but are closely related in typical adults [76]. Thus, future research should carefully consider the kind of tasks used to assess ToM abilities and use a mix of tasks covering both implicit and explicit processes (even considering that children

understand diverse beliefs before FBs, as well as different mental states before belief, with a progression from desire to diverse belief to FB [77]).

Third, the findings by Low [78] in 3- and 4-year-olds indicated that while in explicit FB tasks a relationship between ability for syntactic sentential complements and FB performance is detectable, this is not the case when implicit FB is assessed in this population. On the other hand, the findings by Newton and De Villiers [79] show that in a dual-task setting in adults (ages 18–35), verbal shadowing disrupts the ability to monitor a character's belief in a non-verbal FB task. In contrast, Forgeot d'Arc and Ramus [80] presented a completely non-verbal paradigm and observed an independence between FB understanding and verbal reasoning in adulthood. The results show that, actually, verbal shadowing decreased the overall performance and not only FB understanding. Similarly, Dungan and Saxe [81] found that success in FB tasks in adulthood is equal during verbal and non-verbal interference; these results show that verbal shadowing has no a specific effect, suggesting that syntax is not necessary in FB understanding in adulthood. These results are important as they highlight the second limitation of the current literature, a limitation concerning the comparison of results coming from populations, at least in principle, not comparable.

Fourth, another important question concerns the distinction between the impact of syntax on the development of ToM understanding and the impact of syntax on ToM understanding when ToM is already acquired. This distinction led to a different interpretative structure in the discussion of the state of the art of this field, in particular for what concerns the *kind of dependence* between syntax and ToM. In fact, the hypothesis of ToM development dependence upon syntax could be split in two sub-hypotheses: a *temporary dependence*, *i.e.*, complementation is necessary for the emergence of FB understanding but this dependence disappears later on, and a *permanent dependence*, *i.e.*, that complementation is necessary for the emergence as well as for the maintenance of FB understanding. As previously discussed, findings on case studies of patients with aphasia are discussed by researchers advocating the independence of ToM from grammatical abilities; nevertheless, it is important to note that these findings falsify only the permanent dependence hypothesis, but they can not allow to exclude a temporary dependence between complementation and FB understanding.

One important limitation of the present brief overview is the lack of a careful analysis concerning the influence of culture on the development of both FB understanding and syntax: the experimental data come from many different cultures and languages, and culture has an impact on both dimensions of analysis (see for example [82]). Consequently, the nature of the link between syntax and FB understanding remains unresolved even for reasons related to culture that makes the comparison between studies thorny.

In conclusion, we tried to identify salient features of both the dependence and independence hypothesis, but the cases used by the different authors are not fully comparable. Discussing the relationship between syntactic complementation and FB understanding at developmental stages is one aspect, which differs when both functions have already been acquired [83]. Taking into account the difference between the role played by syntax in ToM development and in ToM understanding when ToM is already acquired is crucial in facing this issue. A lifespan approach taking into account both the emergence and maintenance of FB understanding and using both implicit and explicit FB tasks would be beneficial in the future. Adopting this comprehensive approach would not only have scientific value for our knowledge of the relationship between syntax and ToM but would have significant clinical and educational implications for individuals with ToM difficulties.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

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

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