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Theory-of-mind during childhood: Investigating syntactic and executive contributions

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Abstract

Both syntax and Executive Functions (EF) are involved in Theory-of-Mind (ToM) but their contributory roles have mainly been studied separately. Moreover, researchers have mostly administered False Belief (FB) tasks while they may not be representative of all ToM abilities. Studies of adults give valuable information regarding whether syntax and EF are useful for ToM reasoning (i.e., *Reasoning* account), however, only the study of children brings direct evidence in favor of ToM emergence (i.e., *Emergence* account). Also, because the ToM tasks used often entail verbal and executive demands, the links observed could mostly result from such confounds (i.e., *Expression* account). We evaluated ToM, syntactic and EF abilities in 126 children (3-11 y.o.) using a set of ToM tasks with minimal verbal and executive demands. Our goals were to assess (1) the hierarchical contribution of syntax and EF to ToM, (2) whether results previously obtained for FB tasks are representative of ToM in general, (3) whether the ToM-syntax and ToM-EF links are constant (i.e., *Reasoning* account) or decrease during development (i.e., *Emergence* accounts). Results of stepwise regression analyses showed a predominant role of syntax over EF to predict ToM abilities. The comparison of results for ToM and FB tasks showed that FB is not always representative of ToM. Finally, there was no moderating effect of age

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on the syntax-ToM or EF-ToM relations, thus suggestive of the *Reasoning* account rather than the *Emergence* account.

KEYWORDS
executive functions, false belief, syntax, theory-of-mind

1 | INTRODUCTION

Theory-of-Mind (ToM) is the ability to attribute mental states to others in order to predict or explain their behavior (Premack & Woodruff, 1978). ToM is mainly assessed by means of False Belief (FB) tasks. The most famous FB task is the Sally-Anne task (Baron-Cohen, Leslie, & Frith, 1985) where children are asked to predict where Sally will look for her ball after Anne has moved it in Sally's absence from the basket, where Sally had left it, to the box. Children start to predict Sally's behavior according to her belief rather than according to their own knowledge of reality only after the age of 4 or 5 years (Yirmiya, Erel, Shaked, & Solomonica-Levi, 1998). In doing so, they demonstrate that they are aware of the existence of mental states guiding others' behavior, that is, to say they demonstrate their ability to use ToM (Dennett, 1978).

1.1 | Hierarchical contribution of syntax and executive functions (EF) to ToM

Theory-of-Mind development is related to a set of cognitive skills, especially linguistic skills (Farrar, Benigno, Tompkins, & Gage, 2017; Milligan, Astington, & Dack, 2007; Tompkins, Farrar, & Montgomery, 2019) and executive functions (for a Meta-analysis see Devine & Hughes, 2014).

General language (e.g., Farrar et al., 2009; Tager-Flusberg & Joseph, 2005), receptive vocabulary (e.g., Carlson & Moses, 2001) and mental state lexicon (e.g., Schick, de Villiers, de Villiers, & Hoffmeister, 2007) with syntactic embedding play an important role in the typical development of ToM (Durrleman, Burnel, de Villiers, Thommen, Yan & Delage, 2019; Hale & Tager-Flusberg, 2003; Milligan et al., 2007; Poltrock, 2011; for an alternate view see Farrar et al., 2017). In particular, studies have found a link between both mastery of Relative Clause Sentences (RCS) and Complement Sentences (CS) and FB success (Durrleman, Hinzen & Franck, 2018; Smith, Apperly & White, 2003). CS are complex sentences that allow the embedding of a false proposition into a true one. For example, in "Sally thinks that *the marble is in the basket*," the underlined embedded proposition can be false with the entire sentence being true. Relative Clause Sentences (RCS), such as "Sally plays with *the marble that is in the basket*," are other complex sentences that also allow the embedding of a proposition into another. Nevertheless, contrary to CS, if the embedded proposition is false (i.e., in our example if there is no marble in the basket) the entire RCS is false too. Thus, CS, but not RCS, are particularly well suited to reason that someone is misrepresenting reality. Thus, de Villiers and de Villiers (2000) proposed that CS is a useful tool for representing others' (false) mental states (for a meta-analysis, see Milligan et al., 2007). CS can occur with different types of verbs, such as cognition verbs (e.g., think, believe), but also communication verbs (e.g., say, tell) that do not imply the semantics of mental states. Complements of communication verbs have been claimed to be indicative of a purer measure of complementation abilities precisely because they do not imply mental state concepts, removing this confounding variable with ToM. Studies of typically developing children showed that complementation with communication verbs is related to FB performance (de Villiers & de Villiers, 2012; de Villiers & Pyers, 2002; Durrleman & Franck, 2015; Hale & Tager-Flusberg, 2003; Low, 2010; Ng, Cheung, & Xiao, 2010), and that complementation training improves false belief understanding (Durrleman et al., 2019; Lohmann & Tomasello, 2003; Sellabona et al., 2013). A limitation of previous studies is that CS understanding has been assessed by means of complements that were

explicitly false. However, Sellabona et al. (2013) showed that the training of false complements, but not that of true complements, improved the ability to succeed at FB tasks. They conclude that falsity, rather than embedded syntax, fosters children's understanding of FB. Comparing CS to RCS allows teasing apart (i) the impact of syntactic complexity, also associated with RCS and (ii) the misrepresentation properties specific to CS. To our knowledge, only Hale and Tager-Flusberg (2003) compared CS and RCS contribution to FB. Their results suggest a major role of CS for FB compared to the role of RCS.

ToM skills have also been related to EF (Devine & Hughes, 2014; Pineda-Alhucema, Aristizabal, Escudero-Cabarcas, Acosta-Lopez, & Vélez, 2018). However, it is currently difficult to extract from the literature a particular executive component that would be the most related to ToM. Inhibition has been envisaged as one main executive skill required for success on ToM tasks (e.g., Brock, Kim, Gutshall, & Grissmer, 2018; Flynn, 2007) because children need to be able to suppress their own perspective to accurately grasp others' views and knowledge. In addition, neuroimaging studies in adults have shown that the neural bases of ToM and inhibition partially overlap (Mahy, Moses, & Pfeifer, 2014). According to Rothmayr et al. (2010) and van der Meer et al. (2011), these could be similar in FB tasks and inhibition tasks (like stop signal tasks) in the bilateral inferior and middle frontal gyrus, the right medial and inferior frontal and temporal gyrii, as well as the temporo-parietal junction. Beyond the involvement of inhibition, flexibility, that is to say the ability to shift between tasks or task-rules in order to produce a goal-adapted behavior, has also been proposed as a useful ability to succeed in ToM tasks (e.g., Lewis-Morrarty, Dozier, Bernard, Terracciano, & Moore, 2012) since it allows an individual to shift between conflicting perspectives. The ability to maintain and manipulate information during a short period of time, that is to say Working Memory (WM), is also arguably an important element for ToM (e.g., Austin, Groppe, & Elsner, 2014) as it allows children to maintain crucial information available (e.g., mental states, reality) while using it to predict or explain someone's behavior.

Despite the fact that in the literature both syntax and EF appear to be related to ToM, few studies evaluated them together (Brock et al., 2018; Carlson, Moses, & Claxton, 2004; Durrleman & Franck, 2015; Hughes, 1998; Hughes & Ensor, 2007; Marcovitch et al., 2015). Those that did, however, were primarily focused on ToM-EF links controlling for verbal skills, mostly lexical abilities, and consequently do not yield insights on the potential hierarchical contribution of syntactic and executive abilities on ToM. Only the study from Durrleman and Franck (2015) revealed a predominant contribution of syntax over EF in FB attribution. However, their results should be taken with caution given the small sample size (n = 17). The first goal of the current study was thus to assess the hierarchical contribution of syntax and EF to ToM abilities in children using a substantial sample size.

1.2 | The common use of FB tasks to assess ToM

In children, ToM is mostly studied through FB tasks (Smith & Wu, 2016). These tasks were proposed by Dennett (1978) as the acid test of ToM. Nevertheless, several authors suggested that ToM is not limited to FB understanding (Bloom & German, 2000; Wellman, Cross, & Watson, 2001; Wellman & Liu, 2004) and FB tasks may not be representative of general ToM abilities. For instance, in a review, Saxe, Carey and Kanwisher (2004) provide evidence that the neural substrates associated with belief attribution are distinct from those observed during ToM tasks like goal attribution. In light of this, the massive and almost exclusive use of FB tasks to study ToM is an important limitation to the understanding of global ToM development.

Furthermore, the literature often fails to clearly specify whether the formulated hypothesis concerns ToM in general or solely FB. We argue that, while FB reasoning is an interesting domain of investigation, the study of ToM cannot be limited to FB attribution because conclusions based on FB tasks may not be generalizable to ToM. Many researchers may wish to understand the predictors of ToM other than FB, so as to allow the implementation of remediation programs designed to promote social skills relying on the mastery of ToM abilities other than belief attribution. To increase the potential of such a program, findings beyond FB attribution need to be considered. In particular, even though training on CS is efficient to promote FB understanding, this could be too specific to

improve other ToM abilities, and all the more social skills in daily life. Promoting FB reasoning alone might not be enough to yield wider social benefits, which is of paramount importance for clinical populations where ToM is delayed, such as children with autism spectrum disorders.

In the current study, we examined how syntax and EF are related to ToM development, beyond FB attribution. The second goal was to thus assess if results previously obtained for FB tasks are representative of results obtained for more general ToM abilities.

1.3 | Expression, emergence, and reasoning accounts

Regardless of the specific cognitive abilities studied (e.g., language, EF), three hypotheses can be proposed to explain their relation to ToM (cf. Figure 1). According to the *Expression* account, low ToM performance does not necessarily correspond to low ToM competence, but could also reflect good ToM competence with constraints in the specific task used that prevent the child from succeeding. For example, additional linguistic (Apperly, Samson, & Humphreys, 2009; Craven, 2005) or executive demands (Moses, 2001) coming from task presentation or instructions could restrain ToM performance despite good ToM competence. The *Expression* account can be considered in a *strong* and in a *weak* version (Craven, 2005). In the *strong* version, the links with ToM are considered as entirely determined by task demands. In the *weak* version, even though ToM can be correlated to other cognitive abilities due to additional demands coming from task presentation, a more fundamental link nevertheless exists. In their meta-analysis, Wellman et al. (2001) compared children's success at FB tasks depending on task features. For example, they found that FB tasks were succeeded at a younger age when children were explicitly told that there was a deceptive motive for the change of location (i.e., salience of mental state), when the moved object

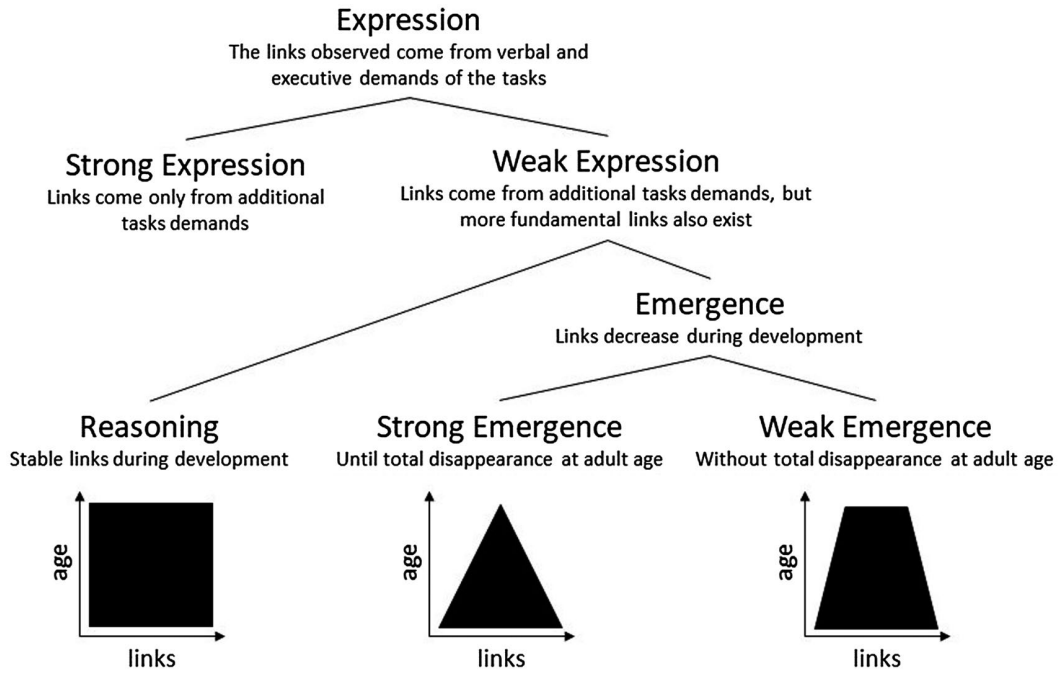


FIGURE 1 The *Reasoning*, *strong Emergence*, and *weak Emergence* accounts are subordinated to the *weak Expression* account which compete with the *strong Expression* account. The three graphics at the bottom represent the evolution of the links between ToM and other cognitive abilities depending on age: wider parts of black shapes represent more important relations

is less salient (i.e., diminishing the need to inhibit its location, for example, when Maxi eats the chocolate rather than moves it), or when the question specifically refers to the protagonist mental states (i.e., "Where Sally thinks that her marble is?" rather than "Where will Sally go to find her marble?"). Nevertheless, some studies on typically developing children showed that the ToM-language (Durrleman et al., 2016) or ToM-EF links (Carlson et al., 1998; Moses, 2001) are not due to task demands only and continue to exist when low-verbal or low-executive ToM tasks are used (i.e., in favor of a *weak* version of the *Expression* account).

Subordinated to the *weak Expression* account, two categories of hypotheses can be proposed in order to understand the fundamental links between ToM and other cognitive abilities such as syntax and specific EF (cf. Figure 1).

Moreover, the *Reasoning* account postulates that certain cognitive abilities are necessary to reason about ToM (Apperly et al., 2009), while the *Emergence* account instead maintains that these abilities are only necessary to enable ToM development (Moses, 2001). Thus, the *Reasoning* account predicts constant links between ToM and syntax or EF throughout the lifespan, and the *Emergence* account predicts weaker links when growing older. In addition, these links could diminish until disappearance at adulthood (i.e., *strong Emergence* account) or they could diminish while remaining present in adults (i.e., *weak Emergence* account).

Importantly, the *strong Expression* account, if validated, would nullify both the *Reasoning* and *Emergence* accounts. By contrast, the *weak Expression* account is compatible with both *Reasoning* and *Emergence* accounts. Indeed, language or EF could limit ToM *Expression* and at the same time they could be useful either for ToM *Reasoning* or for ToM *Emergence* (cf. Figure 1). There is currently no doubt that linguistic and executive demands can affect ToM performance (for a meta-analysis see Wellman et al., 2001). While ToM tasks that are completely void of such demands are probably impossible to create, one must strive nevertheless to use tasks that minimize such demands so as to tease apart *Reasoning* and *Emergence* accounts. Without this, there can be no guarantee that the links identified between ToM and other cognitive abilities could not be solely attributed to the *Expression* account (*strong* version).

Expression and *Emergence* accounts were firstly proposed by Moses (2001) regarding the ToM-EF links. Miller (2001) made a similar proposal regarding ToM-syntax links but with different terminology (i.e., *weak* and *strong* versions of the linguistic determinism hypothesis of de Villiers & de Villiers, 2000). We propose to consider three theories incorporating the various views put forth in the literature regarding ToM-EF and ToM-language relations articulated as follows: *Expression account* (*weak* and *strong* versions), *Emergence* account (*weak* and *strong* versions) and *Reasoning* account (see also Apperly et al., 2009; Craven, 2005).

Studies in adults give valuable information regarding the *Reasoning* vs. *Emergence* accounts. In particular, they allow distinguishing between the *Reasoning* account that predicts the persistence of links between ToM and other cognitive abilities in adults, and the *strong Emergence* account that predicts their absence. Overall, studies on adults suggest that language, and in particular syntax, is not clearly implied in ToM beyond childhood (Dodell-Feder, Koster-Hale, Bedny, & Saxe, 2011; Saxe et al., 2004). Indeed, brain-injured adults with aphasia are able to complete FB tasks even when unable to produce or understand syntactic structures such as complement sentences (e.g., Apperly, Samson, Carroll, Hussain, & Humphreys, 2006; Siegal, Varley, & Want, 2001). Dual-task studies in healthy adults showed that even though being involved in a concurrent linguistic task decreases performance at a FB task, this interference is specific neither to linguistic interference nor to ToM performance (Burnel, Perrone-Bertolotti, Durrleman, Reboul, & Baciu, 2017; Forgeot d'Arc & Ramus, 2011). The literature of ToM-syntax links in adults has, thus, showed indirect evidence in favor of the *strong Emergence* account. By contrast, studies of ToM-EF links in adults reported ToM impairments isolated from executive impairments (Fine, Lumsden, & Blair, 2001) or the co-occurrence of ToM and executive deficits (Henry, Phillips, Crawford, Ietswaart, & Summers, 2006), but no case of a patient exhibiting EF impairments without ToM impairments (see also Bull, Phillips, & Conway, 2008 for a dual-task study in healthy adults). Thus, the literature of ToM-EF links suggests that EF are still implicated in ToM at adulthood. Nevertheless, both the *Reasoning* and *weak Emergence* accounts predict the persistence of ToM-EF links in adults. Only the study of children with a wide age range allows distinguishing the *Reasoning* and

weak Emergence accounts. However, until now and to the best of our knowledge, there is no study evaluating these accounts in a population of typically developing children, neither regarding the ToM-syntax links nor regarding the ToM-EF links. Using a method that has been seldom used in the field, the third goal of the current study was thus to compare the *Reasoning* and *Emergence* accounts (i.e., *weak* and *strong* versions) by examining age as a moderator variable for the relation between ToM and syntax or EF.

1.4 | Goals of the current study

To summarize, the main goal of the current study is to determine the most important components for ToM amongst syntactic and executive abilities. Past studies examining the development of ToM abilities have been limited by relying exclusively on FB tasks as the sole indicator of ToM. These tasks may themselves present syntactic and executive demands, which limit their use for teasing apart the accounts we are concerned with. Both syntax and EF are reported as involved in ToM, however, studies evaluating ToM-syntax and ToM-EF relations leave many questions open: What specific syntactic or executive components are involved in ToM? Is there a priority between syntactic and executive abilities for ToM *Reasoning* or *Emergence*? Which of the *Reasoning* or *Emergence* accounts best explains the findings?

Using a set of ToM tasks with minimal verbal and executive demands in order to guarantee that the links identified could not be solely attributed to the *strong Expression* account, the first goal of the current study was to assess the hierarchical contribution of syntax and EF to ToM abilities in children. Using non-verbal FB tasks, the second goal was to assess if results previously obtained for FB tasks are representative of results obtained for a broader set of ToM tasks. In studying children aged between 3 and 11 years old, the third goal was to assess whether the ToM-syntax and ToM-EF links are constant (i.e., *Reasoning* account) or decrease during development (i.e., *strong* or *weak Emergence* accounts).

2 | METHOD

2.1 | Participants

One hundred and twenty-six French-speaking children (60 boys and 66 girls) participated in the study. They were between 3.2 and 11.9 years old (mean age = 7.0, SD = 2.3), with a 25th percentile of 5.10 years, a 50th percentile of 6.60 years and a 75th percentile of 9.10 years (see Table 1). Children were recruited in two schools in the region of Grenoble, France. Parents gave written consent for their child to participate in the study. The experimental procedure was approved by the local ethics committee for non-interventional research, Pole Grenoble Cognition (N° IRB00010290-2016-01-05-01).

2.2 | Procedure

Children were seen in a quiet room in their school by one of four trained experimenters. The total duration of the experiment varied between 1 hr and 1 hr and a half, depending on how fast children answered. The tasks were divided into three blocks. The order of blocks was counterbalanced across participants and children completed each block in a different session. The study was completed during three test sessions, with a mean gap of three days between the first and last sessions (range 0–28 days). The six experimental tasks are summarized in Figure 2 and detailed below.

TABLE 1 Descriptive data for age, low-verbal Theory of Mind (ToM) scale, False Belief (FB), Complement Sentences (CS), Relative Clause Sentences (RCS), inhibition, flexibility, and Working Memory (WM) depending on age group (All ages, 3 to 5 years old, 6 to 8 years old, and 9 to 11 years old)

	Age group	Age	ToM scale	FB	CS	RCS	Inhibition	Flexibility	WM
N	**All**	**126**	**126**	**125**	**126**	**126**	**125**	**118**	**124**
	3-5 y. o.	50	50		49		50		50
	6-8 y. o.	41	41		41		41		41
	9-11 y. o.	35	35		35		35		35
Mean	**All**	**7.04**	**3.21**	**4.41**	**6.73**	**7.18**	**0.302**	**3.93**	**71.6**
	3-5 y. o.	4.73	2.06	3.39	4.26	4.96	0.468	1.95	60.3
	6-8 y. o.	7.44	3.68	4.95	7.83	8.39	0.234	5.20	80.5
	9-11 y. o.	9.86	4.31	5.20	8.97	8.94	0.138	5.01	77.4
Median	**All**	**6.60**	**3.00**	**4**	**8.00**	**8.00**	**0.200**	**3.11**	**74.0**
	3-5 y. o.	4.70	2.00	3	4.00	5.00	0.450	1.66	62
	6-8 y. o.	7.30	4	5	9	9	0.200	6.04	83.5
	9-11 y. o.	9.50	5	6	10	9	0.100	4.10	78
Standard deviation	**All**	**2.27**	**1.44**	**2.10**	**3.33**	**2.51**	**0.275**	**2.66**	**17.7**
	3-5 y. o.	0.746	1.02	1.66	2.59	2.17	0.305	1.79	17.4
	6-8 y. o.	1.05	1.29	1.80	3.07	1.50	0.192	2.46	14.0
	9-11 y. o.	0.757	0.832	2.44	2.12	1.21	0.160	2.33	12.7
Minimum	**All**	**3.20**	**0**	**1**	**0**	**1**	**0.000**	**0.0600**	**18**
	3-5 y. o.	3.20	0	1	0	1	0.000	0.0600	18
	6-8 y. o.	6.00	0	2	0	5	0.000	2.07	38
	9-11 y. o.	9.00	2	1	1	6	0.000	2.07	53
Maximum possible	–	–	**5**	**8**	**10**	**10**	–	–	**105**
Maximum	**All**	**12.0**	**5**	**8**	**10**	**10**	**1.10**	**11.0**	**101**
	3-5 y. o.	5.90	4	7	10	10	1.10	9.06	96
	6-8 y. o.	8.90	5	8	10	10	0.700	11.0	101
	9-11 y. o.	12.0	5	8	10	10	0.600	11.0	98
25th percentile	**All**	**5.10**	**2.00**	**3.00**	**4.00**	**5.00**	**0.100**	**2.09**	**60.0**
	3-5 y. o.	4.13	1.00	2.00	3.00	4.00	0.300	0.310	50.0
	6-8 y. o.	6.40	3.00	3.00	7.00	8.00	0.100	3.08	71.0
	9-11 y. o.	9.25	4.00	3.00	9.00	8.00	0.0250	3.10	68.0
50th percentile	**All**	**6.60**	**3.00**	**4.00**	**8.00**	**8.00**	**0.200**	**3.11**	**74.0**
	3-5 y. o.	4.70	2.00	3.00	4.00	5.00	0.450	1.66	62.0
	6-8 y. o.	7.30	4.00	5.00	9.00	9.00	0.200	6.04	83.5
	9-11 y. o.	9.50	5.00	6.00	10.0	9.00	0.100	4.10	78.0
75th percentile	**All**	**9.10**	**4.75**	**6.00**	**10.0**	**9.00**	**0.500**	**6.06**	**85.3**
	3-5 y. o.	5.38	3.00	4.00	6.00	6.00	0.675	3.09	72.0
	6-8 y. o.	8.60	5.00	6.00	10.0	9.00	0.400	7.05	90.5
	9-11 y. o.	10.5	5.00	7.00	10.0	10.0	0.200	7.04	88.0

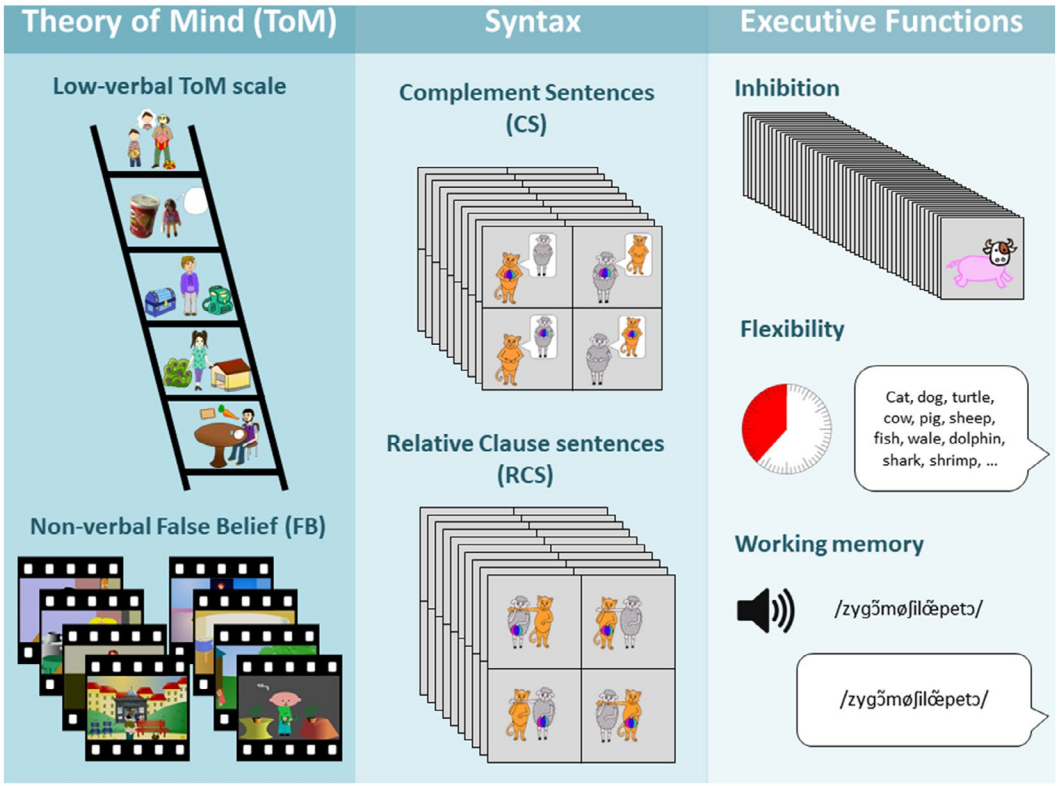


FIGURE 2 Theory-of-mind (ToM) was assessed by mean of a low-verbal ToM scale (Burnel et al., 2018) including five tasks (i.e., Diverse Desire, Diverse Belief, Explicit False Belief, Content False Belief, and Hidden Emotion) and by means of a non-verbal False Belief task including eight trials (Forgeot d'Arc & Ramus, 2011). One task evaluated syntactic abilities (i.e., complement sentences or relative clause sentences) and the remaining three tasks assessed three executive components: inhibition (Wright et al., 2003), flexibility (verbal fluency task), and working memory (Poncelet & Van Der Linden, 2003)

TABLE 2 The five subtasks and corresponding Theory-of-mind abilities assessed in the low-verbal scale

Subtask name	Theory-of-mind abilities assessed
Diverse Desires	Children understand that people will act according to their own desires
Diverse Beliefs	Children understand that people will act according to their own beliefs
Explicit FB	Children link the search behavior of a character to his (explicit) false belief
Contents FB	Children attribute a false belief to a character
Hidden Emotion	Children understand that emotions felt can be different from emotion shown

2.3 | Material

2.3.1 | Low-verbal ToM scale

ToM was assessed by means of the low-verbal ToM scale adapted by Burnel, Perrone-Bertolotti, Baciu, Reboul, and Durrleman (2018) from Wellman and Liu (2004). This tool evaluates ToM development via five subtasks (see

Table 2), with a 0.93 Green's coefficient of reproducibility (Burnel et al., 2018). The total number of correct answers was recorded, with a maximum score of 5. The total duration of the task was 15 to 30 min.

2.3.2 | Non-verbal FB task

The non-verbal FB task consisted of eight silent cartoons selected from those proposed by Forgeot d'Arc and Ramus (2011). This task was designed to assess FB understanding based on various paradigms (i.e., appearance-reality, change of location, and reality unknown). It was tested in typically developing children aged between 4 and 7 years (Forgeot d'Arc, 2009), in deaf children (Levrez et al., 2012) and in adults (Forgeot d'Arc & Ramus, 2011). For example, one cartoon shows two plants, one on a yellow table and another on a red table (see Figure 3). A boy starts watering the plant on the yellow table and then goes to fill his watering can. While he is not watching, a girl enters the scene and swaps the two plants. Then the boy turns around and is standing between the two plants. Children participating in the study are asked at this point to choose if the boy will water the plant on the yellow table (i.e., incorrect answer) or on the red table (i.e., correct answer). The two possible endings were displayed on the screen at the same time. Children responded by pointing to the correct answer. The total number of correct answers was recorded, with a maximum score of 8. The total duration of the task was 15 to 20 min.

2.3.3 | Syntactic tasks

Syntactic tasks were proposed in order to evaluate the understanding of two embedded structures. The 10 CS and 10 RCS were constructed with similar vocabulary and they mainly differed in terms of their syntactic construction. For example, the characters "sheep" and "cat" were used with the action "playing with the ball" in a CS (i.e., "The cat says that the sheep is playing with the ball") and in a RCS (i.e., "The cat bites the sheep that is playing with the ball") but with a different verb for the main clause (e.g., "says" vs "bites"). For each sentence, we proposed a quadruplet of pictures varying the agent of the principal and embedded clauses (cf. Figure 4). For example, four pictures illustrated (1) "the cat bites the sheep that is playing with the ball," (2) "The sheep bites the cat that is playing with the ball," (3) "The cat that is playing with the ball bites the sheep," and (4) "The sheep that is playing with the ball bites the cat." Children were instructed to judge which picture among four best matched the sentence they heard (see Figure 4). Each correct answer was worth 1 point, with a maximum score of 10 per sentence type. The total duration of the task was 10 min.

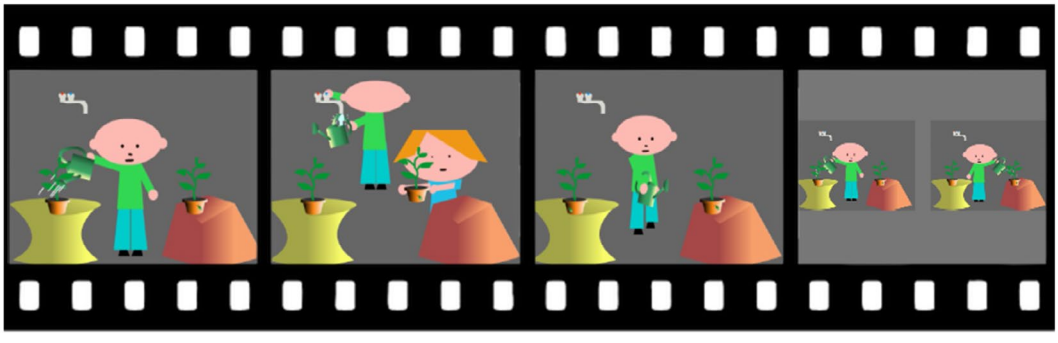


FIGURE 3 Participants see a boy watering the plant on the left of the screen. While the boy is filling his water can and not watching, a girl enters the scene and swaps the two plants. Then the boy comes back between the two plants. The participant is finally asked to choose if the boy waters the plant on the left of the screen (i.e., incorrect answer) or the plant on the right of the screen (i.e., correct answer)

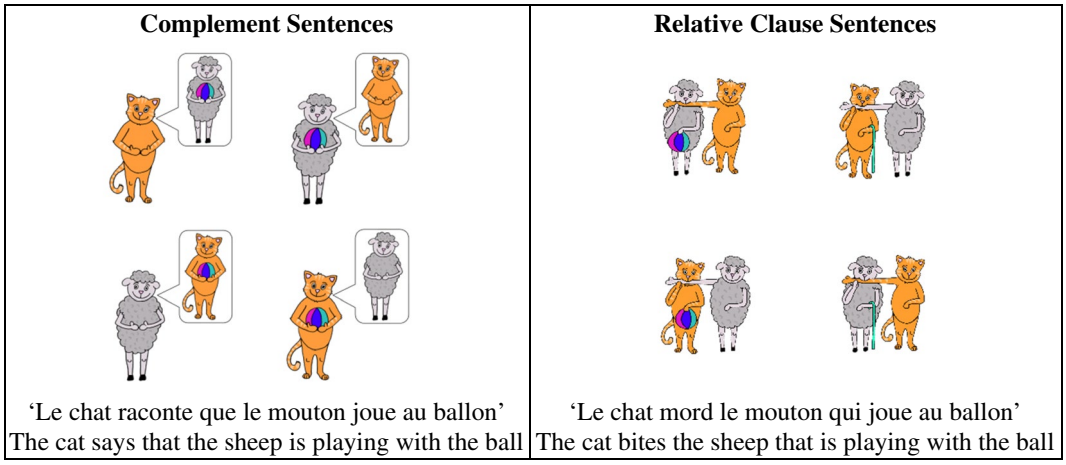


FIGURE 4 Participants choose between four pictures the one corresponding to the sentence presented

2.3.4 | Inhibition task

Inhibition was evaluated by means of an adapted version of the Stroop-like measure proposed by Wright, Waterman, Prescott, and Murdoch-Eaton (2003) using 24 congruent and 24 incongruent pictures of animals (see Figure 5). Individual interference indices (i.e., difference between mean reaction times for congruent and incongruent stimuli) were computed and used as measures of inhibition[1]. The total duration of the task was 5 min.

2.3.5 | Flexibility task

Flexibility was assessed by a semantic fluency task. Children were instructed to name as many animals as they could in 1 min. We computed the number of relative switches (i.e., total number of switches between semantic categories divided by the total number of correct words) as an indicator of flexibility (Begeer et al., 2014; Troyer, Moscovitch, & Winocur, 1997). All answers were coded by two trained experimenters with an inter-rater agreement of 91% resolved to 100% after discussion.

2.3.6 | Working memory task

In order to assess the phonological stock of WM, children participated in a pseudo-word repetition task adapted to French by Poncelet and Van Der Linden (2003). They were instructed to repeat pronounceable pseudo-words presented in the auditory modality. The total number of syllables correctly repeated was computed, with a maximum score of 105 correct syllables per child.

2.4 | Data scoring and statistical analyses

Because data were non-normally distributed we used non-parametric statistics. When non-parametric statistics were not available (i.e., for stepwise regression analyses and moderation analyses), parametric statistics were performed on transformed data using Box-Cox transformations (Osborne, 2010). In reporting the results, we follow Wilkinson (1999) recommendations and report exact p values (unless $p < .001$) and effect sizes. We used

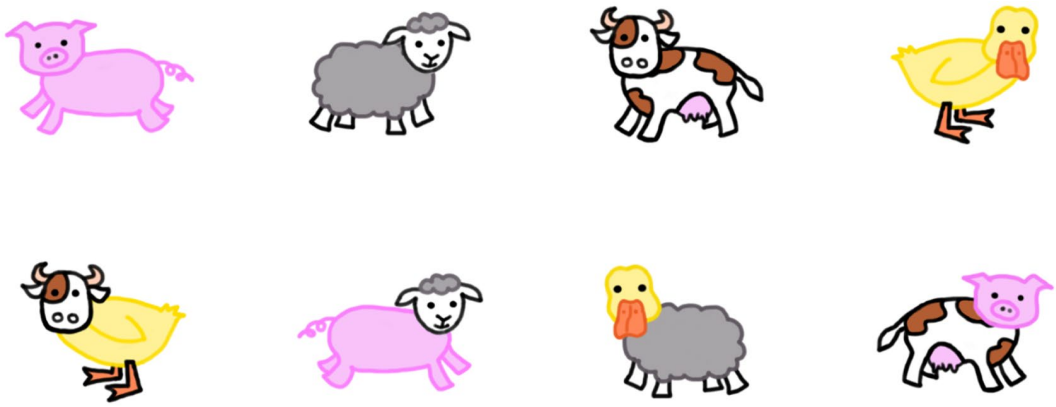


FIGURE 5 Participants name animals according to their body in congruent and incongruent stimuli

studentized deleted residuals analyses to identify outliers (i.e., values greater than 3.0). When data were detected as outliers they were discarded.

The total sample size was 126 children. Missing data varied between 0 and 8 depending on tasks and analyses. Participants were included in multiple regression analyses only if they had complete data for the set of variables analyzed.

Firstly, we assessed the suitability of our tasks for the age range studied. In order to do so we present descriptive data (see Table 1) for the entire sample but also for age groups (i.e., 3-5 years old, 6-8 years old, and 9-11 years old), even though age is not treated categorically in this study.

Secondly, in order to assess whether performance on tasks changes with children's age we evaluated their correlations with Spearman's rank correlation tests (r_s). After that, to examine if syntactic and executive variables were related to ToM or FB beyond their common relation to age, we evaluated their correlations controlling for age with partial correlation analyses.

Thirdly, we ranked the contribution of syntactic and executive variables to ToM scores by means of stepwise multiple regression analysis with forward selection. This analysis allowed us to spot syntactic and executive components that are specifically linked to ToM. The same stepwise multiple regression analysis was then conducted with Non-verbal FB scores as the dependent variable. This analysis allowed us to spot specific syntactic and executive components that are specifically linked to non-verbal FB, and thus to compare our results with previous literature.

Fourth, we tested children's age as a possible moderator of the syntax-ToM and EF-ToM relations by means of moderation analyses, so as to assess the *Emergence* and *Reasoning* accounts. For ease of comparison with previous literature, the same moderation analyses were also run for non-verbal FB scores.

3 | RESULTS

3.1 | Descriptive data and suitability of tasks

The complete descriptive data on tasks are available in Table 1. Percentiles are provided for the full sample (3-11 years old) but also depending on age groups (3-5 years old, 6-8 years old, and 9-11 years old). It is worth noting that all the statistical analyses were conducted in the full sample. Thus, the suitability of tasks should be studied by considering percentiles in the full sample (3-11 years old). We consider that there is a ceiling effect for a task if more than 25% of children obtained the maximum score.

Average performance was 3.21 on the low-verbal ToM scale. In the entire sample, 50th percentile was 3, and 75th percentile was 4.75, near the maximum score of 5. Children aged between 3 and 5 years old did not perform at ceiling (75th percentile = 3.00) contrary to 6-8 years old (75th percentile = 5.00) and 9-11 years old (50th percentile = 5.00).

For FB tasks, average performance was 4.41 for a maximum score of 8. Only nine children performed at ceiling. At 75th percentile was 6 for the entire sample, 4 for 3-5 years old, 6 for 6-8 years old and 7 for 9-11 years old.

CS and RCS scores were on average of 6.73 and 7.18 for a maximum score of 10.

In the entire sample, 75th percentile was 10 for CS and 9 for RCS. In particular, children aged between 3 and 5 years old did not perform at ceiling on CS or on RCS (75th percentile = 6), 6-8 years old were at ceiling for CS (75th percentile = 10) but not RCS (75th percentile = 9), and 9-11 years old children performed at ceiling for both CS (50th percentile = 10) and RCS (75th percentile = 10).

Regarding the inhibition task, the average score was 0.30. 12% of children (i.e., 15/126) achieved ceiling performance of 0 (i.e., no difference between congruent and incongruent items). The 75th percentile was 0.50 in the entire sample, 0.68 for 3-5 years old children, 0.40 for 6-8 years old children and 0.20 for 9-11 years old.

The mean relative number of switches in the flexibility task was 3.93 for the entire sample, with a 75th percentile at 6.06. There was no maximum for the number of correct words and switches between semantic categories, and thus for the flexibility task.

Average scores at the WM task were 71.6, with all children scoring below the maximum of 105. The 75th percentile was 85.3 in the entire sample, 72.0 for 3-5 years old children, 90.5 in 6-8 years old and 88.0 in 6-11 years old.

3.2 | Correlations between tasks

According to Spearman's correlations (see Table 3), age was significantly correlated to low-verbal ToM scale ($r_S(124) = 0.70$, $p < .001$), non-verbal FB ($r_S(123) = 0.38$, $p < .001$), CS ($r_s(124) = 0.68$, $p < .001$), RCS ($r_s(124) = 0.73$, $p < .001$), inhibition ($r_s(123) = -0.49$, $p < .001$), flexibility ($r_s(116) = 0.58$, $p < .001$) and WM ($r_s(122) = 0.45$, $p < .001$). The shared variance between age and the other variables (i.e., Low-verbal ToM scale, non-verbal FB, CS, RCS, inhibition, flexibility, and WM) varied between 14% (i.e., FB) and 73% (i.e., RCS).

After controlling for the effect of age (see Table 4), the low-verbal ToM scale was significantly correlated to CS ($r_s(124) = 0.34$, $p < .001$), RCS ($r_s(124) = 0.28$, $p < .001$), flexibility ($r_s(116) = 0.20$, $p < .001$) and WM ($r_s(122) = 0.23$, $p < .001$), with a shared variance varying between 4% (i.e., flexibility) and 12% (i.e., CS). Nevertheless, the correlation between the low-verbal ToM scale and inhibition that was statistically significant ($r_s(123) = -0.32$, $p < .001$) became statistically non-significant after controlling for the effect of age ($r_s(123) = -0.04$, $p = .51$).

After controlling for the effect of age (see Table 4), non-verbal FB was also significantly correlated to CS ($r_S(123) = 0.16$, $p = .008$), RCS ($r_S(123) = 0.22$, $p < .001$), flexibility ($r_S(115) = 0.15$, $p = .02$) and WM ($r_S(121) = 0.18$, $p = .004$), with a shared variance varying between 2% (i.e., flexibility) and 5% (i.e., RCS). Nevertheless, the correlation between non-verbal FB and inhibition that was statistically significant ($r_S(122) = -0.20$, $p = .02$) became statistically non-significant after controlling for the effect of age ($r_S(122) = -0.04$, $p = .55$).

3.3 | Stepwise multiple regression analyses

A stepwise multiple regression analysis was conducted to assess whether age, CS, RCS, inhibition, flexibility, and WM were useful to predict low-verbal ToM scale performances (see Table 5). At step 1 of the analysis, age entered into the regression equation and was significantly related to the low-verbal ToM scale ($F(1, 115) = 98.5$, $p < .001$). The multiple determination coefficient was .46, indicating that approximately 46% of low-verbal ToM scale

TABLE 3 Results of Spearman's rank correlations between age and tasks for low-verbal Theory-of-Mind (ToM) scale, False Belief (FB), Complement Sentences (CS), Relative Clause Sentences (RCS), inhibition, flexibility, and Working Memory (WM)

	Age	ToM scale	FB	CS	RCS	Inhibition	Flexibility	WM
Age	—							
ToM scale	0.701*	—						
FB	0.396*	0.416*	—					
CS	0.675*	0.599*	0.365*	—				
RCS	0.720*	0.599*	0.418*	0.704*	—			
Inhibition	−0.509*	−0.316*	−0.200*	−0.371*	−0.469*	—		
Flexibility	0.581*	0.484*	0.342*	0.425*	0.508*	−0.343*	—	
WM	0.474*	0.465*	0.362*	0.376*	0.535*	−0.252*	0.437*	—

*$p < .05$.

performance could be accounted for by age. At step 2, CS entered the model and was significantly related to low-verbal ToM scale ($F(2, 114) = 56.0$, $p < .001$), increasing the total variance explained from 0.46 to 0.50, an increase of 0.04. By itself, CS explained 34% of the variance in low-verbal ToM scale performance, but a portion of what it

TABLE 4 Results of Spearman's rank correlations controlling for age on low-verbal Theory-of-Mind (ToM) scale, False Belief (FB), Complement Sentences (CS), Relative Clause Sentences (RCS), inhibition, flexibility, and Working Memory (WM)

	ToM scale	FB	CS	RCS	Inhibition	Flexibility	WM
ToM scale	—						
FB	0.218*	—					
CS	0.229*	0.169	—				
RCS	0.177	0.230*	0.439*	—			
Inhibition	0.022	0.018	−0.066	0.329*	—		
Flexibility	0.157	0.180	0.065	0.329	−0.115	—	
WM	0.194*	0.180	0.083	0.329*	−0.063	0.245*	—

*$p < .05$.

could explain had already been attributed to age. At step 3, WM entered the model and was significantly related to the low-verbal ToM scale ($F(3, 113) = 39.7$, $p < .001$), increasing the total variance explained from 0.50 to 0.51, an increase of 0.01. By itself, WM explained 19% of the variance in low-verbal ToM scale performance, but a portion of what it could explain had already been attributed to age and CS. No other variable entered into the equation at step 4 of the analysis. Thus, the regression equation for predicting low-verbal ToM scale performance was: $\textit{Low-verbal ToM scale}^{1.39} = 0.71 \times \textit{Age} + 0.23 \times \textit{CS} + 0.03 \times \textit{WM} - 1.17$.

A stepwise multiple regression analysis was conducted to evaluate whether age, CS, RCS, inhibition, flexibility, and WM were useful to predict non-verbal FB performances (see Table 5). At step 1 of the analysis, RCS entered into the regression equation and were significantly related to non-verbal FB ($F(1, 114) = 28.5$, $p < .001$). The multiple determination coefficient was 0.20, indicating that approximately 20% of non-verbal FB performance could be

TABLE 5 Results of stepwise multiple regression analyses for the low-verbal Theory-of-mind (ToM) scale and the non-verbal False Belief (FB) task

Dependent variable	Steps	Predictors	N	F	Adjusted R^2
Low-verbal ToM scale	1	Age	117	F(1,115) = 98.5, $p < .001$	0.46
	2	Complement sentences		F(2,114) = 56.0, $p < .001$	0.50
	3	Working Memory		F(3,113) = 39.7, $p < .001$	0.51
Non-verbal FB task	1	Relative clause sentences	116	F(1,114) = 28.5, $p < .001$	0.20
	2	Flexibility		F(2,113) = 17.0, $p < .001$	0.23

accounted for by RCS. At step 2, flexibility entered the model and was significantly related to non-verbal FB ($F(2, 113) = 17.0$, $p < .001$), increasing the total variance explained from 0.20 to 0.23, an increase of 0.03. By itself, flexibility explained 14% of the variance in non-verbal FB performance. No other variable entered into the equation at step 3 of the analysis. Thus, the regression equation for predicting non-verbal FB performance was: $Non\text{-}verbal\ FB^{.79} = 0.16 \times RCS + 0.09 \times Flexibility + 1.96$.

3.4 | Moderation analyses

Variables particularly useful to predict low-verbal ToM scale scores according to stepwise multiple regression analyses results were CS and WM. We, thus, evaluated the moderation effect of age on the links between low-verbal ToM scale and these two variables.

Age and CS were used to predict ToM scale scores. The overall model of age and CS were significant predictors of the low-verbal ToM scale ($F(3, 122) = 44.16$, $p < .001$, adjusted $R^2 = 0.52$). Older children obtained significantly better low-verbal ToM scale scores ($b = 0.35$, $t(122) = 6.40$, $p < .001$). Low-verbal ToM scale scores also improved with better mastery of CS ($b = 0.10$, $t(122) = 2.63$, $p = .01$) but they were not significantly predicted by the interaction between CS and age ($b = -0.002$, $t(122) = -0.09$, $p = .93$).

Age and WM were used to predict low-verbal ToM scale scores. The overall model of age and WM were significant predictors of low-verbal ToM scale ($F(3, 111) = 37.04$, $p < .001$, adjusted $R^2 = 0.50$). Low-verbal ToM scale scores increased significantly with age ($b = 0.40$, $t(111) = 8.23$, $p < .001$) and with WM levels ($b = 0.02$, $t(111) = 2.93$, $p = .004$) but were not significantly predicted by the interaction between WM and age ($b = 0.004$, $t(111) = 1.44$, $p = .15$).

For ease of comparison with previous literature where ToM was assessed by means of non-verbal FB tasks, we also evaluated the moderation effect of age on the links between non-verbal FB and CS or WM. Age and CS were used to predict non-verbal FB scores. The overall model of age and CS were significant predictors of non-verbal FB ($F(3, 112) = 10.35$, $p < .001$, adjusted $R^2 = 0.22$). Older children obtained significantly better non-verbal FB scores ($b = 0.25$, $t(112) = 2.44$, $p = 0.02$). Non-verbal FB scores also improved with better mastery of CS ($b = 0.16$, $t(112) = 2.22$, $p = 0.03$) but they were not significantly predicted by the interaction between CS and age ($b = 0.05$, $t(112) = 1.69$, $p = 0.09$).

Age and WM were used to predict non-verbal FB scores. The overall model of age and WM were significant predictors of non-verbal FB ($F(3, 112) = 9.54$, $p < .001$, adjusted $R^2 = 0.20$). Non-verbal FB scores increased significantly with age ($b = 0.33$, $t(112) = 3.65$, $p < .001$) and with WM levels ($b = 0.02$, $t(112) = 2.07$, $p = 0.04$) but they were not significantly predicted by the interaction between WM and age ($b = 0.004$, $t(112) = 0.72$, $p = 0.47$).

4 | DISCUSSION

4.1 | Suitability of tasks for the age range studied

The ToM tasks appear well suited to the age range studied. The low-verbal ToM scale had a 75th percentile below the maximum score. More specifically, all 3- to 5-year-old children, three quarters of 6-8 year olds and half of 9–11 year olds performed below ceiling. Regarding the FB task, only a few children performed at ceiling (i.e., 9 out of 126) with half of children performing above chance level.

Regarding the syntactic tasks, a quarter of the children were at ceiling for the CS and RCS tasks. More specifically, 25% of 6-8 year olds and 50% of 9-11 year olds obtained maximum scores on the CS task, as did 25% of 9–11 year olds on the RCS. The syntactic tasks thus appear more prone to ceiling effects.

EF tasks were not at ceiling, with 12% of the entire sample obtaining maximum scores on the inhibition task, and no child obtaining the maximum score on either the working memory task or the flexibility task. The set of tasks used thus appear to be well suited to the age range studied, except for the CS task for which a quarter of the children were at ceiling.

4.2 | Ranking contributions of syntax and EF to ToM

The main goal of the current study was to examine the relative predictive value of syntactic and executive abilities for ToM.

The correlations indicated that as children grow older, their ToM, syntactic, and executive skills improve. In addition, results of partial correlations controlling for age were still significant (except for inhibition) with low intensity for the ToM scale and a very low intensity for the set of FB tasks. These results indicate that apart from inhibition, other EF skills as well as syntactic skills continue to relate to ToM throughout childhood. This last result, as well as the absence of a significant correlation between non-verbal FB and inhibition after controlling for the effect of age, seems contrary to reports that suggest that inhibition still contributes to verbal FB after controlling for age and vocabulary (Carlson & Moses, 2001; Carlson, Moses, & Breton, 2002; Carlson, Mandell, & Williams, 2004; Chasiotis, Kiessling, Hofer, & Campos, 2006) and could suggest that verbal FB, but not non-verbal FB, is what is continuously related to inhibition.

Correlation analyses overall suggest that even when verbal and executive demands are kept low in ToM tasks, the ability to attribute mental states to others in order to predict or explain their behavior improves independent of age with the mastery of CS with communication verbs, RCS, flexibility and WM. More specifically, a stepwise multiple regression analysis indicated that among the different syntactic and executive measures, age, CS, and WM were, in this order, useful to predict ToM scale performance.

Overall, syntactic abilities (i.e., CS with communication verbs) thus appear more essential than executive abilities (i.e., WM) to explain variations in ToM skills. Among syntactic abilities, CS were particularly related to general ToM abilities. This result was found for low-verbal ToM tasks (Burnel et al., 2018) demonstrating a fundamental link between ToM and CS understanding (i.e., *weak Expression* account). In addition, sentences with a similar syntactic complexity (i.e., RCS) contributed less than CS to ToM scale performance indicating that the semantic properties of CS allowing misrepresentation, rather than their syntactic complexity, are essential to ToM. It is worth noting that the ToM tasks administered generally involved children attributing mental states different from their own (e.g., different desire or belief), which do not necessarily entail a conflict with reality. Moreover, the specific impact of CS on these tasks was observed for CS with communication verbs and true complements. These findings suggest that the mastery of syntactic structures allowing for misrepresentation is related to general ToM abilities, not only the semantics of CS (i.e., mental state verbs) or misrepresentation itself (i.e., false complements). However, future work should include additional lexical and syntactic measures to control for the potential impact

of general language, and determine whether it may be a more important contributor to ToM than CS. Indeed, a recent meta-analysis on 18 studies (Farrar et al., 2017) suggests that general language could be predominant for FB development in typically developing children, while a general language measure was not included in the current study.

Among executive abilities, WM was found as sufficient, with CS understanding, to predict ToM scale scores. It is interesting to note that for each of the ToM tasks used in the current study, the WM demand was kept very low by having pictures depicting the short narrations remain visible throughout the task. Thus, WM appears important to ToM beyond task demands, which supports the *weak Expression* account. Specifically, in the current study we assessed the phonological stock of WM and not the ability to refresh or manipulate information *per se*. What appeared the most crucial between the different EF abilities assessed is thus the ability to store short-term information. Nevertheless, further studies are needed to determine if the link observed here is only due to the phonological stock size or rather to its link with the ability to refresh or manipulate information.

4.3 | Are FB tasks representative of ToM?

The second goal was to assess whether results previously obtained for FB tasks are representative of results obtained for a broader set of ToM tasks. Results of correlations were similar for non-verbal FB and low-verbal ToM tasks. Indeed, they were both significantly correlated with age. Moreover, both scores on the ToM scale and on non-verbal FB task were significantly correlated to CS, RCS, flexibility, and WM but not to inhibition after controlling for the effect of age. Some results are, therefore, the same regardless of the ToM measurement used. In addition, non-verbal FB as well as low-verbal ToM scores were predicted by a combination of syntactic and executive abilities with a predominant role of syntax over EF (for a similar result with verbal FB tasks, see Durrleman and Franck, 2015). Nevertheless, the syntactic and executive predictors of ToM scale and non-verbal FB appear to be very different. We saw that general ToM abilities were better predicted from age, CS, and WM. However, in the same group of children, non-verbal FB abilities were predicted from RCS and flexibility.

This inconsistency of results for non-verbal FB and low-verbal ToM scale raises several questions. Firstly, CS appeared to be the major predictor for ToM scale scores but not for non-verbal FB scores. The predominant role of CS for FB seems to be a classic result in the literature. It is, thus, intriguing that RCS appeared to be more related to FB compared to CS. Nevertheless, recall that RCS have rarely been directly compared to CS. To our knowledge, only Hale and Tager-Flusberg (2003) compared the role of CS and RCS training on FB skills. The authors found that CS but not RCS training improved children's verbal FB abilities on post-tests. However, in Hale and Tager-Flusberg (2003), RCS understanding did not improve as much as CS understanding. RCS could, therefore, have required more training so as to attain the levels required to improve FB abilities. At the same time, the fact that previous studies assessed false complements alongside verbal FB tasks could have increased the risk of their identifying links stemming from experimental confounds (cf. *Expression* account). It is nevertheless theoretically unexpected that non-verbal FB is better predicted by RCS when low-verbal ToM is better predicted by CS. This could suggest that syntactic complexity rather than misrepresentation is fundamentally related to non-verbal FB abilities, as suggested by Smith et al. (2003) as well as Durrleman et al (2018) for verbal FB abilities. Another explanation could be that a lack of variability in CS scores, due to a ceiling effect, could have prevented us from detecting a relation to FB scores. However, this is unlikely because CS successfully explained scores on low-verbal ToM scale. This result requires replication as well as further investigation.

A second inconsistent result is that flexibility appeared particularly important to predict FB abilities, whereas WM was particularly important to predict ToM abilities. Because the WM demand was kept very low in the ToM scale used (Burnel et al., 2018), it is unlikely that this task entailed an increased WM demand compared to the non-verbal FB task. We rather argue that the non-verbal FB task could have entailed an increased flexibility demand. Indeed, this task was part of a larger task including four other conditions (i.e., true belief and two control

conditions) with a randomized order of presentation. This could have increased the requirement of flexibility because children had to switch between focusing on characters' mental states and focusing on the physical state of objects. So, the increased flexibility demand in the FB task could explain why flexibility appeared particularly useful to predict non-verbal FB abilities. WM was significantly correlated with non-verbal FB, but it did not add any explanatory power to the model that already included RCS and flexibility. This result thus highlights the importance to use ToM tasks that entail minimal executive demands.

Overall, even though non-verbal FB and low-verbal ToM abilities are predicted by a combination of syntactic and executive abilities with a predominant role of syntax over EF, the results of the current study indicate that they do not require the same syntactic and executive abilities. Therefore, FB tasks may not be representative of general ToM abilities. These results, thus, highlight the need to study ToM beyond FB tasks. However, a limitation of the current study is that even though we aimed to assess broad ToM abilities, our ToM measure nevertheless relied solely on five tasks. The results of the current study should thus be replicated using different sets of ToM tasks.

4.4 | Reasoning and emergence accounts

After identifying the syntactic (i.e., CS) and executive abilities (i.e., WM) particularly useful to predict low-verbal ToM abilities, our third goal was to assess whether these abilities were important for ToM reasoning *per se* (i.e., *Reasoning* account) or for ToM development (i.e., *Emergence* accounts).

As previously mentioned, although extremely useful, the literature on adults does not bring direct evidence in favor of the *Emergence* accounts and does not distinguish between the *weak Emergence* and *Reasoning* accounts. By studying children aged between 3 and 11 years old, our goal was to overcome these limitations. We hypothesized that if syntactic and executive abilities are solely useful for ToM development then their relation should decrease during development. Results of moderation analyses showed that the links between a low-verbal ToM scale and CS or WM were not significantly moderated by the age of children. Moreover, the same results were found regarding non-verbal FB abilities. Our results thus do not support the *Emergence* accounts neither regarding the ToM-CS links nor regarding the ToM-WM links.

Previous studies showed that adults with WM impairments also exhibit ToM impairments (Rowe, Bullock, Polkey, & Morris, 2001; Stone, Baron-Cohen, Calder, Keane, & Young, 2003). Thus, the existing literature on ToM-WM links in adults is in favor of the *Reasoning* and *weak Emergence* accounts. Our results, which showed no evolution of the ToM-WM links between 3 and 11 years of age do not argue in favor of the *weak Emergence* hypothesis. They could rather indirectly suggest that the ToM-WM links are constant during development (i.e., *Reasoning* account). Nevertheless, in Null Hypothesis Significance Testing conclusions cannot rely on statistically non-significant results. Further studies should thus continue to explore the ToM-WM relation during development, especially between 11 years old and adulthood.

Overall, studies on the ToM-syntax links in adulthood are in favor of the *strong Emergence* account, suggesting that language, and more specifically embedded syntax such as CS, is not clearly implied in ToM at adult age. Nevertheless, in the current study the results are not in favor of an *Emergence* account. They did not show a significant decrease in the ToM-syntax links in children aged between 3 and 11 years old, and would, therefore, indirectly argue in favor of the *Reasoning* account. Different arguments can be put forward to explain the apparent discrepancy between our results and previous literature. Firstly, studies on adults entail some limitations. It is not clear if what is affected in patients with aphasia after brain-lesions is linguistic performance or linguistic competence (Caplan, 1992), thus patients could be able to use language to reason about ToM but not to perform linguistic tasks. Regarding studies on healthy adults, even if Forgeot d'Arc and Ramus (2011) and Burnel et al. (2017) used substantial samples (i.e., 58 and 50 participants, respectively), their conclusions rely on statistically non-significant results which are less reliable and informative than statistically significant results. Limitations of

the current study are also that our conclusions are based on statistically non-significant results, and that we may have failed to show a different impact of language on ToM depending on age due to a limited sample size or to our choice of statistical tools. Indeed, according to McClelland and Judd (1993), moderator effects are extremely difficult to detect. Another possibility that could reconcile our results with results from previous studies could be that the ToM-syntax links progressively decrease over the course of life (i.e., *Emergence* accounts) but not significantly before the age of 11. It is possible that in our study children were not old enough yet to exhibit an important loosening of the ToM-CS links. Further investigations are obviously needed to confirm this hypothesis. These should take an interest in larger age range, including adolescents. The major difficulty will be to identify adapted syntactic and low-verbal ToM tasks for older children or adolescents.

5 | CONCLUSION

To sum up, the current study showed that both syntax and EF are useful to predict ToM abilities, with a predominant role of syntax over EF. More specifically, CS and WM appeared particularly related to ToM beyond the *strong Expression* account (i.e., with no confounding variables in the ToM task used). The results of the current study also provided arguments against the idea that FB tasks can be representative of global ToM, and thus highlight the need to study ToM beyond FB tasks. In addition, the results did not argue in favor of the *weak Emergence* account regarding the ToM-WM links. Combined with literature on adults, they rather suggest that WM is useful for ToM reasoning regardless of age (i.e., *Reasoning* account). Regarding the ToM and CS links, even though our results did not argue in favor of the *strong Emergence* account in children aged between 3 and 11 years, further investigations including a larger age span are needed to tease apart *Reasoning* and *strong Emergence* accounts, given that results of previous literature in adults have upheld the *strong Emergence* account. It is possible that the nature of the tasks used here, that is, testing global ToM rather than FB, may have contributed to the differences between our findings and those reported in previous studies. Further investigations should thus continue to study sets of ToM tasks rather than FB tasks only. Moreover, they should study a larger age range including adolescents. Results of this study, and further research as suggested, appear useful for understanding cognitive disturbances involved in social cognition disorders. Indeed, it allows to better identify the neurocognitive substrates and the shared impairments associated with ToM deficits (i.e. syntax, WM, and flexibility) in developmental disorders.

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CONFLICT OF INTEREST

We declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in Open Science Framework at http://doi.org/10.17605/OSF.IO/S54XU

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ENDNOTE

[1] Results of Wilcoxon signed-ranks test indicated that participants had significantly lower reaction times for the congruent items (Mdn = 1.25s) compared to the incongruent items (Mdn = 1.64s) (Z = 9.43, p < .001, r = .84), indicating that this task is efficient as a measure of inhibition in children aged between 3 and 11 years. In addition, children also gave significantly more correct answers for the congruent items (Mdn = 1.00) compared to the incongruent items (Mdn = 0.96) (Z = 5.63, p < .001, r = .50).

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