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CAN TWO-YEAR-OLDS UNDERSTAND OTHERS' FALSE-BELIEFS ABOUT  
OBJECT IDENTITIES?

By

GALA STOJNIC

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Alan M. Leslie

And approved by

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## ABSTRACT OF THE THESIS

Can Two-Year-Olds Understand Others' False-Beliefs About Object Identities?

by GALA STOJNIĆ

Thesis Director:

Dr. Alan M. Leslie

Is early theory of mind (ToM) fundamentally different from late ToM, in particular, is it incapable of representing false-beliefs about individuals' identities (Butterfill & Apperly 2013)? We explore this issue by using proper names to index particular individuals. 20- to 34-month-olds and adults were tested over four pairs of Teach-and-Test trials to see if they could learn proper names from videos showing an actor who named one of two toy-animals. The first, Pointing-Teach showed the actor pointing at one of the two toy-animals and naming it, "Daxy". In True-Belief-Teach, two new toy-animals are introduced, one is placed in a box and the other removed; the actor points to the box and says: "Mody is in here!" In False-Belief-Teach, the actor turned away and didn't see that the boxed toy was replaced with the other one; she then turns back, points to the box and says: "Toma is in here!" The final, Common-Noun-Teach, showed the toy-animals from False-Belief-Teach and the actor said: "Toma is a wuggy!" Each Teach trial was followed by a Test trial in which two previous animals were presented and the voiceover said: "Look at [Daxy/Mody/Toma/the wuggy]!" Subjects' eye-gaze was measured by Tobii XL-T60. Children and adults looked longer at the named animals in Pointing-Test

and True-Belief-Test. However, there was no looking preference in either False-Belief-Test or Common-Noun-Test. These findings are consistent with early ToM incapability of representing false-beliefs about object identities. However, the possibility remains that the pattern of results we got is due to performance factors that future research should address.

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## **Introduction**

### *Overview.*

As human beings are inherently social creatures, it is of a crucial importance for them to successfully coordinate complex social interactions. In order to do so, they ought to be able to understand others' observable behaviors in terms of unobservable, inner mental states that are, presumably, causing them. This ability to attribute mental states to oneself and to others (as well as to explain and predict their external actions in terms of these mental states) is known as Theory of Mind (ToM) (e.g. Premack & Woodruff, 1978) and it has been actively explored for more than the past three decades. Yet, researchers are still far from a consensus regarding its nature and underlying developmental mechanisms. The main issue leads us back to the well-known "nativists vs. empiricists" conflict: is the computational structure of ToM innate or does it emerge over time, as a child interacts with her environment?

Current perspectives on the nature of ToM can be separated into three different views. The first conceptualizes ToM as the ability that emerges gradually, through series of conceptual changes that a child undergoes as she interacts with her environment; prior to these conceptual changes, ToM is essentially limited in regard to its representational repertoire (Gopnik & Meltzoff, 1997; Gopnik & Wellman, 1994; Perner, 1991; Perner 1995; Perner & Ruffman, 2005; Wellman, Cross, & Watson, 2001). The second view conceives of the ToM as a specialized cognitive mechanism, whose fundamental computational structure is innately present and actively operates early on in one's life; representational understanding of mental concepts is, hence, available much earlier than the conceptual-changes approach assumes (Leslie & Firth, 1990; Leslie, 1994a; Leslie,



1994b; Leslie, Friedman & German, 2004; Sholl & Leslie, 2001).

The most recent, third view, suggests that the nativists-empiricists conflict could be resolved by abandoning the conception of ToM as being a uniform ability (Apperly & Buterfill, 2009; Surtees, Apperly & Buterfill, 2012; Buterfill & Apperly, 2013; Low & Watts, 2013; Rakoczy, Bergfeld, Schwarz & Fiske, 2014). The proponents of this perspective argue for the two distinct ToM systems: the early ToM and the late ToM. Importantly, the claim is that these two systems differ fundamentally with respect to their representational characteristics: the early ToM is subject to specific representational limits that the late ToM is free from. One of the notable limits of the early ToM is representing beliefs about *identities* of particular individuals, as this would require a specific form of mental representations that early ToM, arguably, cannot construct.

This thesis explores the question of the nature of ToM ability. We focus on the computational characteristics of ToM that are manifested early on in life. Specifically, we explore the question of whether the early manifested ToM is, indeed, representationally limited in the sense that the dual-systems approach suggests; in particular, whether or not it can compute false-beliefs about objects' identities. In the following sections, I shall first provide a brief overview of the main theoretical perspectives and empirical findings regarding the nature of ToM. I shall, then, proceed to describe the study we use to explore the question of whether early ToM can represent false-beliefs about identities, by exploiting proper names to index identities of particular individuals.

*1. Early competence or conceptual changes? A long lasting debate.*

The traditional way to explore ToM has been through false-belief (FB) tasks, designed to test whether a child understands that another's perspective could differ from their own. A standard version of this task takes a form of a short story that features two characters, Sally and Ann: Sally has a marble, but she doesn't want to play with it at the moment, so she puts it in a basket and goes away. While Sally is away, Ann takes her marble from the basket and puts it in a box. When Sally comes back, where will she look for her marble? (Baron-Cohen, Leslie & Frith, 1985; Wimmer & Perner, 1983). To succeed on this task, a child has to set aside her own perspective, which will lead her to correctly predict Sally's actions.

A well-established finding is that children at about 4 years of age mostly pass the standard FB task, whereas those who are younger than 4 typically fail to correctly predict Sally's actions, but instead, go with the current location of the object (for a meta-analysis, see Wellman, Cross & Watson, 2001). This has led a number of researchers to conclude that children do not attain the concept of false-belief until the age of 4 as, prior to this age, their ToM is still *conceptually* underdeveloped (e.g. Gopnik & Astington, 1988; Gopnik & Meltzoff, 1997; Gopnik & Wellman, 1994; Perner, 1991; Perner 1995; Perner & Ruffman, 2005). According to this perspective, as a child gets older, and interacts with her social environment, her ToM gradually reaches the milestones, where with each new milestone new concepts become available in its computational repertoire. Around the age of 4, ToM undergoes a critical developmental change, as its immature, non-metarepresentational structure transforms into an adult-like, representational understating of mental states, as reflected through successes on standard FB tasks.

The conceptual-changes approach has been dominating the field for a long time. Nevertheless, a number of researchers have suggested a different perspective: the failure of younger children could be explained in virtue of performance-related factors, rather than by their underdeveloped capacity (Bloom & German, 2001; Carlson, Moses & Hix, 1998; Hale & Tager-Flusberg, 2003; Leslie & Polizzi, 1998; Leslie, German & Polizzi, 2005; Mitchell & Lacohce, 1991; Rakoczy, 2010; Surian & Leslie, 1999; Friedman & Leslie, 2004b). The later suggestion has received empirical support through a number of studies, which had demonstrated that younger children's performance could be significantly improved by lowering the demands of standard FB tasks (e.g. Bartsch, 1996; Siegal & Beattie, 1991; Setoh, Scott & Baillargeon, *in press*; Zaitchik, 1991). For instance, Siegal and Beattie (1991) found that 3-year-olds performed much better on the standard FB task when the critical question, "*Where will Sally look for the toy?*" was changed into "*Where will Sally look FIRST for the toy?*" which indicated the role of pragmatic factors (e.g. understanding the question) in the standard FB tasks (Siegal & Beattie, 1991). Similarly, it has been shown that young children are much better at predicting where an actor will search for the target object if it was previously removed from the scene (e.g. Bartsch, 1996; Carpenter, Call & Tomasello, 2002; Koos, Gergeley, Csibra & Biro, 1997; Zaitchik, 1991).<sup>1</sup> Even more striking evidence in favor of the early-competence accounts comes from the studies that employed implicit measures<sup>2</sup> to test

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<sup>1</sup> This is explained in terms of reducing the inhibitory demands of the standard FB task; namely, in the standard task, a child first needs to inhibit the most salient answer, i.e. the one that is in accordance with a child's (and the agent's) true belief, in order to successfully attribute a false-belief. Since younger children have underdeveloped inhibitory processes, they fail to do so; yet, when the prepotent answer is removed from the scene, the inhibitory demands of the task are lowered, which enables younger children to pass the test (e.g. Leslie & Polizzi, 1998; Leslie, German & Polizzi, 2005).

<sup>2</sup> Implicit measures assume obtaining children's responses without engaging them verbally. Common implicit measures in developmental psychology include capturing children's eye-gaze (looking times measures) or eliciting their reaching/pointing behavior or spontaneous helping behavior.

young children's ToM. Remarkably, these studies demonstrated successful false-belief reasoning even in preverbal babies (e.g. Baillargeon, Scott & He, 2010; Buttelmann, Carpenter & Tomasello, 2009; Onishi & Baillargeon, 2005; Onishi, Baillargeon & Leslie, 2007; Southgate, Senju & Csibra, 2007; Southgate & Vernetti, 2014). For example, in now a classic study, Onishi and Baillargeon (2005) showed that children as young as 15 months are capable of understanding others' false-beliefs when tested on a specially designed non-verbal version of the standard false-belief task, where children's responses were measured indirectly, through their looking times to certain locations.<sup>3</sup> In another study, Scott, He, Baillargeon and Cummins (2012) showed that 2.5-year olds passed even a verbal FB task if their performance was measured by spontaneous looking behavior, rather than by elicited, verbal responses.

The evidence of early false-belief understanding provided strong support for the early-competence accounts of ToM (e.g. Leslie, 1987; Leslie & Frith, 1990; Leslie & Thaiss, 1992; Leslie & Roth, 1993; Leslie, 1994a; Leslie, 1994b; Leslie, Friedman & German, 2004; Sholl & Leslie, 2001). These accounts conceptualize ToM as a cognitive module, specialized to recognize a relevant input (viz. intentional agency of an object<sup>4</sup>) and to compute and attribute mental states representations to one-self and others.

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<sup>3</sup> This is known as the "violation of expectation" (VOE) paradigm. The rationale behind this paradigm is that infants are more likely to look longer at an event that seems unexpected (as if they were "surprised"). In Onishi's and Baillargeon's (2005) study, an agent who appeared to have a false belief about a location of a certain toy, approached either a container in which the toy actually was (unexpected event) or an empty container in which the toy was originally placed (expected event). They found that infants looked significantly longer in the case of an unexpected event.

<sup>4</sup> I capture the notion of *intentional agency* by appeal to Leslie's Tripartite Theory of Agency (Leslie, 1994). It proposes that the concept of agency is obtained by three sub-processing systems where each of them represents different real world properties of agency. The first component, Theory of Body Mechanism (ToBy), represents mechanical properties of agents and objects. The second and third components are subsystems of the theory of mind mechanism (ToMM). These components represent the *intentional agency*, i.e. the goal-directed actions of agents (ToMM1) and their mental states (ToMM2).

Crucially, the assumption is that this fundamental computational structure is innately present; thus ToM does not forgo dramatic *conceptual* changes.<sup>5</sup> Hence, developmental changes that enable a child to pass the standard FB task do not concern the very structure of ToM capacity, but rather concern supporting abilities, such as domain general, executive processes. Leslie's (e.g. 1998, 2005) dual-component model of ToM effectively captures this idea: the first component is the Theory of Mind Mechanism (ToMM), an innate, domain-specific module that computes beliefs and desires. The second component is a selection processor (SP), understood as a domain-general control process needed to select among the alternative, competing candidates for a belief content. On the standard FB tasks, after ToMM computes a character's belief, SP needs to select its possible content; true-belief is always favored by SP by default, thus it has to be inhibited by a cognitive system in order to enable successful performance on the task. This selection-by-inhibition process develops relatively slowly, which explains the performance discrepancy between children who are younger than 4 and those who are 4 years old (or older).

## *2. Is early ToM the "real" ToM? The dual-systems account.*

In spite of the growing evidence in favor of the early-competence accounts, a group of researchers are still skeptical about the very nature of the early ToM ability (e.g. Apperly & Robinson, 2003; Apperly & Buterfill, 2009; Surtees, Buterfill & Apperly, 2012; Buterfill & Apperly, 2013; Low & Watts, 2013; Rakoczy, Bergfeld, Schwarz &

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<sup>5</sup> It is important to notice that the innateness does not assume that an entirely mature, fully developed ToM exists at birth. Rather, the inborn computational structure is still open to further advances, supported by the development of additional processing components; however, these advances do not assume fundamental, representational changes of the very ToM capacity (e.g. Leslie, 1987; Leslie et al., 2004; Sholl & Leslie, 2001).

Fizke, 2014). These researchers suggest that the contradictory findings, i.e. the early successes in ToM reasoning contrasted with the later failures on standard FB tasks, could be accounted for by conceptualizing ToM as comprising distinct systems, rather than taking it to be a uniform ability.

The central claim is that the properties of ToM reasoning are determined by competing demands for efficient and flexible processing. Namely, ToM needs to be fast enough to capture the rich dynamics of social situations; yet, it also has to be flexible enough to support reasoning about mental states in more complex situations, for instance, in the cases that involve manipulations of others' impressions (Apperly & Butterfill, 2009). As it is unlikely for a single system to satisfy both the efficiency and flexibility demands, these authors suggest the two ToM systems. On the one hand, there is a slow, but flexible ToM system, which takes more time to develop and (presumably) depends upon language.<sup>6</sup> On the other hand, there is a fast, yet inflexible ToM system, which is present early on in one's life and accounts for the early successes on implicit FB tasks.

Both systems are assumed to coexist in adults, (e.g. Samson & Apperly, 2010; Samson, Apperly, Braithwaite, Andrews & Boddley Scott, 2010), yet the representations they compute take fundamentally different forms. While late ToM is metarepresentational, early ToM is said to be incapable of representing propositional attitudes and, hence, of representing beliefs *as such*. Since it cannot represent that an agent *represents that X*, the best that early ToM can do is to represent that an agent *registers X*, where *registrations* are defined as relations between an agent, an object and a location of the object (Butterfill & Apperly, 2013). Butterfill and Apperly (2013) argue

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<sup>6</sup> Note that, according to this view, language development is not assumed to foster the ToM performance, but is rather considered a formative factor for the late ToM competence (e.g. Carruthers, 2015).

that registrations will suffice to allow for success on a number of implicit FB tasks, notably on the location-changes tasks; yet they will fall short of success on the tasks that involve false-beliefs about identities. The reason lays in the formal distinction between propositional attitudes and registrations, which leads us back to *Frege's Puzzle*, a well-known problem concerning the identity statements and propositional attitude reports (see Frege, 1948). To see what is at issue, consider the following inference:

- (1) Mary believes that Hesperus is in the sky.
- (2) Hesperus = Phosphorus.
- (3) Mary believes that Phosphorus is in the sky.

The inference (1)—(3) is invalid, although both “Hesperus” and “Phosphorus” refer to the *same identity*. This is because propositional attitude reports hold the property of referential opacity: coreferring terms occurring within the complement clause of an attitude report are not freely substitutable *salva veritate*. That is, substituting a term ‘t’ for a coreferring one ‘t<sub>1</sub>’ within the *that*-clause of an attitude report does not guarantee the preservation of truth. By contrast, consider the corresponding inference, which involves registrations:

- (1') Mary registers < Hesperus, on the sky>
- (2') Hesperus = Phosphorus.
- (3') Mary registers <Phosphorus, on the sky>

Butterfill and Apperly (2013) claim that, in the later case, the inference (1')—(3') is logically valid, since registrations are merely relations between agents, objects and

locations and, hence, remain referentially transparent. That is, unlike propositional attitudes, registrations do not create opaque contexts. This difference in form underlies the crucial distinction between a propositional attitude and a registration.

If early ToM is, indeed, limited in the sense that it cannot compute propositional attitudes, this should be reflected in FB tasks that involve understanding others' beliefs about object identities. However, there is evidence that suggests the opposite (e.g. Buttelmann, Suhrke & Buttelmann, 2015; Scott & Baillargeon, 2009). For example, Scott and Baillargeon (2009) demonstrated that even 18-month-olds were successful on an implicit, FB task that involved reasoning about object identities. They presented infants with an agent who interacted with two toy-penguins, one indivisible and the other divisible. Both penguins were always presented together (the divisible penguin in two pieces), and the agent always reached for the divisible one to hide her keys in it and she would conjoin it afterwards. In the false-belief test trial, the divisible penguin was in its assembled state, whereas the indivisible one was hidden behind an opaque cover. Infants looked longer when the agent reached for the divisible penguin than when she reached behind the cover, indicating that they expected the agent to act in accordance with her (false) belief about the identity of the assembled penguin (Scott & Baillargeon, 2009).

Nevertheless, Butterfill and Apperly (2013) disagree that these findings demonstrated infants' understanding of false-beliefs about object identities; rather, they argue that infants more likely ascribed false-beliefs about object *types*. Namely, infants could have ascribed to the agent the belief that the visible penguin is *an* indivisible penguin (rather than that it is *the* divisible penguin); this, combined with the belief that a divisible penguin is always present with together with an indivisible one, might have



accounted for the infants' success (Butterfill & Apperly, 2013).<sup>7</sup>

There have been quite a few studies that employed implicit measures, to provide evidence in favor of early ToM's incapability of representing false-beliefs about identities (e.g. Low & Watts, 2013; Low, Drummond, Walmsley & Wang, 2014). For instance, Low and Watts (2013) tested 3-year-olds, 4-year-olds and adults to see if they can spontaneously anticipate where an actor would reach for an object based on her false-belief about object identity. The participants were previously familiarized with the agent's goal to always reach for the object of one color, rather than the other. In the false-belief test trial, the actor observed a red object, traveling from the right box to the left one in which it rotated for 180 degrees to reveal its blue side (the rotation was visible only to the participants, but not to the actor). The object then traveled back to the right-hand container, with its blue side facing the participants. Children of both ages (3-year-olds and 4-year-olds), as well as adults, anticipated rather poorly where the actor would reach for the object (Low & Watts, 2013). Although the authors interpreted this finding along the lines of the signature limits of early ToM, this experiment has been criticized for being too cognitively taxing. For instance, apart from the demands on ToM reasoning, this task also imposed significant working memory demands, involving mental rotation of a memory image of the moving object (see Carruthers, 2015). Hence, the poor performance might have been the result of the overall cognitive load, rather than a reflection of early ToM's representational limit.

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<sup>7</sup> Carruther (2015) points out that this type of reasoning should still be beyond the reach of non-representational early ToM, as it involves ascriptions of beliefs as such. Hence, Scott's and Baillargeon's (2009) findings still present a challenge for Butterfill's and Apperly's account.

*The present study.*

Taken together, the empirical findings do not offer a clear picture regarding early ToM representational capability. It is still unclear if early ToM can represent false-beliefs about identities and (if yes) under which circumstances this capacity can be manifested. In the current study, we explore these questions, both with two-years old children and with adults, by employing a novel word-learning version of the implicit FB task. In particular, we focus on the process of mapping novel *proper names*, which are used to index identities of particular individuals, onto their referents in virtue of early ToM, and, in particular, in virtue of others' false-beliefs about identities of the referents.

The assumption that early ToM could be a vehicle for the mapping novel labels onto their referents is influenced by the intention-based approaches to word-learning process (e.g. Bloom, 2000; Baldwin & Tomasello, 1998; Baldwin & Mosses, 2001).<sup>8</sup> These approaches, contrasting the common, *associationist* models,<sup>9</sup> emphasize the inherently social nature of language and communication, as they postulate that it is the recognition of others' intentional states in virtue of which a social agent manages to successfully infer meanings of novel words (e.g. Baldwin, 1991, 1993a; Baldwin, Markman, Bill, Desjardins, Irwin & Tidball, 1996; Baldwin & Tomasello, 1999; Grassmann, Stracke & Tomasello, 2009; Tomasello, 1992, 1999). Several studies showed

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<sup>8</sup> The intention-based approaches assume that in order to solve the referential ambiguity problem and, hence, correctly map novel labels onto the appropriate referents, young children have to recognize and appreciate others' referential intentions, hence, they have to be engaged in ToM reasoning. These approaches have been largely inspired by Grice's (1969) intention based semantics, which grounds semantic content in the process of mutual intention recognition among interlocutors in a communicative setting.

<sup>9</sup> *Associationist models* postulate that the process of mapping labels to meanings is established in virtue of forming associations between labels and their corresponding visual images. According to these approaches word acquisition is based on statistical learning of co-occurrences between linguistic and non-linguistic inputs. However, these models fall short of solving the referential ambiguity problem, as the number of things a certain novel label can refer to is enormously large.

that young children's performance on FB tasks was enhanced when these tasks were placed into a communicative context, which required them to discern a speaker's *referential intention*, rather than to simply predict their actions (e.g. Carpenter et al., 2002; Happé & Loth, 2002). These studies focused on how communicative and word learning setting could affect ToM reasoning. Here, we explore more closely the actual role of early ToM in the word acquisition process, i.e. if it could serve as a vehicle for mapping novel labels onto correct referents.

We focus on the acquisition of proper names as they are of particular relevance for our main question, i.e. if early ToM can represent others' epistemic states about identities. Unlike common nouns, proper names are not generalizable across instances of the same category membership, but rather apply to a single individual. Hence, in order to map a proper name onto its referent, one first has to represent the referent as holding a unique identity that the proper name directly refers to. Previous studies provided evidence that children start understanding that proper names mark particular individuals rather than category-based commonalities, between 16 and 20 months of age (Bélanger & Hall, 2006). Here, we aim to explore if they can map a proper name onto its referent in virtue of early ToM and, in particular by relying on another's false-belief about the referent's identity.

The purpose of this study is, thus, twofold: a) to test the question of whether early ToM can represent others' false beliefs about identities and b) to test the question of whether early ToM presents a vehicle for mapping novel words, in particular, novel proper names, onto their referents. To test these questions we employ an implicit proper names-learning FB task, by measuring two-years old children's spontaneous looking

responses. If correct mapping between proper names and their referents could, indeed, be achieved by relying on another's false beliefs regarding referents' identities, this would tell us not only that early ToM is capable of representing false-beliefs about identities (contrary to the assumption raised by Apperly and Butterfill (2009; 2013)), but moreover, that it could have an important role in the process of word acquisition.

## **Experiment I**

### **Method**

#### *Participants.*

We tested 16 two-years old children (mean age = 26.3 months, range: 20.15- to 34.14 months; 7 females). Additional 6 children were excluded from the sample (3 due to calibration error, two due to fussiness and one due to vision impairments). All children were recruited from local preschools. We obtained the consent forms for of all the participants.

#### *Materials and Procedure.*

We used Tobii T60 XL eye-tracker to present stimuli and record subjects' eye-gaze. Each child was tested individually, in a quiet environment (either in the lab or at their preschools). Children sat on their parent's (or a teacher's) lap, 60 to 80 cm away from the eye-tracking monitor. Before the actual experiment, a 5-point calibration was applied to ensure that the eye-tracker would collect enough and precise data.

All subjects were presented with a short movie (approximately 5 minutes long) that consisted of the following four conditions: the Pointing (P), the True Belief (TB), the False Belief (FB) and the False Belief + Category condition (FBC). All the conditions were always presented in the same order: the P condition was presented first (it was

supposed to familiarize a child with the general setup), the TB was presented second, the FB was presented third, and the FBC was presented last. Each of the conditions consisted of two parts: the Teach trial, in which the subjects were introduced to the experimental setup and the Test trial, in which the subjects' eye-gaze responses were measured.

In the P Teach trial (Fig.1), a puppet introduced two distinct toy animals and placed one at each side of the stage, while an actor was observing; the actor then pointed to one of the toys and said: "Look! Look at Daxy! His name is Daxy!" In the TB Teach trial (Fig.2), the puppet, again, brought two distinct animals to the stage, placed one of them in an opaque box and closed the lid while the actor was observing; the puppet, then, left the scene taking the second toy with itself and the actor pointed to the box saying: "Look! Mody is in there! His name is Mody!". The FB Teach trial (Fig.3) followed the same form as the TB condition, but with one crucial difference: after the puppet placed one of the toys in the box, the actor turned her back to answer the phone; while she was not observing, the puppet switched the toys in the box and left the scene taking the toy that was originally placed in the box away. The actor, then, turned back again, now facing the child, pointed to the box and said: "Look! Toma is in there! His name is Toma!". Finally, in the FBC Teach trial (Fig.4), the same toys from the FB condition were presented one at each side of the stage and the actor said (looking directly to the child and without pointing): "Toma is a wuggy! Toma is a wuggy!". We included this condition to see if children can use the knowledge gained from the FB trial to further infer which of the two toy-animals is "the wuggy". More precisely, we wanted to see if, on top of mapping a proper name to its referent in virtue of the actor's false-belief about

the referent's identity, two-year-olds could further use this knowledge to learn novel information about the referent, i.e. its category membership.

Each of the Teach trials was immediately followed by a 10 second Test trial in which children saw the toys from the previous trial, placed one at each side of the stage, and heard the actor's voiceover (absent the actor and the puppet): "Look! Look at Daxy/Mody/Toma/the wuggy!". Children's looking time toward each of the toys was measured for three seconds, after the label was uttered.



Figure 1. *The Pointing condition (P). In the Teach trial an actor observes a puppet placing two distinct toys one on each side of the screen (A.); she then points to one of them and says: "This is Daxy! His name is Daxy!" (B.). In the Test trial, that follows 1 second after the Teach trial, subjects see the toys from the Teach trial and hear the actor's voice that says: "Look, look at Daxy!" (C.); their looking time towards both of the toys is measured for 3 seconds.*

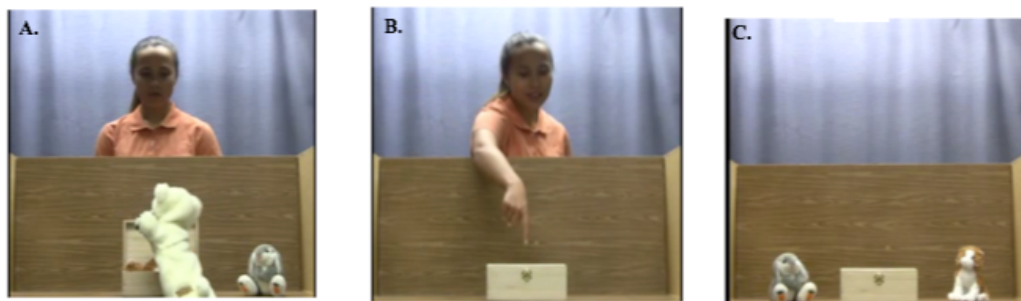


Figure 2. *The True Belief condition (TB). In the Teach trial the actor observes the puppet placing one of the toys in the box, and then leaving with the other toy (A.). The actor then points at the box and says: “Look, Mody is in there! His name is Mody!” (B.). The “test trial” flows a second after the “tell trial”; children see the toys from the previous trial and hear the actor’s voice: “Look, look at Mody!” (C.).*

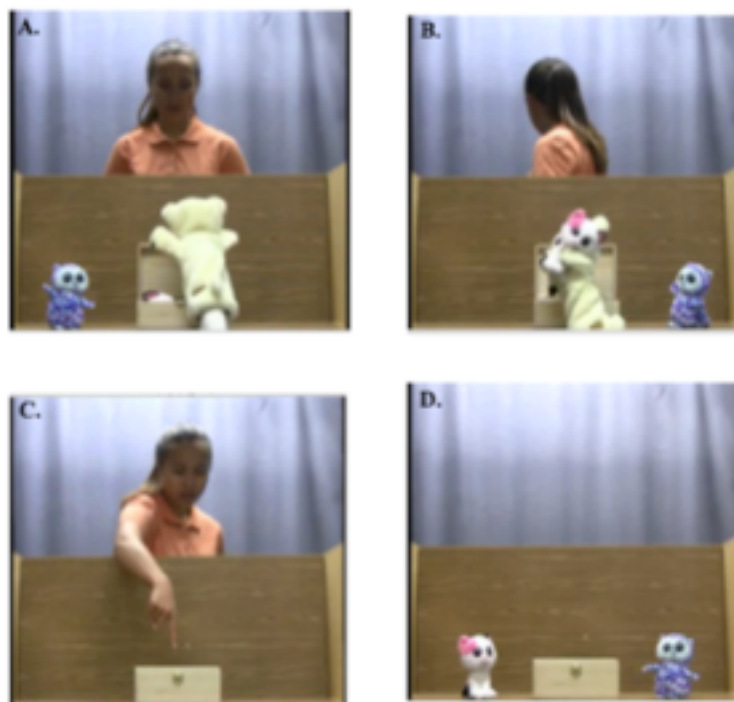


Figure 3. *The False Belief condition (FB). The actor sees a puppet placing one of the toys in the box and leaving the scene with the other one (A.). The sound of a phone ringing is heard, and the actor turns her back; the puppet then reappears, removes the*

first toy from the box, replaces it with the other one and leaves the scene (B.). The actor, then, turns again to face the child, points to the box and says: “Look! Toma is in here! His name is Toma!” (C.). The “test trial” follows after a second; two toys from the “tell trial” are shown and the actor’s voice says: “Look, look at Toma!” (D.).

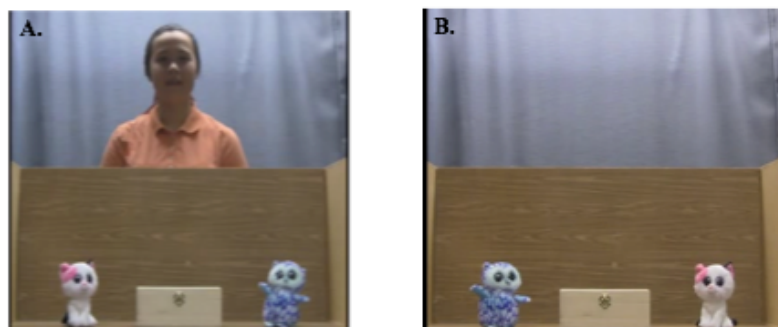


Figure 4. *The False Belief + Category condition (FBC). The toys from the FB trials are presented on the scene and the actor simply announces: “Toma is a wuggy! Toma is a wuggy!” (A.). After a second, the “test trial” follows in which the toys from the previous trial are shown on the screen and the actor’s voice says: “Look, look at the wuggy! (B.).*

We balanced which toy animal from each of the three pairs was the correct referent (i.e. in accordance with the actor’s belief) as well as the side on which it appeared on the screen. This created four different balancing conditions to which the subjects were randomly assigned.

## Results

Children’s performance was measured using the Differential Looking Score (DLS; Senju, Southgate, White, & Frith, 2009), a measure that indicates whether children tend to look more at the toy that the actor had in mind as the referent at the time she



provided a label. The DLS was calculated by subtracting the time subjects spent looking at the incorrect referent (i.e. the one that was not in accordance with the actor's belief) from the time they spent looking at the correct referent (the one that the subject had in mind while uttering a label), divided by their sum. Hence, the positive DLS indicated that children mapped a label with the correct referent for the P and the TB trials, and the negative DLS indicated the correct mapping for the FB and FBC trials.

Preliminary analyses revealed that neither the gender nor the balancing condition played a significant role in determining the subjects' looking performance, so we excluded these factors from the following analyses.

In the P condition, children preferred to look longer at the toy animal that was the correct referent, i.e. the one that the actor pointed at, mean DLS = 0.35,  $t(9) = 2.17$ ,  $p < .05$  (one-tailed). In the TB condition, they also looked longer at the toy animal that the actor had in mind as the referent of the name, mean DLS = 0.34,  $t(12) = 2.26$ ,  $p < .05$  (one-tailed). However, in the last two conditions, the FB and the FBC, children did not show significant looking preferences, as their DLS scores were not significantly different from 0 (mean DLS for FB = 0.09,  $t(10) = -.52$ ,  $p = .31$  (one-tailed) mean DLS for FBC = -0.17,  $t(10) = -0.74$ ,  $p = .24$  (one-tailed)) (see Fig. 5).

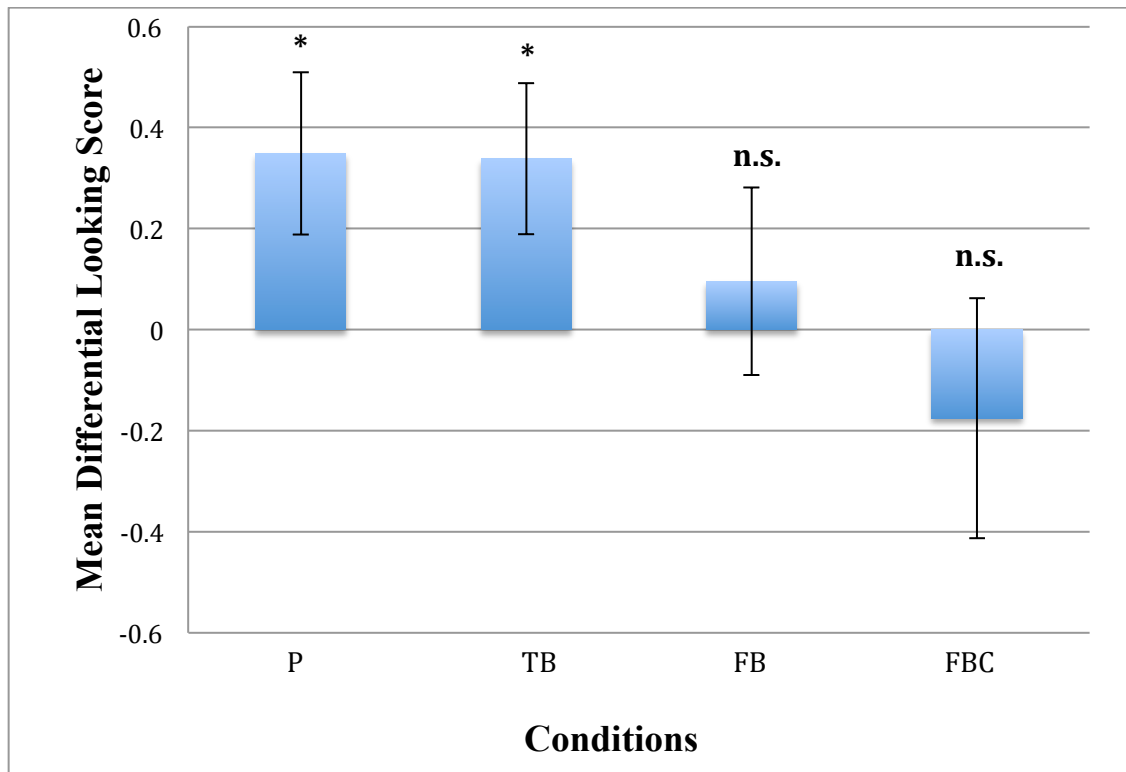


Figure 5. *Two-Year-Olds' Mean Differential Looking Scores (DLS) by the Test Trial: Pointing (PT), True Belief (TB), False Belief (FB) and False Belief + Category (FBC), over the time interval of 3 seconds. \*:  $p < .05$ .*

### Discussion

Two-year olds looked significantly longer to the toy-animals that the actor had in mind as the names' referents in both the PT and the TB conditions, which indicates that in these conditions, they successfully solved the referential ambiguity problem, correctly mapping novel proper names onto their referents. Nevertheless, this was not the case in the FB and FBC conditions. When the actor held a false-belief about the identity of the toy-animal hidden in the box, children's looking preferences were not different from what would be expected by chance. Since they were unable to figure out the referent of

the proper name in this case, children were, consequently, not successful in the following condition either, which required them to discern the referents' category membership based on its proper name.

These results seem to go along with the assumption that early ToM is limited when it comes to representing others' false-beliefs about object identities, as suggested by the proponents of dual-systems approaches (Apperly & Buterfill, 2009; Buterfill & Apperly, 2013). However, before jumping to such conclusion, we have to rule out the possibility that the two-year olds' poor performance on FB and FBC conditions simply reflects the task noise, rather than a fundamental property of early ToM system. The FB Tell trial contained more sequences of events that a child had to encode, compared to the PT and the TB Tell trials (e.g. the phone ringing, the actor turning back and forth, the switching of the toys), which might have overloaded their memory resources. The phone ringing and the actor turning her back might have also distracted the two-year olds, so they could not successfully encode what was happening on the scene afterwards (i.e. the toy-animals being switched by the puppet), which was critical for the success on the task (Heyes, 2014a). Finally, since the FB and the FBC were always the last two conditions, it could be that the two-year olds were simply too cognitively exhausted to pay enough attention to the sequence of events in the FB Tell trial.

To address these possibilities and to further explore the characteristics of ToM reasoning involved in this task, it would be useful to test adult subjects' performance as well. Adults have enough memory and attention resources to successfully encode the events in the FB Tell trial. Hence, if they exhibit the similar patterns of successes and failures across trials as do young children, this would reveal something specific to the

implicit ToM reasoning involved in this task. By contrast, if adults show successful mapping in all of the conditions, the possibilities would remain that the task was too taxing for general processes in the two-year olds or, alternatively, that the ToM reasoning employed by the two-year olds was immature compared to that of the adults.

The goal of the second experiment was to further explore these possibilities.

## **Experiment II**

### **Method**

#### *Participants.*

10 adult subjects participated in the experiment (8 females), with a mean age of 34.10 years (age range: 18- to 71-years). One additional subject was tested, but excluded due to a calibration error. Subjects were Rutgers university undergraduate and graduate students who all consented to participate in the study.

#### *Materials and Procedure.*

We used the same materials and procedure as with two-year olds in the Experiment 1. Tobii T60 XL eye-tracker was used to present stimuli and record subjects' eye-gaze. Each subject was tested individually, in a quiet environment, in the lab. Subjects sat 60 to 80 cm away from the eye-tracking monitor. Before the actual experiment, a 5-point calibration was applied to ensure that the eye-tracker would collect enough and precise data.

All subjects went through the 4 experimental conditions that were the same as in the Experiment 1. We measured their eye-gaze in the test trials for 3 seconds after the actor uttered the name.

## Results

We calculated the Differential Looking Score (DLS) to the toy animals in the test trials, to measure the adult subjects' performance. Again, positive DLS scores indicate correct mapping of a novel name and its referent in the P and TB conditions and negative DLS scores indicate correct mapping in the FB and FBC conditions.

In the P and the TB Test trials, the adult subjects looked significantly longer to the correct referent, i.e. the toy-animal that the actor had in mind when she uttered the name. The mean DLS score in the P condition was 0.72,  $t(9) = 3.62$ ,  $p < .05$  (one-tailed). The mean DLS score in the TB condition was 0.56,  $t(8) = 2.81$ ,  $p < .05$  (one-tailed). However, there was no significant looking preference in either the FB or the FBC Test trials (mean DLS in the FB condition was -0.22,  $t(8) = -0.82$ ,  $p = .22$  (one-tailed), mean DLS in the FBC condition was -0.25,  $t(8) = -0.80$ ,  $p = .22$  (one-tailed)) (see Fig. 6).

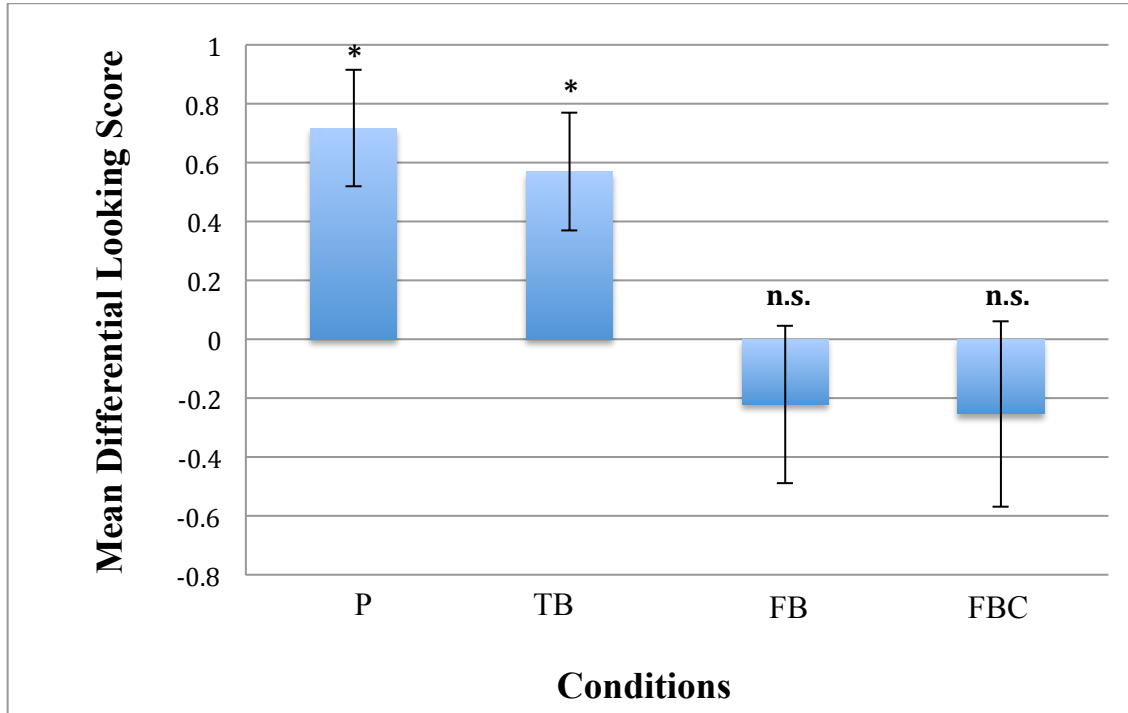


Figure 6. *Adults' Mean Differential Looking Scores (DLS) by the Test Trial: Pointing (P), True Belief (TB), False Belief (FB) and False Belief + Category (FBC), over the time interval of 3 seconds. \*:  $p < .05$ .*

### Discussion

Adult subjects successfully solved the referential ambiguity problem in both the P and the TB conditions, as they looked significantly longer to the toy-animals that the actor had in mind as the referents of the novel names. Strikingly, however, they did not show a looking preference to either of the toy-animals in the FB and the FBC conditions. Hence, adult subjects exhibited the same pattern of looking behavior across trials as the two-year olds: when the actor held a true belief about the identity of the referent, both the two-year olds and the adults were successful at correctly mapping the proper name to its

referent; nevertheless, when the actor had a false-belief about the identity of the toy being named, neither the two-year olds' nor the adults' looking preferences differed significantly from what would be expected due to chance.

These results suggest that the task at hand triggered the same underlying cognitive mechanism in both the adults and the two-year olds. Given the similar looking patterns across trials between the adults and the two-year olds, it seems unlikely that the two-year olds' looking behavior could be accounted for by their immature memory and attention resources. Rather, it seems that the patterns of responses in both the adults and the two-year olds reveal something specific to the ToM reasoning employed in this task.

### **General Discussion**

The present study aimed to investigate the computational properties of early ToM competence. Although there has been an abundance of empirical findings demonstrating that a young child can pass false-belief tasks rather early on in her life (Baillargeon, Scott & He, 2010; Buttelmann, Carpenter & Tomasello, 2009, Onishi & Baillargeon, 2005; Onishi, Baillargeon & Leslie, 2007; Southgate, Senju & Csibra, 2007; Southgate & Vermetti, 2014), there is still skepticism regarding the nature of the mental representation that underlies the early successes. Specifically, the proponents of the dual-systems account argue that early ToM competence is non-metarepresentational, i.e. that it cannot construe mental representations in the form of propositional attitudes; therefore, it is subject to several signature limits, one of which is its incapability of representing false-beliefs about object identities (Apperly & Robinson, 2003; Apperly & Buterfill, 2009; Surtees, Apperly & Buterfill, 2012; Buterfill & Apperly, 2013; Low & Watts, 2013; Rakoczy, Bergfeld, Schwarz & Fiske, 2014).

Here, we tested the question of whether early ToM can represent others' false-beliefs about object identities by employing an implicit, proper names-learning FB task. We manipulated an agent's epistemic states about the identities of the toy-animals being named, to see if the subjects would be able to map a proper name onto its referent on the basis of the agent's false-belief about the referent's identity. We found that the two-year olds successfully mapped proper names to their referents when the actor held a true-belief about the referent's identity. Nevertheless, this was not the case when the actor was mistaken about the identity of the toy-animal that was in the box at the time of naming. In the later case, subjects showed no significant looking preference to either of the toy-animals in the test trial. Consequently, their looking preferences were not different from what would be expected due chance to in the following condition either, which required them to infer the category membership of the previously named toy-animal. Surprisingly, this pattern of looking responses was not only observed in the two-year olds, but in the adult subjects as well, as shown in the second experiment. Namely, the adult subjects too, were successful at mapping novel proper names onto their referents in the PT and TB test trials, but did not show significant looking preferences in the last two conditions. This suggests that both the adults and the two-year olds spontaneously employed the same underlying cognitive mechanism in the implicit, proper names-learning FB task.

Taken together, the results from the Experiment I and the Experiment II seem to be consistent with the dual-systems account proposed by Apperly and Butterfill (2009; 2013). Recall that according to this account, early ToM system would reveal a blind spot when it comes to scenarios that involve others' false beliefs about object identities. Indeed, our subjects struggled to map a proper name onto its referent in the FB condition,



i.e. when the correct mapping required correcting for the actor's false belief about the referent's identity. Moreover, not only was this evident in the two-years old subjects, but in the adult subjects as well, as demonstrated in the Experiment II. This is consistent with the dual-systems account, as it assumes that both the early (implicit) and the late (explicit) ToM are simultaneously present in adults (Samson & Apperley, 2010; Samson, Apperley, Braithwaite, Andrews & Boddley Scott, 2010). Namely, the dual-systems account predicts that adults would reveal the early ToM's signature limit in regard to representing false-beliefs about identities when implicit, non-verbal measures are employed; nevertheless, they would have no struggles with the identity false-belief scenarios when explicit, verbal responses are measured, as they tackle the late, metarepresentational ToM system (unfortunately, the present study did not employ explicit measures, which would directly test this prediction).

The question remains open whether our results necessarily reflect a *representational* limit of early ToM or, alternatively, whether they could be accounted for by *performance* factors. As previously mentioned, it has been well established that performance on explicit, verbal ToM tasks depends upon the processes of response inhibition and selection (Batsch, 1996; Carpenter, Call & Tomasello, 2002; Koos, Gergeley, Csibra & Biro, 1997; Zaitchik, 1991, Leslie & Polizzi, 1998; Leslie, German & Polizzi, 2005). In a recent study, Wang and Leslie (2016) demonstrated that early ToM, reflected through implicit measures, does not escape the demands of inhibitory-selection processes either. They employed the anticipatory-looking (AL) method to test preschoolers' and adults' performance on both the high-demand and the low-demand FB

tasks.<sup>10</sup> They found that in the low-demand FB condition, both the preschoolers and the adults spontaneously anticipated that the agent would act in accordance with her false-belief about the object's location (i.e. they preferred to look longer to the FB anticipatory window – the one through which the actor would reach if she held a false-belief about the objects' location). However, in the high-demand FB condition, there was no looking preference to either the FB window or the TB window, revealing chance performance when AL method was employed. This was the case with both the preschoolers and the adult subjects, although the adults had no problems predicting the actor's actions in the same (high-demand) task when explicit, verbal measures were employed (Wang & Leslie, 2016). As the authors suggest, these findings imply that: a) the implicit (non-verbal) ToM is subject to processing demands of the task, much like the explicit (verbal) system and b) the implicit ToM is independent from explicit ToM and it does not change significantly over the years.<sup>11</sup>

Our results are consistent with the picture proposed by Wang and Leslie (2016). We found that both the two-year olds' and the adults' spontaneous looking performance was at chance in the FB condition, similarly to what Wang and Leslie (2016) observed in their high-demand FB task. Importantly, our FB condition was a version of a high-demand FB task, since the distractor toy-animal remained in the box at the time of naming. It is, thus, possible that our subjects struggled with the FB condition, because they could not effectively inhibit the prepotent response (i.e. the one that would be the

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<sup>10</sup> The critical difference between the two FB tasks was that in the low-demand task, the target object was completely removed off the screen after the puppet switches its locations, whereas in the high-demand task, it remains in one of the locations.

<sup>11</sup> It is important to notice here that, although the findings by Wang and Leslie (2016) suggest that there are, indeed, two independent ToM systems, their perspective differs significantly from the one offered by Apperly and Buterfill, as no fundamental representational limits are ascribed to the early, spontaneous ToM.

referent *if* the actor held a true-belief about the identity of the object in the box) rather than because of a representational limit of the early ToM. In that regard, it should be noted that our subjects' eye-gaze patterns in the FB condition did not reveal a systematic preference for the true-belief target and it is unclear why this would be the case if the early ToM was completely incapable of appreciating the actor's false-belief about object identity in the FB condition. That no significant looking preference to any of the two targets was found in the FB condition is more likely to reflect the competition between the two belief candidates, the FB target and the TB target. Because the implicit ToM does not escape the inhibitory demands of the task (Wang & Leslie, 2016) and, hence, (by default, prepotent) TB target cannot be inhibited, the competition between the two answers in our FB condition could not be effectively resolved. Employing a low-demand version of our FB condition would further explore this possibility. For instance, after switching the toy animals, the puppet could remove the non-referent animal from the box before it leaves, so that the box remains empty at the time of naming. Removing the prepotent answer (i.e. the true-belief candidate) off the scene would, presumably, lower the inhibitory demands and would, consequently, help subjects select the correct response (i.e. the false-belief candidate). This prediction remains to be tested in the future.

### **Conclusion**

In the present study, we tested the question of whether early ToM can represent false-beliefs about object identities with both the two-year olds and the adult subjects. We employed an implicit, word-learning FB task in which subjects were supposed to map a novel proper name and its referent on the basis of the actor's epistemic states about the referent's identity. We found that, although they did not struggle with the TB condition,

both the two-year olds and the adults could not correctly map a proper name and its referent in the FB condition. These results are consistent with the conjecture proposed by the dual-systems account (Butterfill & Apperly, 2013), namely that representing false-beliefs about identities presents a blind spot in the early ToM system. However, the results are also compatible with the picture offered by Wang and Leslie (2016): the inhibitory demands of the task could be responsible for the subjects' failure to select the correct referent in the implicit, high-demand FB task. It is possible that our subjects' failure in the FB condition did not reflect the early ToM's representational limit, but rather their inability to inhibit the salient, true-belief response candidate. Future research is necessary to further explore these possibilities.

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