Beyond Philology No. 14/1, 2017
ISSN 1732-1220, eISSN 2451-1498

Theory of Mind, linguistic recursion and autism spectrum disorder

IRINA POLYANSKAYA
PATRICK BLACKBURN
TORBEN BRAÜNER

Received 1.10.2016,
accepted 8.05.2017.

Abstract

In this paper we give the motivation for and discuss the design of an experiment investigating whether the acquisition of linguistic recursion helps children with Autism Spectrum Disorder (ASD) develop second-order false belief skills. We first present the relevant psychological concepts (in particular, what Theory of Mind is, and what it has to do with false beliefs) and then go on to discuss the role of language in our investigation. We explain why compositional semantics seems of particular relevance to second-order false beliefs, and why training children with ASD in the comprehension and production of (recursive) possessive noun-phrases and sentential complements might be beneficial. After our discussion of these fundamental ideas motivating the study, we outline our experimental program in more detail.

Keywords

Theory of Mind, false beliefs, linguistic recursion, autism spectrum disorder

Teoria umysłu, rekurencja językowa i spektrum autyzmu

Abstrakt

W niniejszym artykule przedstawimy motywacje dla przeprowadzenia i omówimy projekt eksperymentu mającego na celu zbadanie, czy nabycie rekurencji językowej pomaga dzieciom ze spektrum autyzmu (ASD) rozwinąć zdolności rozumienia fałszywych przekonań drugiego rzędu. Na początek przedstawimy istotne pojęcia z dziedziny psychologii (zwłaszcza objaśnimy, czym jest teoria umysłu i co ma ona wspólnego z fałszywymi przekonaniami), a następnie przejdziemy do omówienia roli języka w naszych badaniach. Wyjaśnimy, dlaczego semantyka kompozycjna wydaje się szczególnie ważna w odniesieniu do fałszywych przekonań drugiego rzędu, i dlaczego ćwiczenie dzieci z ASD w rozumieniu i tworzeniu (rekurencyjnych) dzierżawczych fraz rzeczownikowych oraz dopełnień zdaniowych może być korzystne. Po przedyskutowaniu tych fundamentalnych pojęć odnoszących się do prowadzonych badań, przedstawimy nasz eksperymentalny program w szczegółach.

Słowa kluczowe

fałszywe przekonania, rekurencja językowa, spektrum autyzmu, teoria umysłu

We recently began an ongoing empirical investigation into whether the acquisition of linguistic recursion helps children with Autism Spectrum Disorder (ASD) develop second-order (SO) false belief (FB) skills; in this paper we give the motivation for and discuss our experimental design. Linguistic recursion lies at the heart of our experimental work, and in later sections we will discuss some aspects of recursion and explain their relevance. But we will start by introducing Theory of Mind (ToM), as our work draws heavily on ideas and approaches which originated in the ToM research literature.

1. Theory of Mind

ToM is a broad term, and has a number of synonyms or near synonyms including mindreading, empathy, folk psychology, social cognition, and the intentional stance. Broadly construed, ToM is the ability to infer and attribute mental states in order to explain and predict behaviour. It is a crucial human ability, and adults typically apply it effortlessly in a wide range of situations, such as when they help someone with a heavy suitcase without being asked, or understand a sarcastic comment. Human beings are social creatures, and acquisition of ToM is part of what enables them to enter the complex web of human interaction.

ToM is a comparatively recent research topic. It originally arose in primatology (Premack and Woodruff 1978, Dennett 1971), but is now one of the central concepts in contemporary cognitive and developmental psychology. Research over the last 30-35 years, starting with the classic work of Wimmer and Perner (1983), has produced an impressive body of empirical data about when it is acquired, and what factors facilitate its development (Wellman 2001). But how can we measure something as broad and complex as ToM? What are these experimental results based on?

2. The relevance of false beliefs

The best-known method of detecting development of ToM has been to approach it via false belief understanding. This term is self-explanatory: as used in contemporary psychology, a false belief (FB) is simply a belief which does not correspond to reality. But what does this seemingly simple concept have to do with the complexities of ToM? And why is it experimentally valuable? To explain this, we shall present the first-order Sally-Anne task, one of the best-known first-order FB tasks. Note: the words *first-order* are important here. Later in the paper, we will introduce the *second-order* Sally-Anne task, as our own research focuses on second-order FB tasks. But first-order FB tasks are simpler, and a lot more is known about them, so they are a good way of explaining the relevance of FB tasks to ToM research. Here, then, is the first-order Sally-Anne task:

> A child is shown a scene with two doll protagonists, Sally and Anne. Sally has a basket and Anne has a box. Sally first places a marble into her basket. Then Sally leaves the room, and in her absence, Anne removes the marble from the basket and puts it in her box. Then Sally returns, and the child is asked: "Where will Sally look for her marble?"

At first glance, this question may seem trivial: *of course* Sally will look in her basket; after all, that's where she left it! But this apparent 'triviality' is something that has to be learned: typically developing children under the age of four usually answer this question incorrectly: they say that Sally will look in the box. This is certainly where the marble is, but Sally has no way of knowing that. To put it another way: to answer the question, the child has to grasp the notion that other individuals can have beliefs that can be *false*. Learning that beliefs can be false is a significant cognitive attainment – a major stepping-stone in the child's acquisition of ToM, which enables successful interaction with others. Social cognition hinges on being able to understand other's beliefs, desires and intentions; learning the basic – but crucial – fact that beliefs can be *wrong* is an important part of attaining social competency.

3. Findings about first-order TOM

There is now a vast body of experimental work on ToM that uses first-order FB tasks and many such tasks have been developed and applied (Doherty 2008, Wellman et al. 2001). So before moving on, let us note the three main findings of relevance to this paper that this work has yielded.

The first finding is that ToM develops in stages. There is a zero-order, a first-order (FO) and a second-order (SO) stage. We presented the FO version of the Sally-Anne task, and findings about FO FB tasks are extremely robust: they have been replicated in different cultures, in different languages, and across genders. And the conclusion is clear: at around the age of four, typically developing children can pass FO FB tasks; and before this age (that is, when they are at the zero-order stage) they usually cannot. After the first-order stage the child moves on to the second-order stage. This phase has been less studied, but again there is a distinct shift: most researchers would agree that typically developing children begin to acquire SO competency at around the age of six (Miller 2012).

The second finding is that children with Autism Spectrum Disorder (ASD) seem to develop ToM in a different manner, and at a slower pace, than typically developing children (Baron-Cohen et al. 1985, Happe 1995, Peterson et al. 2005). ASD is a neurodevelopmental disorder, characterized by impairments in social behaviour and communication, and by restricted, repetitive behaviour (according to DSM 5). The ToM deficit hypothesis, claiming that it is an attenuated ToM that underlies the social and communicative impairments in ASD, is one of the leading hypotheses in autism research today (Tager-Flusberg 2007). As we will discuss later, the fact that children with ASD handle the FB task differently from typically developing children lies at the heart of our experimental design: the children we have recruited for testing and training are all children diagnosed with ASD.

However, it is the third finding that has guided the direction our work has taken: there is a strong relationship between the development of language and the development of ToM – this is the case even though much of ToM is pre-linguistic or does not directly involve language at all (Astington Baird 2005, Miller 2006, Milligan et al. 2007, de Villiers 2007). Moreover, there are studies on these links for both the typically developing population as well as for various clinical populations (such as children with ASD and deaf signing children). But which aspects of language are relevant?

4. Syntax and lexical semantics: first-order false beliefs

Empirical results seem to show that FB reasoning is linked with the ability to use language. Why is this? Two distinct aspects of language have been appealed to: syntax and semantics.

Talk of semantics in this context usually means the use of *mental state vocabulary*. These are words that let us assert that someone is in a particular mental state, taking an attitude towards some content: examples like *I hope that…*, *Susan thinks that…*, *We believe that…*, *He imagines that…*, and so on, are typical examples. This form of semantic competency is measured by mental vocabulary scores, and the basic result of relevance here is: the larger the mental vocabulary is, the higher the success on ToM tasks (Guajardo and Watson 2002, Peskin and Astington 2004, Farrar and Maag 2002).

What does mental state vocabulary allow us to do? Roughly this: it makes it possible to talk about certain mysterious mental entities that cannot be directly observed. We can readily see what it means to run, to talk, or to jump, but we cannot in such a straightforward sense see what it means to think, to hope, or to wish.[1] But language gives us access to the mental world – indeed, it gives us highly sophisticated access. The utterance "Susan regrets that Henriette's Porsche is white" not only picks out Susan's mental state (she is in a regretting state), it also links this state to a fact about the world (namely Henriette's Porsche being white). Language lets us link an unobservable mental world with the concrete real world.

Thus, via mental state vocabulary, the child gets broad access to the invisible inner world of another person. There are many mental vocabulary words – the child learns them gradually, and in different contexts. Bit by bit they let the child build up an impression of mental worlds and how they operate. To put it another way: the child does not learn about false beliefs in a vacuum. Arguably, it is precisely because children are

[1] Advances in neuroscience are increasingly narrowing this gap by rendering patterns of brain activity visible.

born into a linguistic community, and gradually learn the rich vocabulary of mental states in everyday settings that makes it possible for them to enrich and enlarge their concept of belief. Moreover, being a part of the linguistic community makes it possible to enter a *community of minds*, a term developed by Nelson (2005). She argues that the "theory of mind" notion needs to be re-conceptualized in order not to exclude domain general achievements (such as language and memory) and social experiences (such as attachment and conversation). Being included in a community of minds, children learn that mental states can be created and changed, which eventually allows them to arrive at a full conceptual understanding of first-order false beliefs: the content of beliefs does not always correspond with reality.

Because of this, semantic aspects of language have a plausible link with the attainment of FB competency. But there is another aspect of language development, which yields another explanation: syntax. It has been suggested that sentential complementation comprehension predicts FB mastery (de Villiers and de Villiers 2000). Consider the sentence "Leo thinks that bulls give milk", where "that bulls give milk" is the sentential complement. Studies provide evidence for the hypothesis: the correlation has been confirmed for English (de Villiers and Pyers 2002), German (Perner et al. 2003), American Sign Language (Schick et al. 2007), Tibetan (De Villiers et al. 2007), and Turkish (Aksu-Koc et al. 2005). Two training studies reported that improvement in sentential complementation leads to better false belief understanding (Hale and Tager-Flusberg 2003, Lohmann and Tomasello 2003). Moreover, a longitudinal study with autistic children showed that mastery of sentential complement comprehension with verbs of communication was the strongest predictor of any changes in the children's false belief performance (Tager-Flusberg and Joseph 2005). Why is this?

The first explanation is: sentential complementation provides a format – a reliable pattern – that can facilitate reasoning about FB, as it has the useful property of attributing a view – a perspective – to an individual and distinguishing it from the reality that the perspective points towards. Furthermore, it offers precision. Consider first a view which is contributed by the words proceeding "that". This provides both information about the relevant agent (say, Sally or Leo), and which variety of perspective it is (a thought, a belief, a desire). More importantly, the child must learn that this first portion can remain the same, while the content it governs can vary: Leo may believe that bulls give milk or that mother is sweet or that Denmark is the finest country in the world. But in all these examples something remains unchanged: these are all Leo's *beliefs*. Learning that the perspective can be held constant while the content it governs varies, is a useful prerequisite in learning how beliefs operate, and points the way to the attainment of FO FB mastery, which is that these beliefs may be either true or false.

The second explanation is that language gives us access to a different world, the mental world of another person and at the same time gives us the possibility to assign different truth values to parts of the same sentence: the whole sentence is true (Leo does think that bulls give milk), even though the complement part is clearly false (bulls do not really give milk). According to de Villiers (2005), such truth contrasts provide a scaffolding for learning false believe reasoning.

However, we will not attempt to adjudicate the syntax/ semantics discussion that we have just outlined. This is because it is tangential to our own work. Until now, we have only considered *first-order* false beliefs and the discussions they have engendered; our own research focuses on *second-order* false beliefs, and these bring new issues into play, notably the concept of recursion.

5. Second-order false beliefs

Here is a version of second-order (SO) Sally-Anne task. Note its form: with the exception of the two items in italics, it is identical with the first-order version of the task we presented earlier:

A child is shown a scene with two doll protagonists, Sally and Anne. Sally has a basket and Anne has a box. Sally first places a marble into her basket. Then Sally leaves the room, and in her absence, Anne removes the marble from the basket and puts it in her box. *But Sally sees at the door what Anne is doing – and Anne doesn't notice her standing there.* Then Sally returns, and the child is asked: *"Where does Anne think that Sally will look for her marble?"*

Again the correct answer is clear: Anne expects Sally to look in the basket, as that is where Sally left it and Anne has no idea that Sally saw it being moved. But typically developing children only demonstrate mastery of the task when they are six years old; before this age they will generally say that Anne expects Sally to look in the box. But this is wrong – the marble is indeed in the box, and indeed Sally knows this, Anne knows this, and the child knows this too! Thus, the zero- and first-order developments are in place here. But – crucially – Sally does *not* know that Anne knows this, and hence the second-order answer is incorrect. Once again, the ability to determine the correct answer relies on skills that need to be developed, and several theories exist regarding what skills exactly a child needs to develop (Miller 2012). As stated earlier, experimental evidence clearly indicates that typically developing children start giving correct answers to the SO FB tasks about two years after they acquire their first-order skills (Miller 2009). Children with ASD acquire them even later, but here the conclusions are not so clear: some findings suggest that they are impaired relative to typically developing children (Brent et al. 2004), others suggest that success largely depends on general cognitive abilities (Bauminger and Kasari 1999), while some show that children with ASD only differ in their ability to justify their answers (Bowler 1992).

The important thing we can say about SO FB mastery is that it marks the stage where the child has grasped the fact that we can have *beliefs about beliefs*. The content of a belief may be about another belief - beliefs do not have to be about concrete facts concerning the real world; in fact, beliefs can be recursive. In fact, the propositional nature of beliefs allows them to enter into recursive chains of potentially any length: many agents and many mental beliefs embedded inside one another.[2]

6. Linguistic recursion

We have just seen that beliefs can have a recursive structure. As linguists have demonstrated, most if not all natural languages exhibit recursion (though Pirahã may be an exception (Everett 2005)) and indeed recursion is sometimes taken to be the property of human languages that renders them unique (Hauser et al. 2002). As for our experimental work, linguistic recursion lies at its heart. By linguistic recursion we simply mean the standard definition: the embedding of a constituent inside a constituent of the same category (Pinker and Jackendoff 2005). We make use of two common recursive forms: possessive NPs and sentential complements. Here are some examples of the first form we shall use, recursive possessive NPs:

John's car (non-recursive)
John's friends's car (one level of linguistic recursion)
John's friend's sister's car (two levels of linguistic recursion)

---

[2] Thus although in this paper we are dealing with SO FB, the fact that recursion has entered the picture means that we are touching on the more general issue of higher-order beliefs more generally (that is: beliefs about beliefs, beliefs about beliefs about beliefs, beliefs about beliefs about beliefs about beliefs, and so on). Social cognition can be regarded as higher-order reasoning that involves the recursive interaction of various components including beliefs, and also desires, intentions, and much else besides.

John's friend's sister's cousin's car (three levels of linguistic recursion)

Here are examples of the second form, recursive sentential complements:

*John thinks the car is cool (*non-recursive)
Mary says that John thinks that the car is cool (one level of linguistic recursion)
Susan hopes that Mary says that John thinks that the car is cool (two levels of linguistic recursion)

We have just started a randomized controlled study to investigate the potential importance of linguistic recursion, and our central research question is: does competency in linguistic recursion (and in particular: embedded possessives and sentential complements) predict the second-order false belief reasoning ability of children with ASD?

Now, in order to clarify in what respect linguistic recursion need play a role in second-order false beliefs, we need to return to the question of syntax and semantics that we raised when discussing FO FB. As we shall see, matters are different in SO FB, for we move to the realm of compositional semantics. That is, we are concerned with the syntax-semantics interface.

7. Compositional semantics

When we discussed syntax and semantics in connection with FOFB tasks, semantics meant lexical semantics, and in particular the acquisition of mental state vocabulary. But when we talk about constructs such as possessive NPs and sentential complements, we are dealing with what is often called compositional semantics (Szabó 2009). That is, we are concerned with how the meaning of a whole is built out of the meaning of its parts. This type of semantics has been explored extensively in linguistics ever since the pioneering work of Richard Montague (Janssen 2011) in the early 1970s. The core idea is that syntactic structure guides the process of semantic construction: syntactic structure provides the ‘frame’ and the semantics of the top level constituent is built up by combining the meanings of its various components using the pattern provided by the syntactic frame. Such analyses have the merit of providing a clear account of how the meanings of recursively constructed constituents are formed, as the following example will make it clear. Consider the sentence: “Susan hopes that Mary says that John thinks that the car is cool”.

How is its meaning formed? Well, the innermost sentence, “the car is cool” has a meaning (whatever that may be). But then the meaning of the sentence one level up, “John thinks that the car is cool”, arises by combining the meaning of “John thinks” with this initial meaning. But this meaning in turn can be combined with this meaning of “Mary says that” to provide the meaning of “Mary says that John thinks that the car is cool”. Finally, this meaning is combined with the meaning of “Susan hopes” to form the meaning of the top level sentence.

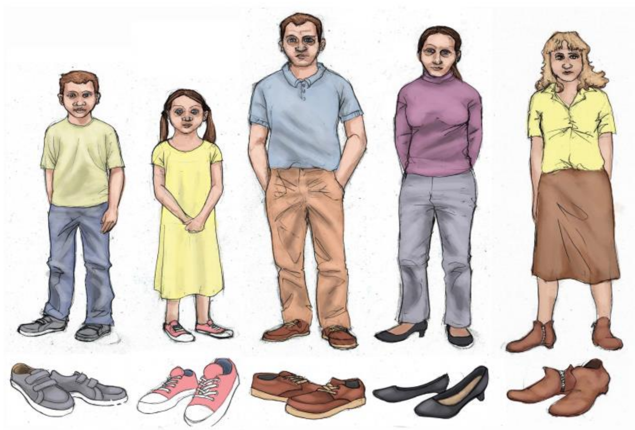
To put it another way, our example sentence has the following (course grained) syntactic structure:

(*Susan hopes that* (*Mary says that* (*John thinks that* (*the car is cool*)))).

The brackets show the relevant syntactic structure – and the meaning of the whole sentence is formed out of the meaning of its parts in the uniform way just described: at every level we combine the semantics of various complementizers (ending in “that”) with the meaning already formed. This is a process that can be iterated indefinitely – that is, it supports the recursive formation of meaning.

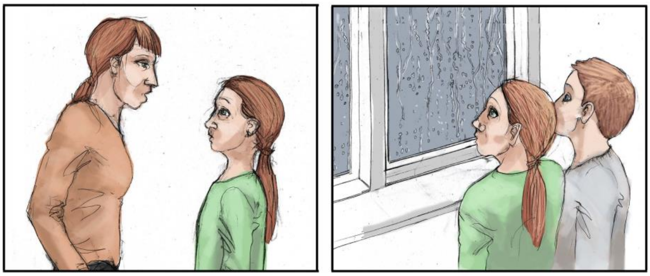
Summing up: compositional semantics does not deal with the meaning of individual words – these are usually assumed to be given. Rather, it is concerned with how to form new meanings out of old ones in a way that mirrors syntactic structure. For this reason, compositional semantics is often said to be dealing with the syntax-semantics interface. And it is because of the compositional semantics of recursive structures that we believe them to be correlated with second-order false belief skills. As we have seen, beliefs can have a recursive structure, as beliefs can be about other beliefs, and so on *ad-infinitum*. But language provides us with the recursive structure suitable for describing recursive beliefs (namely, recursive sentential complementation) and compositionality provides us with a tool for processing them.

Naturally, much has to be learned in the process of acquiring recursive compositional competency. To give an example that plays a role in our experimental work: word order matters (at least in languages like English and Danish where word order is responsible for determining grammatical roles). Consider the following picture and its accompanying text: the recursive possessive NP "Sister's dad's shoes" will pick out different shoes than "Dad's sister's shoes" does. The two NPs have different meanings, and the child must eventually grasp the linguistic regularity that governs this behaviour.



This is Tobias, this is Tobias' sister, this is dad, this is dad's sister and this is mom. And these are their shoes. Tobias would like to play with dad's sister's shoes. Will you show me which shoes Tobias would like to play with? (Tranlation from the Danish original.)

Or consider the following picture, and its text which makes use of sentences with multiple embedded complements; this illustrates more of what the child must learn:



Lilja is talking to her mom in the kitchen. Mom says: "The sun is shining outside. Go get your brother from his room and let's go out and enjoy the sun". Lilja goes to her brother's room and they are looking out of the window. It is raining outside. Lilja tells brother that mother says that the sun is shining outside. What does mom say? What does Lilja say to her brother? (Translation from the Danish original.)

What does Lilja say to her brother? The answer we are looking for is (some variant of) "Lilja says that mother says that the sun is shining". Now first note that, as in the previous example, word-order matters: answering "Mother says that Lilja says that the sun is shining outside" would simply be incorrect. But also note that omitting one level of embedding by answering "Lilja says that the sun is shining outside" would also make the answer incorrect (which is signaled by the fact that Lilja is looking at rain). Getting the child to grasp the subtle interplay of syntax (such as word-order and level of embedding) and semantic (such as truth value contrasts) illustrated by such examples lies at the heart of our testing and training program.

But before we start discussing our testing and training in more detail, we must address one last issue: why we believe that such matters may be of particular relevance to children with ASD.

8. Syntactic scaffolding and ASD

We are in the process of recruiting children with ASD for our study, and in what follows we will explain why. Even though research has firmly and consistently established that children with ASD do not pass FB tasks at the same age as typically developing children do (at a statistically significant level) there is a fact that must not be ignored: some children with ASD *do* pass FB tasks. Indeed, in the seminal study by Baron-Cohen et al. (1985), which was an inspiration for much later research, 20 per cent of them did so. The standard explanation offered is that since children with ASD do not have full access to typical ways of understanding others' mental states, they must use some compensatory technique, a mechanism of some other kind. And language seems to be one such mechanism. In other words, for typically developing children it is generally assumed that a shift to a representational ToM underlies success on FB tasks. But for children with ASD, on the other hand, it has been postulated that successful performance is not underpinned by such a conceptual change, but rather by compensatory mechanisms, of which language seems to be a primary example.

There are several theories about how this might work. Some studies say that children with ASD use language to "hack out" the solutions to FB tasks (Bowler 2009), and other studies say that they use language as a "scaffold" in developing the capacity to understand mental states (Tager-Flusberg and Joseph 2005).

However previous discussions of this topic have been restricted to FO FB understanding; we believe they are even more important in the SO case. As we have discussed, SO FB reasoning is intrinsically recursive: it deals with beliefs about beliefs. But in many languages beliefs about beliefs are encoded using recursive sentential complementation (Father believes that mother believes that the sun is shining outside). Thus linguistic recursion seems to be a plausible compensatory mechanism for SO FB reasoning for children with ASD.

9. Empirical part of the study

We are now ready to discuss our testing and training program. This has two main aims:

- The first aim is to investigate whether there is correlation between mastering second-order (SO) false-belief (FB) and mastering recursive embeddings.
- The second aim is to test the efficacy of our linguistic recursion training and provide experimental evidence for the role of recursion mastery in the development of SO FB understanding.

In what follows we discuss in some detail the testing and training regime we have devised to investigate these two aims. We will also briefly discuss how we handle the control group, and about our investigation of a rival *non-linguistic* explanation for success in SO FB tasks, namely that success is due to better executive functioning.

9.1. Participants

All the participants in our study are recruited from schools for children with special educational needs in the Zealand region in Denmark. They have to satisfy the following criteria in order to be initially included in the study: parental consent must be obtained, they must be diagnosed with ASD (based on a formal evaluation by a specialist), they must be aged 7-15, and they must have no medical treatment affecting cognitive performance. Moreover, they must have Danish as their native language, be monolingual, have no learning difficulties or language delays (initially based on a teacher's assessment) and have the emotional readiness to undergo a testing situation and a training program (again, based on a teacher's assessment). Our goal for the correlation part of the study is to recruit a minimum of 60 children. As for the training part, as reported in Cappadocia and Weiss (2011), the minimum sample size to demonstrate the pre-post outcome is 18 participants for each group. We aim to recruit three groups: for linguistic recursion training, a control group, and a group for working memory training.

9.2. Design

In order to accomplish the aims, our research design has three testing stages: (1) pre-training testing, (2) training and (3) post-training testing.

At the first stage (pre-training testing), children are given Working Memory (WM) and Verbal Comprehension (VC) tasks from WISC-IV as well as a receptive grammar test (TROG-2). The results of these three tests serve as quantitative inclusion criteria: we only select children with an IQ higher than 80 and language skills within the age norms stated in the manual. Children who have met the above-mentioned criteria will be included in the correlation part of the study, and the remaining tests of this stage measure the cognitive and language baseline abilities in question, namely SO FB reasoning and linguistic recursion. Teachers are asked to complete a Social Responsiveness Scale questionnaire, which is a valid quantitative measure of autistic traits, developed by Constantino et al. (2003) and feasible for use in research studies of autism spectrum conditions.

Participants who do not perform SO FB tasks at ceiling are included in the second stage: training. More specifically, a child has to gain a maximum of 9 points out of the 18 possible in the SO FB tasks. Furthermore, they have to *fail* at least 50 per cent of both Sally-Anne style test questions (Where does protagonist 1 think protagonist 2 will look for her ball?) and justification questions (Why does she think that?).

At the training stage, children are randomly assigned to the linguistic recursion training and interaction-only (control) conditions. Initially, we will only randomly assign between these two conditions. This is because recruiting 54 suitable participants for the training is an ambitious task, and our first priority is to test and train linguistic recursion. Thus only once we have recruited sufficient children for these two conditions, will we start randomly assigning to the working memory condition.

Not later than 3 days after completing the training, all the participants will be given SO FB tests and linguistic recursion tasks. SO FB tasks at the post-training stage have exactly the same logical structure and level of complexity as those at the pre-training stage. A comparison of the difference in the pre- and post-training scores in both training and control groups indicates the significance of training effect. Approximately 6 months later, children will be given follow-up second-order false-belief tests in order to determine if the effects of intervention hold up over time.

The pre-training, training and post-training stages are covered by nine or ten sessions, each lasting between 30-45 minutes. Each child is tested individually by a trained psychologist in a reasonably comfortable room away from the classroom. The sessions are recorded and scoring is carried out at a later time.

10. Linguistic recursion training

For our study, we have devised the Linguistics Recursions Training (LRT) program from scratch.

When devising the LRT program, we adopted the developmental pragmatic approach, which is one of the methods applied in work with children with ASD (Brynskov 2014). The essence of the method is to establish good dialogical contact so that the child's engagement is supported and strengthened by concrete and meaningful praising; this gives the child the feeling that she can communicate and initiate something in the unusual (and potentially intimidating) setting of an experiment.

Furthermore, in the LRT program, we address the learning style, emotion regulation and cognitive characteristics of children with ASD whenever possible. This means, for example, developing a visual teaching style in order to increase understanding and predictability and to reduce anxiety. In general, visual support is highly recommended when working with ASD children (Rao and Gagie 2006). Visual based techniques, supported by interactive dialogue, supports the recall of information and sequences of information and thus leads to better learning. The communication style developed in the interaction is functional – *useful and helpful* – so that children do not need to use non-verbal behaviour to express what they need. The language used is therefore very direct and clear, and the use of metaphors is avoided. For example, each day begins with the child and the psychologist reading a card with things to be learnt that day, and at the end of each day the child reads the same card again. Each new session began with reading the card from the previous day and a new card for the new day. As another example: during the sessions, a red card is placed very visibly so that a child can point at it if she needs a break (requesting a break verbally may be difficult for some participants). To date very few participants have used the red card, but it has proved useful for those who did.

As for the content: in essence, our training of children with ASD amounts to training them in recursive compositional semantics – in getting them to appreciate the expressive nuances provided by the syntax-semantics interface. More precisely, our training attempts to understand the following four principles, each of which works as a guideline for a day in the training program:

1. That several linguistic constituents of the same type may be combined together.
2. That these constituents may be embedded one inside another.
3. That changing the order of embedding changes the meaning.
4. That the number of embedded constituents is potentially unlimited.

Our training material makes heavy use of drawing, illustrations, small puzzles and stories, all designed to make children talk, think and internalize these four principles via multiple examples of recursive possessive noun phrases and sentential complements. Pictures of familiar characters (for example, Harry Potter) and pictures from well-known books and magazines are used; and one of the most common tasks for the children is to produce sentences that would describe the pictures and illustrate the rules they have learnt. On the fifth day children have to repeat and rehearse all four rules.

11. Interaction-only condition

The interaction-only program was designed to function as a control condition for the LRT. Hence, it mirrors the LRT program in terms of materials and length, but excludes the training component and the mention of the embedding procedure. The central differences between LRT and IOC consist of the following:

– The four rules are not discussed explicitly, and no exercises reflect the third rule about changing the order.

– The number of embedded constitutes does not exceed two (so we would use "girl's dog", but never "girl's dog's tail").

– Even when embedding one constitute into another, the child is not asked to support it visually. That is, she does not have to place relevant cards next to each other, which is the case in the LRT.

– The word "embedding" (in Danish: *at putteind, at indsætte, at indlejre*) is never used in the interaction with the child, while it is regularly and heavily applied in the LRT.

12. Working memory condition

The LRT condition is designed to test the hypothesis that linguistic recursion is a useful compensatory method (a "scaffold" or "hack") that some children with ASD can use (and may be trained to use) to acquire SO FB competency. But linguistic competency is not the only factor to affect the acquisition of ToM: several studies have shown the central role of executive functions,[3] and working memory has been reported to predict TOM abilities in typically developing children (Carlson et al. 2002, Arslan et al. 2015) as well as children with ASD (Pellicano 2007). Thus it seems important to test and train for ability in working memory. We hope to enroll sufficient participants to have a third group training their working memory ability, so that we can assess the relative impact of both linguistic and non-linguistic factors. As we have already mentioned, we will only start randomly assigning participants to this third group once we have enough participants (roughly 18) assigned to the LRT and control groups.

As for the content of the WM condition: The training program consists of three computer-based games. In the first game children train verbal working memory and word recognition skills; in the second – visual-spatial working memory, and in the third game working memory and math skills are trained. Children train working memory skills for the same period of time as in the other two conditions.

13. Concluding remarks

In this paper, we have described some of the theoretical background which has led to our ongoing training study of children with ASD, as well as sketched out our testing and training program.

We started from three well-known results: that acquisition of ToM is something that happens in stages, that typically developing children and children with ASD acquire ToM differently, and that skills with language are relevant to the acquisition of ToM. But whereas typically developing children seem to develop their ToM skills at least in part by learning the meaning of mental state words by using them in rich everyday con-

[3] Executive functions is an umbrella term for a set of cognitive processes necessary for the cognitive control of behavior and reasoning. Research on ToM usually covers executive functions such as inhibitory control, planning, set-shifting, cognitive flexibility, and working memory.

texts, it is unclear to what extent such a path is available to children with ASD.

In our discussion of the relevance of language to SO FB we emphasized the importance of the syntax-semantics interface, and in particular, compositional semantics. We put forward the following question: Could an "artificial path" towards ToM be provided by linguistic recursion? In particular, could training in recursive NPs and sentential complements improve the acquisition of second-order false belief competence for children with ASD? Our training program is essentially an attempt to explore this hypothesis. The experiment is presently in its preliminary stages so we have no results to report as yet – but the line of reasoning which has guided our experimental design should now be clear, as should our interest in testing the impact of non-linguistic factors such as working memory competence.

To close the paper, we briefly mention another line of work which has contributed to our formulation of this hypothesis. In other work we have analyzed the type of logical reasoning used in second-order false belief tasks (Braüneretal. 2016a, Braüneret al. 2016b). Our logical analyses clearly highlights the importance of recursion – it shows that second-order reasoning can be viewed as the recursive embedding of first-order reasoning about different agents. It is a clear and logically natural model, and suggested to us that recursion was important in the analysis of SOFB tasks. This played an important role in our decision to investigate the impact of training in linguistic recursion on success in SOFB tasks. However our logical analysis is not directly linked to the sort of linguistic considerations discussed in this paper. Furthermore, as recursive logics of belief are more complex than those required to analyze FO FB tasks, it leaves open the possibility that processing issues (such as working memory) are also relevant and thus should be experimentally investigated.

The authors acknowledge funding received from the VELUX FOUNDATION for the project *Hybrid-Logical Proofs at Work in Cognitive Psychology* (VELUX 33305).

References

Aksu-Koç, A., G. Avci, C. Aydin, N. Sefer, Y. Yasa (2005). "The relation between mental verbs and theory of mind performance: Evidence from Turkish children". International Association for the Study of Child Language Convention, Berlin, July 2005.

Arslan, B., S. Wierda, N. Taatgen, R. Verbrugge (2015). "The role of simple and complex working memory strategies in the development of first-order false belief reasoning: A computational model of transfer of skills". *Proceedings of the 13th International Conference on Cognitive Modeling*, 100-105.

Astington, Janet Wilde, Jodie A. Baird (2005). "Why language matters for theory of mind". In: Janet Astington, Jodie A. Baird (eds.). *Why Language Matters for Theory of Mind.* Oxford: Oxford University Press, 3-25.

Baron-Cohen, Simon, Alan M. Leslie, Uta Frith (1985). "Does the autistic child have a 'theory of mind'?" *Cognition* 21/1: 37-46.

Bauminger, Nirit, Connie Kasari (1999). "Brief report: Theory of mind in high-functioning children with autism". *Journal of Autism and Developmental Disorders* 29/1: 81-86.

Bowler, Dermot M. (1992). "'Theory of Mind' in Asperger's Syndrome Dermot M. Bowler". *Journal of Child Psychology and Psychiatry* 33/5: 877-893.

Braüner, Torben, Patrick Rowan Blackburn, Irina Polyanskaya (2016). "Recursive belief manipulation and second-order false-beliefs". In: *Proceedings of the 38th Annual Meeting of the Cognitive Science Society, Philadelphia, Pennsylvania, USA*. Cognitive Science Society, Inc.

Braüner, Torben, Patrick Rowan Blackburn, Irina Polyanskaya (2016). "Second-order false-belief tasks: Analysis and formalization". In: Jouko Väänänen, Åsa Hirvonen, Ruy de Queiroz (eds.). *Lecture Notes in Computer Science* 9803: 125-144.

Brent, Ella, et al. (2004). "Performance of children with autism spectrum disorder on advanced theory of mind tasks". *Autism* 8/3: 283-299.

Brynskov, Cecilia (2014). "Intervention rettet mod sproget hos børn med autisme". *Logos: Audiologopædisk Tidsskrift* 72: 15-17.

Cappadocia, M. Catherine, Jonathan A. Weiss (2011). "Review of social skills training groups for youth with Asperger syndrome and high functioning autism". *Research in Autism Spectrum Disorders* 5/1: 70-78.

Carlson, Stephanie M., Louis J. Moses, Casey Breton (2002). "How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory". *Infant and Child Development* 11/2: 73-92.

Constantino, John N., et al. (2003). "Validation of a brief quantitative measure of autistic traits: comparison of the social responsiveness scale with the autism diagnostic interview-revised". *Journal of Autism and Developmental Disorders* 33/4: 427-433.

de Villiers, Jill G. (2005). "Can language acquisition give children a point of view." In: Janet Astington, Jodie A. Baird (eds.). *Why Language Matters for Theory of Mind.* Oxford: Oxford University Press, 186-219.

de Villiers, Jill G. (2007). "The interface of language and Theory of Mind". *Lingua* 117:1858–1878.

de Villiers, Jill G., et al. (2007). "Preliminary studies of acquisition of Tibetan evidentials". Symposium paper, SRCD Convention, Boston.

de Villiers, Jill G., Peter A. de Villiers (2000). "Linguistic determinism and the understanding of false". In: P. Mitchell, K. Riggs (eds.). *Children's Reasoning and the Mind.* Hove: Psychology Press, 191-228.

de Villiers, Jill G., Jennie E. Pyers (2002). "Complements to cognition: A longitudinal study of the relationship between complex syntax and false-belief-understanding". *Cognitive Development* 17/1: 1037-1060.

Dennett, Daniel C. (1978). "Beliefs about beliefs". *Behavioral and Brain Sciences* 1/04: 568-570.

Doherty, Martin (2008).*Theory of Mind: How Children Understand Others' Thoughts and Feelings*. Hove, UK: Psychology Press.

Everett, Daniel (2005). "Cultural constraints on grammar and cognition in Pirahã: Another look at the design features of human language". *Current Anthropology* 46: 621–46.

Farrar, M. Jeffrey, Lisa Maag (2002). "Early language development and the emergence of a theory of mind". *First Language* 22/2: 197-213.

Guajardo, Nicole R., Anne C. Watson (2002). "Narrative discourse and theory of mind development". *The Journal of Genetic Psychology* 163/3: 305-325.

Hale, Courtney Melinda, Helen Tager-Flusberg (2003). "The influence of language on theory of mind: A training study". *Developmental science* 6/3: 346-359.

Happé, Francesca G. E. (1995). "The role of age and verbal ability in the theory of mind task performance of subjects with autism". *Child Development* 66/3: 843-855.

Hauser, Marc D., Noam Chomsky, W. Tecumseh Fitch (2002). "The faculty of language: What is it, who has it, and how did it evolve?" *Science* 298/5598: 1569-1579.

Janssen, Theo (2011). "Montague semantics". In: Edward N. Zalta (ed.). *Stanford Encyclopedia of Philosophy*. Spring 2017 Edition. Available at <https://plato.stanford.edu/archives/spr2017/entries/montague-semantics/>.

Lind, Sophie E., Dermot M. Bowler (2009). "Language and theory of mind in autism spectrum disorder: The relationship between complement syntax and false belief task performance". *Journal of Autism and Developmental Disorders* 39/6: 929-937.

Lohmann, Heidemarie, Michael Tomasello (2003). "The role of language in the development of false belief understanding: A training study". *Child Development* 74/4: 1130-1144.

Miller, Carol A. (2006). "Developmental relationships between language and theory of mind". *American Journal of Speech-Language Pathology* 15/2: 142-154.

Miller, Scott A. (2009). "Children's understanding of second-order mental states". *Psychological Bulletin* 135/5: 749.

Miller, Scott A. (2012). *Theory of Mind: Beyond the Preschool Years*. Hove, UK: Psychology Press.

Milligan, Karen, Janet Wilde Astington, Lisa Ain Dack (2007). "Language and theory of mind: Meta-analysis of the relation between language ability and false-belief understanding". *Child Development* 78/2: 622-646.

Nelson, Katherine (2005). "Language pathways into the community of minds." In: Janet Astington, Jodie A. Baird (eds.). *Why Language Matters for Theory of Mind.* Oxford: Oxford University Press, 26-49.

Pellicano, Elizabeth (2007). "Links between theory of mind and executive function in young children with autism: Clues to developmental primacy". *Developmental Psychology* 43/4: 974.

Perner, Josef, et al. (2003). "Want that is understood well before say that, think that, and false belief: A test of de Villiers's linguistic determinism on German–speaking children". *Child Development* 74/1: 179-188.

Peskin, Joan, Janet Wilde Astington (2004). "The effects of adding metacognitive language to story texts". *Cognitive Development* 19/2: 253-273.

Peterson, Candida C., Henry M. Wellman, David Liu (2005). "Steps in Theory-of-Mind development for children with deafness or autism". *Child Development* 76/2: 502-517.

Pinker, Steven, Ray Jackendoff (2005). "The faculty of language: What's special about it?" *Cognition* 95/2: 201-236.

Premack, David, Guy Woodruff (1978). "Does the chimpanzee have a theory of mind?" *Behavioral and Brain Sciences* 1/04: 515-526.

Rao, Shaila M., Brenda Gagie (2006). "Learning through seeing and doing: Visual supports for children with autism". *Teaching Exceptional Children* 38/6: 26.

Schick, Brenda, et al. (2007). „Language and theory of mind: A study of deaf children". *Child Development* 78/2: 376-396.

Szabó, Zoltán Gendler (2009). "Compositionality." *Stanford Encyclopedia of Philosophy*. February 2014 Edition. Available at <https://stanford.library.sydney.edu.au/archives/sum2010/entries/compositionality/>.

Tager-Flusberg, Helen, Robert M. Joseph (2005). "How language facilitates the acquisition of false-belief understanding in children with autism". In: Janet Astington, Jodie A. Baird (eds.). *Why Language Matters for Theory of Mind.* Oxford: Oxford University Press, 298-318.

Tager-Flusberg, Helen (2007). "Evaluating the theory-of-mind hypothesis of autism". *Current Directions in Psychological Science* 16/6: 311-315.

Wellman, Henry M., David Cross, Julianne Watson (2001). "Meta-analysis of theory-of-mind development: The truth about false belief". *Child Development* 72/3: 655-684.

Irina Polyanskaya
Roskilde University
Department of People and Technology
Universitetsvej 1
4000 Roskilde
Denmark
irinap@ruc.dk

Patrick Blackburn
Roskilde University
Department of Communication and Arts
Universitetsvej 1
4000 Roskilde
Denmark
patrickb@ruc.dk

Torben Braüner
Roskilde University
Department of People and Technology
Universitetsvej 1
4000 Roskilde
Denmark
torben@ruc.dk