Is PP Opacity on the Path to False Belief?

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1. Introduction

Children exhibit notorious difficulty understanding and using propositional attitude verbs, such as *believe* or *think* (cf. de Villiers 1995, Papafragou *et al.* 2007 and references therein). The delayed acquisition of such mental verbs has been shown to correlate with children's delayed mastery of a theory of mind (ToM), i.e., the ability to carry out reasoning in attributing False Belief to others.[1] Children fail ToM reasoning tasks at age 3 and succeed around age 4, crucially around the time when they master attitude verbs. Jill de Villiers and colleagues (e.g., de Villiers 1995, de Villiers and de Villiers 2000) have argued that this correlation is, in fact, a causal connection, with full mastery of ToM tasks being contingent on full mastery of sentence complementation: "The child needs the full syntax of mental verbs plus sentential complements in order to *represent* in his own mind the belief states of other people, not simply to *encode* them for reporting about them in speech" (de Villiers and Pyers 1997). However, when compared to other verbs, mental verbs have not only complex syntactic properties, but conceptually difficult semantic properties involved in the attribution of belief to others (i.e., modeling the belief state of the subject, e.g., as a set of possible worlds). Do children acquire both kinds of properties at the same time, or is the acquisition timeline more complex? Could it be that young children grasp the belief attribution component of a verb like *think* (i.e., are able to model a belief state) without fully mastering sentence complementation?

This study aims at teasing apart two factors involved in the mastery of attitude verbs, namely, syntactic complexity (sentential complementation and recursion) on the one hand, and conceptual difficulty in attributing (different) beliefs to other minds, on the other. To do so, we contrast sentences involving attitude verbs and sentences modified by Prepositional Phrases such as '*According to John*', which, we argue, are syntactically simpler (i.e., they lack the recursion property of attitude verbs). We show that children perform better on the latter category, suggesting that children may acquire the ability to attribute beliefs to other minds *prior* to fully mastering attitude verbs, and that the final stumbling block in the acquisition of attitude verbs is syntactic in essence.

Semantically, attitude verbs relate a proposition (expressed by its complement clause) to the mental state of an individual (the subject). For instance, (1) attributes to John the belief that the apple is in the box, without committing the speaker to the truth or falsity of the proposition expressed by the complement clause. Thus, (1) can be uttered truthfully in contexts where the apple is not in the box, so long as John believes that it is:

(1) John thinks that the apple is in the box.

Three-year-olds, however, seem unable to comprehend sentences like (1) in contexts where they know that the apple is not in the box, regardless of what John thinks. Evaluating the truth of a sentence like (1) is taxing in several respects, and children's difficulty could in principle be due to several linguistic and non-linguistic factors. One such factor could be memory load: there are two

[1] As distinct from implicit forms of False Belief. (See Sowalsky 2008 for evidence that children comprehend but cannot discuss False Belief, Roeper 2007, Ruffman *et al.* 2001, among others.)

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sentences that children need to keep track of and hold in memory for the computation of truth conditions: the one expressing a belief attribution and the one expressed by the complement clause. Another is the lack of direct observability: one cannot 'see' *thinking*. Finally, the syntax and semantics of the attitude verb itself is more complex than that of a regular verb: sentences with attitude verbs require a complex syntactic structure which involves embedding a proposition, and are conceptually difficult, as their role is to attribute to another mind beliefs possibly different from one's own. Once we control for non linguistic factors such as direct observability and memory load, do children still exhibit difficulties, and if so, is the difficulty children have with sentences like (1) due to (i) syntactic limitations in grasping sentential complementation or (ii) conceptual difficulty in attributing beliefs to others, or both?

Production data indicate that children's first uses of attitudes are as parentheticals/modifiers (Diessel 2005), suggesting that they might acquire part of their meaning (as belief attributors) before they master their subcategorization properties. This study asks whether this partial knowledge of attitude verbs can be found in comprehension as well: what is the timeline of the acquisition of the various syntactic and semantic components of attitude verbs?

Specifically, we aim at teasing apart syntactic complexity, and in particular sentence complementation, from the conceptual difficulty of belief attribution, by contrasting sentences involving attitude verbs with sentences modified by prepositional phrases (PP) such as '*According to John*' or even cases like '*To John*'. Such PPs allow us to express the same belief attribution as attitudes like *think*, but via a (we assume) syntactically simpler structure:

(2) According to John, the apple is in the box.

We suggest that the main problem children have with sentential complements is recursion, a factor that differentiates attitude verbs from PPs such as *'According to John*'. While attitude verbs can easily be used recursively, PP adjuncts cannot (at least in English):

(3) John thinks that Paul thinks that Bill is happy.
(4) ??According to John, according to Paul, Bill is happy.

We hypothesize that mastery of sentential complementation requires full grasp of the recursive properties of verbs like *think*, which PPs, such as *according to X*, lack. Stated differently, adjunction is inherently non-recursive with respect to the node it attaches to. Thus, if sentential complementation is at the source of children's difficulty with attitudes, we predict that, once memory load and lack of direct observability issues are controlled for, children should perform better on sentences like (2) vs. (1)[2].

2. Materials and Methods

In a Truth Value Judgment Task, we compared children's comprehension of opaque utterances prefaced with *according to X* and those attributing belief with *X thinks that.* The experimenter showed pictures and read stories to the child and to a puppet (Elmo). The child was instructed to make sure that the puppet was following along, and correctly reporting the story. After each story, the puppet uttered two target sentences using either *according to* or *think that*. The child was asked to reward the puppet if the sentence was true or give him a consolation price if it was false. To minimize memory load and provide direct observability, we used pictures of characters and of their beliefs as depicted by thought bubbles. A sample story is presented in section 2.2.2.

[2] A reviewer points out that 'according to' can also report a speech rather than a belief attribution. This could provide an unfair advantage, since children acquire verbs of speech before mental verbs. In future research, we could add an 'X said that' condition. In the interim, note that 3 year olds are reported to still have difficulty with verbs of communication (cf. de Villiers and Pyers 1997) and quotation in particular.

2.1. Subjects

Thirty-eight children participated in the study. Participants ranged in age from 2;10 to 5;11 (median 3;9; mean 4;0). All of the children were reported by their parents to be monolingual speakers of English, and none of the children's parents reported any diagnosed speech or language disorders. The children were attending preschool in Amherst or Northampton, Massachusetts. Eight children were excluded from the sample either because they were bilingual speakers of languages other than English (N=6) or because they were identified later as having a language delay or disability (N=2).

A group of 12 adult controls were also tested. This group consisted of undergraduate psychology students at the University of Massachusetts Amherst who were monolingual speakers of English. None of those tested were familiar with the hypothesis being tested before their participation. The procedures followed were identical in all relevant respects to those followed in testing the children. Each participant received 2 extra credit points toward a psychology course in exchange for their participation in this study.

2.2. Materials and Procedures

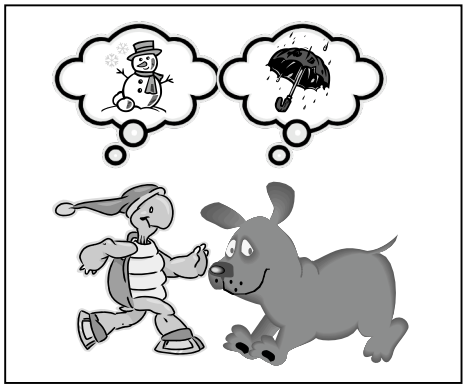
2.2.1. Pretest

Before beginning the experiments, the experimenter engaged the child in loosely structured conversation. During this time she explained the procedures and encouraged the child to ask questions and make comments throughout the session. She also reviewed the names of characters in the stories and presented the thought-bubble training item. At this time, a pretest was given. The pretest involved a thought-bubble test item (see Appendix), modeled after a procedure for teaching children to identify belief-based stories (Howlin *et al.* 1999) and a truth value judgment test item, which did not involve an attitude verb or a PP. The thought bubble test item ensured that all participants knew to associate the contents of a thought bubble with the thoughts of the character below it. All of the children who participated in the study could correctly name and discriminate between the characters referred to in the experiments. Only children who completed both tasks in the pretest satisfactorily were included in the sample.

2.2.2. Materials

Following each participant's successful completion of the pretest, the experiment started. The experiment consisted of eight stories, where participants were presented with a picture of one or two characters with thought bubbles above their heads. The experimenter told a story describing each picture and then the participants made their truth value judgments based on a puppet's retelling of part of the story. The following sample story illustrates this.

Figure 1: Sample item without reality



(5) Experimenter: This is Turtle. This is Puppy. Turtle and Puppy sit in the playroom with no windows and they talk about the weather. Turtle says, "I bet there's snow outside. I want to make a snowman. Puppy says, "No way. I bet it is just raining. You can't make a snowman out of rain."

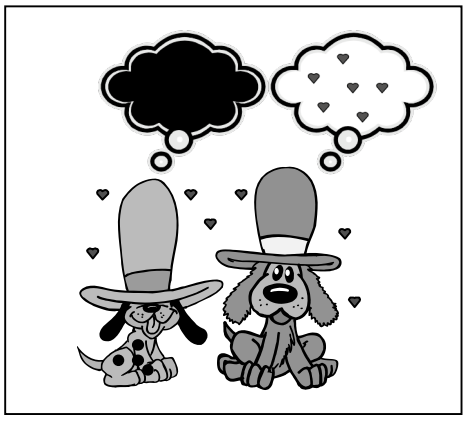
After the story, the puppet, when prompted, uttered the following two target sentences:

(6) According to Turtle, it is snowing outside.
(7) Puppy thinks that it is raining outside.

We predicted that subjects would do better on sentences like (6) than (7); that is, they would correctly judge the sentence to be true when true, and false when false. The target sentences were balanced for truth.

Note that in the above story, the child has no independent knowledge about whether it is in fact raining or snowing outside, i.e., the story lacks a *reality* backdrop. This was done to simplify the child's task: the child could not evaluate the truth of the embedded sentence against his on knowledge, and only had to map a thought to an individual. The task, then, was simpler than a false belief task, as it simply involved a belief attribution. Six of our stories followed this template. Two others provided a 'reality' background, so that one of the characters was right, and the other was wrong. One such story is presented below

Figure 2: Sample item with reality



(8) Experimenter: This is Spot. This is Bruno. Spot and Bruno try on hats in the costume room. There are blue hearts on the walls in the costume room. Spot's hat covers his eyes and everything looks dark. When Spot looks at the walls even the walls look black. Bruno's hat fits just right and he can see. So when Bruno looks at the wall he sees the blue hearts on the wallpaper.

To make sure the child was aware of the presence of reality, the puppet uttered the following sentence, prior to the target sentences:

(9) Experimenter: OK Elmo, do you get the picture so far?
Elmo: Yes this is a going to be a story about Bruno and Spot.
There *are* blue hearts on the walls in the costume room.

Target sentences: **Spot *thinks* that it is dark in the costume room.**
***According to* Bruno, it is dark in the costume room.**

We predicted that children would do worst on the stories with a reality background than for those without. The remaining six stories are provided in the Appendix.

3. Results

Data analysis was conducted using logistic linear mixed effect models, in order to accurately account for the binary response data (Jaeger 2008; Baayen 2008). Mixed-effects modeling yielded three main effects: (i) **Age**, with older children doing significantly better than younger children; (ii) **Syntax** (*think that* vs. *according to*), with children performing significantly better on the *according to* sentences; and (iii) **Presence of reality**, with children performing significantly worst when the stories depicted reality in the background. The details of the results are reported below. Model comparison proceeded by iteratively removing non-significant factors from a fully specified model with all possible interactions. The resultant best-fit model, log odds, and their *p*-values are summarized below in Table 1.

Table 1: Summary of the data analysis

Factor	**Estimated Log Odds**	***p***
Age: *from age 2-3 to age 4*	3.22	< .00001
Age: *from age 4 to age 5*	4.26	< .00001
Syntax: *according to*	4.7	< .00001
Reality: *Absent*	2.01	< .00001

The above estimated log odds can be interpreted as follows: (i) being in the age 4 group makes a subject more than 3 times as likely to get a correct answer than being in the age 2-3 group; (ii) being in the age 5 group makes a subject more than 4 times as likely to get a correct answer than being in the age 4 group; (iii) an *according to* sentence makes it almost 5 times more likely to yield a correct answer than a *think that* sentence; (iv) the absence of reality makes it twice likely to yield a correct answer than its presence.

3. 1. "According to" versus "thinks that"

The overall results for the children's performance on the two syntax conditions (*think that* and *according to*) are given in Table 2 and those by age groups in Tables 3-5. A highly significant effect of syntax was found on correctness ($p<.00001$), with children performing better on the *according to* condition (78% correct responses) than on the *think that* condition (47% correct responses). Adult controls were 100% accurate on both conditions.

Table 2: Overall responses to the two syntax conditions

Condition	**Correct**	**Incorrect**	**Total**
According to	238 (78%)	66 (34%)	304
Thinks that	143 (47%)	161 (53%)	152

Table 3: Overall responses to the two syntax conditions from two- and three-year-olds

Condition	**Correct**	**Incorrect**	**Total**
According to	100 (66%)	52 (34%)	152
Thinks that	53 (35%)	99 (65%)	152

Table 4: Overall responses to the two syntax conditions from four-year-olds

Condition	**Correct**	**Incorrect**	**Total**
According to	95 (91%)	9 (9%)	104
Thinks that	58 (56%)	46 (44%)	104

Table 5: Overall responses to the two syntax conditions from five-year olds

Condition	**Correct**	**Incorrect**	**Total**
According to	43 (90%)	5 (10%)	48
Thinks that	32 (67%)	16 (34%)	48

3. 2. "Reality" vs. "no reality"

Recall that two of our stories involved a reality background. The presence of reality had a highly significant effect ($p<0.0001$), with children performing much better in agnostic scenarios (66% vs. 52% correct answers). Table 6 shows the overall responses form all subjects to the stories that lacked a reality background, and Table 7 their responses to stories with a reality background.

Table 6: Overall responses from all subjects in the absence of reality

Condition	**Correct**	**Incorrect**	**Total**
According to	190 (83%)	38 (17%)	228
Thinks that	112 (49%)	116 (51%)	228
Total	302 (66%)	154 (34%)	456

Table 7: Overall responses from all subjects in the presence of reality

Condition	**Correct**	**Incorrect**	**Total**
According to	48 (63%)	28 (37%)	76
Thinks that	31 (41%)	45 (59%)	76
Total	79 (52%)	73 (48%)	152

4. Discussion

We see that children overall perform better on the '*according to X'* than on the '*X thinks that'* condition. Why should this be the case? Both constructions involve the attribution of a belief to another individual: hence, the difficulty children have with attitude verbs cannot be solely due to the conceptual difficulty of attributing beliefs to other minds. Instead, this difference could be due to syntactic factors that differentiate between the two types of constructions. An alternative explanation suggested by a reviewer, is that what is responsible for the difference between the two types of conditions is the fact that *according to* may be interpreted as a speech report, which would give this condition a further advantage, given that children seem to acquire verbs of communication before mental verbs (but see footnote 2). We will tease these two possibilities apart in a further study contrasting *according to X* and *X said that*.

When we break the results into age groups, we see that younger children have difficulties with both conditions. Recall from the literature that 3 year olds both fail ToM tests and do not understand attitude verbs with sentential complements. This was corroborated with the results of the '*X thinks that*' condition, for which 2 and 3 year olds provided correct answers only 35% of the time. Interestingly, they perform much better on the '*according to X*' condition, providing correct answers 66% of the time. 4 and 5 year olds still showed some difficulty with the '*X thinks that*' condition, providing correct answers only 56% and 67% of the time, respectively, despite the fact that they should be of age to pass ToM tasks. This suggests that they still may not have mastered fully the construction. Their performance on the '*according to X'* condition, on the other hand, was much closer to that of adult controls (around 90% vs. 100% for adults). These results suggest that the difficulty children have understanding attitude verbs with sentential complements could be due (in part) to syntactic complexities involved with the embedding of sentential complements.

Recall from the introduction our hypothesis that the main problem children have with sentential complements is recursion. While attitude verbs can easily be used recursively, PP adjuncts cannot (at least in English):

(3) John thinks that Paul thinks that Bill is happy.
(4) ??According to John, according to Paul, Bill is happy.

This is corroborated by the fact that (older) children who successfully understand mental verbs with sentential complements still have difficulties with recursive embeddings (Hollebrandse et al. 2008, Sowalsky 2008):

(5) Mom said that Billy said that mud is fun.

Hence, it appears that, already by age 3, children may have acquired part of the concept of the attribution of beliefs to individual minds, while still not having fully mastered the syntax and semantics of attitude verbs. A major stumbling block to the mastery of attitude verbs seems to be syntactic embedding, which may carry over in older children as well, and be a source of communication disorders.

Probing further the role that 'reality' plays in the attribution of beliefs, we see that children seem to do better in agnostic scenarios, which simply report the beliefs of different characters. This, we believe, is due to the fact that in these cases, the task is much simpler, in that children do not have the additional task of withholding what they, themselves, believe. The majority of our stories did not involve a reality background. The task simply required children to map a thought to an individual. Despite the simplification of the task, children still showed difficulties, and that to a greater extent for the *think that* condition than for the *according to* one—even with older children—suggesting that attitude verbs like *think* involve an additional level of complexity.

To sum up, our basic result is that the attribution of a belief can be accomplished via a PP, and in fact more easily than via an attitude verb. This result appears most straightforwardly when there is no reality to confuse the issue in the mind of the child. It is an important question to ask exactly where and how the reality factor plays a role. One of the accomplishments of this experiment is precisely to enable us to examine the semantic accomplishments of children when reality is factored out. Where should one factor it back in? Reality can be inferred from various means: visual cues, spoken sentences, world knowledge. When present, the child has to, in effect, discount its role, and avoid the looming question of why someone would think something that is not true or what the consequences would be. When attitude verbs are finally comprehended in the context of reality, the child, in effect, first determines what someone thinks, and then, in a separate comparison determines that the belief is true or false. At that moment, they have mastered the pragmatics of integrating contextual knowledge and syntactic knowledge. Before that point, they may feel that it is pragmatically odd to make an attribution to someone else that is not in keeping with reality, even when they have correctly computed the connection between the complement and the PP.

5. Conclusions

We have shown that children can correctly understand belief attributions, when relieved from the burden of computing sentence embedding, even at an age when they tend to fail Theory of Mind tests. This indicates that sentence embedding (and perhaps recursion) seems to be a crucial hampering block. These results support the hypothesis that the full ability to generate opacity with propositional force has an intermediate step via the weak opacity of PP's and early adjunct uses of "I think." Full false belief reasoning capacity appears when the recursive forms of subordination are available for the representation of propositional attitudes. Careful correlation among belief attribution, false belief attribution, and recursion is called for, if we are right that a child does not move into opacity in a single leap, with adjunction preceding recursive embedding. How to model the semantic/pragmatic connections of each micro-step in acquisition is the next challenge.

Appendix

Pre-test: the participants were told a brief background story in which the character in the picture is identified as 'the birthday girl'. The contents of her thoughts are identified as 'a warm scarf, a winter hat, and mittens', all of which the character hopes to discover upon opening the wrapped birthday gift.
Show me the birthday girl.

(Prompt, if needed) This is the birthday girl.
Show me what the birthday girl thinks.

(Prompt, if needed) This picture tells us what the birthday girl thinks.
(Prompt, if needed) The birthday girl is thinking about a warm scarf, a winter hat, and mittens.

Story 1 (with presence of reality): This is Cat. Cat looks up at the sky and sees that it is very cloudy. "Oh phooey," says Cat, "it is a rainy day! I'm going back to sleep." So Cat goes back to sleep… and while Cat is sleeping, the sun comes out!

Targets: ***According to*** **Cat, it is a sunny day.**
Cat *thinks* that it is a rainy day.

Story 2 (no reality): This is Frog. This is Owl. Frog and Owl are hanging out in the backyard when they start to get hungry for a snack. "A caterpillar makes a yummy snack," says Owl. "Lets eat a caterpillar for snack." "Ew, that's gross," says Frog. "Let's eat a spider for snack instead." A spider is a yummy snack."

Targets: **Frog *thinks* that a caterpillar is a yummy snack.**
According to **Frog, a spider is a yummy snack.**

Story 3 (no reality): This is Bear. This is Little Frog. Bear and Little Frog are hanging out in the backyard when they hear a sound. "It sounds like an owl," says Bear. "No," says Little Frog, "it sounds like a monkey to me."

Targets: ***According to*** **Little Frog, a monkey made the sound.**
Bear *thinks* that a monkey made the sound.

Story 4 (no reality): This is Papa Bear. This is Little Bear. Papa Bear and Little Bear are getting hungry for dinner. Little Bear says, "Let's have ice cream for dinner. Ice cream is good for dinner." Very funny, says Papa Bear. "Pizza is good for dinner."

Targets: ***According to*** **Little Bear, pizza is good for dinner.**
Papa Bear *thinks* that ice cream is good for dinner.

Story 5 (no reality): This is Bear. This is Pig. This is a soccer ball. This is a football. Bear and Pig are roller-skating. After skating all morning, they decide to do something else. Bear says, "It's time to play football." "No, no, says Pig, "But we always play football. Now, it's time to play soccer."

Targets: ***According to*** **Bear, it's time to play football.**
Bear *thinks* that it's time to play soccer.

Story 6 (no reality): This is Elephant. This is Lion. Elephant and Lion want to have a picnic in the park. They decide what to bring to their picnic. Elephant says, "Cherry pie is the best picnic food." "No, no, says Lion, "Juicy strawberries are the best picnic food."

Targets: ***According to*** **Lion, juicy strawberries are the best picnic food.**
Elephant *thinks* that juicy strawberries are the best picnic food.

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