

A Formal Analysis of the False-Belief Task

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“...There are soooooooooo many angles one can look at [it]
and still feel that something more can be said.”
Jeannette

Abstract

The false-belief task has become the cornerstone of a branch of developmental psychology. However, although Henry Wellman and Colleagues (Wellman, Cross and Watson, 2001) did an outstanding job at clearing up the with regards to certain possibly intervening variables, most of the deep-rooted questions about the false-belief task still stand. This paper will discuss a way of making these questions evident for further theorizing and empirical research by means of a formal model of the false-belief task.

Introduction

Not long ago I was lecturing about children’s performance in the false-belief task (see 1 below). My students, like most researchers in the Theory of Mind area, loved Wimmer & Perner’s (1983) beautifully crafted and skillfully controlled experiment. However, just like most researchers in the Theory of Mind area, my students had lots of questions about the false-belief task. Questions like: why do you think children are not just saying their own beliefs? Why do you think children remember about Sally at all when the experimenter asks them the question? How do children get to answer the B-Question correctly, for that matter? Is the false-belief task actually testing children’s ability to ascribe a false belief to someone else?

The purpose of this paper is not exactly to try to answer these questions but to try to give an account of why they get asked in the first place. To do so, I will create a formal version of the false-belief task and for this, I will make the following (harmless, I hope) assumptions:

- a) I will assume that folk psychology is a (naïve) theory about the psychology of people;
- b) I will assume that the theory mentioned in (a) is similar, in many important respects, to formal scientific theories; and
- c) I will assume a generic ‘narrative’ version of the false-belief task.

The assumptions made above are well supported somewhere or other in the literature (Astington, Harris, & Olson, 1988; Carruthers & Smith, 1996 and references cited therein; Davies & Stone, 1995a; Davies & Stone, 1995b), so

I take it I am not ‘inventing’ them, with corresponding disastrous consequences. My job will be, then:

- d) to identify the events, states and entities involved in the false-belief task;
- e) to propose a system in which the entities, states and events mentioned in (d) interact in particular ways (and not others, that is) and;
- f) to explain, by means of the model specified in (e) and in various different ways, children’s correct and incorrect responses in the false-belief task.

Some of the hypotheses I will put forward in these pages have already been answered somewhere in the developmental literature (see each individual section for the relevant references), but I doubt that *all* the hypotheses that could *potentially* be drawn from this paper have, and that is the purpose of the paper. I have, therefore, two general objectives in these pages: Objective1) to provide the tools to eventually make the false-belief task a non-criticism-prone experiment and Objective2) and most importantly, to try to answer my students’ questions.

Folk Psychology as a ‘Theory’

I will use the term “folk psychology” to refer to our ability to describe, explain and sometimes even predict i) our own behavior, ii) the behavior of other members of our species and iii) possibly the behavior of members of related species also (Davies & Stone, 1995a; Dennett, 1978). In trying to give a scientific account of this ability, theory of mind researchers have postulated two mutually exclusive hypotheses. Details aside, they are: H₁) folk psychology is a (naïve) *theory* about psychology (a.k.a Theory-theory of mind; see Carruthers & Smith, 1996; Davies & Stone, 1995; Wellman, 1990; Wellman, 1991) and H₂) folk psychology is a *skill* by which we imaginatively identify with someone else (a.k.a Simulation-Theory of Mind; see Gordon, 1986; Harris, 1991). For the purposes of this paper, I will assume (H₁).

To emphasize, then, the main idea in (H₁) is that our folk psychological abilities can be explained by postulating the existence of a (naïve) theory about psychology, a theory that ‘resides’, as such, somewhere in the human mind. This

means that the way we explain and predict behavior is by having/using a theory (similar to a formal scientific theory) about the psychology of people. In yet other words, and to use a fashionable expression in developmental psychology, every human being is an *untrained* psychologists (as well as an untrained physicists, physicians, biologists, etc.). So, we have some sort of theory inside our heads, a theory of psychology in this case. What are the characteristics of this theory?

Think about how the story goes: i) we see behaviors out there in the world; ii) on the basis of our folk psychology, we analyze those behaviors, we come up with an explanation and probably predict a future behavior and iii) we act accordingly; that is, on the predictions and explanations of (ii). It is (ii) that takes the form of a theory, if we assume that folk psychology is a theory inside our heads. Now, take formal scientific theories (henceforth, FSTs), they seem to have, at least, the following characteristics: FST₁) in explaining a phenomenon FSTs invoke abstract entities (quarks, phlogiston, etc.); FST₂) FSTs invoke laws (causal laws) that govern the interaction of the entities invoked in (FST₁) and lastly, FST₃) on the basis of (FST₁) and (FST₂), FSTs provide explanations of the phenomenon at stake and also build generalizations that could in principle be extrapolated to new evidence. Taking (FST₁)-(FST₃) into account, theory-theorists would like to tell the following story about folk psychological explanations (henceforth, FPEs): consider that, like FSTs, FPE₁) in explaining behavior (the phenomenon) FPEs seem to invoke abstract, unobservable entities like beliefs, desires and the rest of the propositional attitudes; FPE₂) FPEs seem to invoke causal laws that govern the interaction of the entities in (FPE₁), for example: IF x THEN p ; and lastly FPE₃) on the basis of (FPE₁) and (FPE₂), FPEs provides explanations of the phenomenon at stake (behavior) and build generalizations that could in principle be extrapolated to new evidence, for example, the famous ‘practical syllogism’ (see Fodor, 1987; Wellman, 1990; Wellman & Gopnik, 1995): IF x wants that P AND x believes that $\sim P$ UNLESS Q THEN x tries to bring it about that Q . Let’s analyze a ‘real-life’ example: ObservableBehavior1) Leo drinks hot water (not tea or coffee) during class; ObservableBehavior2) Leo told me: ‘I like hot drinks (especially tea and coffee) but I want to sleep at night’; Therefore: If Leo wants a hot drink during class and he believes that tea or coffee would prevent him from having a good night’s sleep, then he will avoid tea or coffee and drink hot water instead. Sounds like a good explanation of why I may be having hot water, and it was brought to you by (FPE₁)-(FPE₃). This is the notion of ‘theory’ that I will employ from now on.

An Ontology of the False-Belief Task

The following is a slightly modified ‘narrative’ version of the false-belief task (henceforth, F-BT), taken from Frith (1989):

- (1) The child is introduced to two puppets: Sally and Anne. While playing, Sally puts a marble into a basket and then goes outside (the puppet disappears under the table, for example). When Sally is not around, naughty Anne changes the location of the marble. She takes it out of the basket and puts it in a box. Some time later, Sally comes back and wants to play with her marble. Subjects are then asked the critical question: where will Sally look for her marble?

Of course, no formalization in any domain would work without an ontology. In this paper, when I talk about an ‘ontology’, I mean the set of entities and events that are identifiable in a restricted cognitive domain. Thus, for example, taking the situation described in (1) as our cognitive domain, ‘a marble’ (qua entity) and ‘look for’ (qua event) seem to be members of the sets of entities and events identifiable in this domain, while both ‘a bird’ (qua entity) and ‘eat’ (qua event) do not. The following three sets and their members have been identified:

En={self, sally, anne, experimenter, basket, box, marble}
Pr={is, is-in, have, put, into, go out, takes, come back, look for, away, ask, answer, want, believe}

where **En** = entity involved in the F-BT; **Pr** = predicate involved in the F-BT. Also, notice the following three points:

- a) since I am trying to formalize the F-BT from the point of view of a child performing in it, I do need an entity like ‘self’, which will stand for the child being tested and an entity like ‘experimenter’, which will stand for the person running the experimenter and asking the child the relevant questions¹;
- b) ‘is, into, go out, come back, away’ are one-place predicates, ‘is into, have, take, look for, see, want, believe, know’ are two-place predicates, ‘put, ask, answer’ are three-place predicates, and that;
- c) in all predicates, the first argument stands for the entity that would lexicalize the grammatical subject in active sentences; in all predicates with two arguments, the second argument stands for the entity that would lexicalize the grammatical object in active sentences, except for ‘is in’, whose second argument would lexicalize a place adjunct; lastly, in all three-place predicates, the third argument stands for the entity that would lexicalize a grammatical adjunct in active sentences, in this case, always a ‘place’ adjunct.

¹ Note that the labels are arbitrary. I could have just talked about ‘self’ as En₁, about ‘sally’ as En₂, etc.

I hope I have now identified all and only the relevant entities and events pertaining to the false belief task. What we now need is a *hilo conductor* (a connecting ‘thread’), something that would give us a starting point to find out what arguments enter into what relations by means of what predicates in our model of the F-BT. For us, our *hilo conductor* will be T (time); counting from when Sally is first introduced to the child (T_0) until the latter has answered the last question posed by the experimenter (T_{end}). The story, I think, would go something like Table 1, give or take a detail or two.

Table 1: Possible relations among the arguments in our model of the F-BT².

T_0	\rightarrow IS(sally)
T_1	\rightarrow IS(anne)
T_2	\rightarrow HAVE(sally, basket)
T_3	\rightarrow HAVE(anne, box)
T_4	\rightarrow HAVE(sally, marble)
T_5	\rightarrow PUT(sally, INTO(marble, basket))
T_6	\rightarrow GO OUT(sally)
T_7	\rightarrow TAKE(anne, marble)
T_8	\rightarrow PUT(anne, INTO(marble, box))
T_9	\rightarrow COME BACK(sally)
T_{10}	\rightarrow WANT(sally, marble)
T_{11}	\rightarrow ASK(experimenter, self, LOOK FOR(sally, marble, x))
T_{12}	\rightarrow [some processing occurs, see (2)]
T_{end}	\rightarrow ANSWER(self, experimenter, LOOK FOR(sally, marble, x))

where \rightarrow = the child’s (implicit) realization (at time T) of the bit on the right-hand side of the arrow and where x = an empty argument that has to be filled by the child’s response.

Children’s Performance in the F-BT

I think we now have a model of the relevant stages in the F-BT. Our next task is to explain children’s (correct and incorrect) performances in this task. A little bit of history now: According to empirical evidence, it is not until around four years of age that children master most of the concepts possessed by adults in the latter’s mature theory-instantiated folk psychology (Wellman, Cross, & Watson, 2001; Wimmer & Perner, 1983). Older subjects, whose ages are just under five years, will know that Sally does *not* know that the marble has been moved from the basket to the box (or, in other words, believes that the marble is in the basket, a functionally equivalent description, I hope) and will therefore correctly predict that she will look for it in the basket, and not in the box. In turn, the younger group fails to answer this question correctly. They predict that Sally will look for her marble in the last location; that is, where it is now (in the box) not where she actually left it in the beginning (the basket). How would my formal system give an account of a correct response in the F-BT?

² Of course this table can be revised, expanded and what not, but I think it is more than good enough for our first approximation to a formalization of the F-BT.

Possibility 0: Children’s Correct Answer

It is (FPE₃) that I hope will take us from T_{11} to T_{end} ; that is, to answering the question posed by the experimenter (see Fodor, 1987). Recall that in its ‘raw’ form, the practical syllogism is simply a *modus ponens* of sorts ($p \supset q, p, / \therefore q$). Applied to our version of the F-BT discussed in these pages, I think the practical syllogism would look something like this, should the child answer correctly of course:

- (2) PrS_[correct]: IF WANT(sally, marble) AND IS-IN(marble, box) AND BELIEVE(sally, IS-IN(marble, basket)) THEN LOOK FOR(sally, marble, basket).

If I am right and children (or any system) try to answer the question in T_{11} in a fashion similar to our syllogism in (2) above, then there are a few things that could actually explain the young child’s inability to answer the belief question (henceforth, B-Question) correctly. They are:

Possibility 1: No Concept of Belief

The standard assumption in the developmental literature is that children who don’t get the answer right fail because they haven’t yet developed (acquired, whatever) the concept of BELIEF (see Perner, 1991b, and indeed all the literature on ‘Theory of Mind’). Of course, the concept of BELIEF (qua event) belongs to our ontology of the F-BT. If we take it out, then our formal system (or a child, for that matter) might want to answer the question posed by the experimenter in T_{12} somewhat along the following lines:

- (3) PrS_[no-concept]: IF WANT(sally, marble) AND IS-IN(marble, box) THEN LOOK FOR(sally, marble, x).

There are a two things to be said about (3): first, unlike PrS_[correct] in (2) above, there is no (proposition being entertained during the inference process as to where Sally *believes* the marble is (nowhere in it is there even a mention of the entity ‘basket’, for that matter). It seems the only entity that the child (or in this case our formal system) has access to to fill the adjunct position in the LOOK FOR event is ‘box’ and that is, I think, the entity he or she will bind to variable x . Second, notice that an explanation like this also accounts for the empirical evidence available in the following way: if Sally wants the marble then she *should* go look for it in the box (where it actually is) because, in the child’s mind, looking for it in the basket would not satisfy Sally’s desire for the marble. This is a position forcefully advocated by Henry Wellman and probably also Josef Perner (Perner, 1991a; Perner, 1991b; Wellman, 1990; Wellman, 1991).

So far, however, I haven’t done much more than telling you (albeit formally) what you already know from the developmental literature; namely, that children may lack the concept of belief. But I do think this is a very good start; for, obviously, there is a way in my formalism to account for this ‘received’ story of what might be going on. Interestingly, however, this formalized version of the F-BT

provides us with some other hypotheses that are worth exploring. I now turn to a second view, also drawn from the literature, of what could explain children's performance in the F-BT.

Possibility 2: No Concept of False Belief

A second hypothesis as to why young children fail in the F-BT is the following: children *do* have the concept of BELIEF, however, they lack the concept of FALSE BELIEF (Wellman, 1990; Wellman, 1991; Wellman, 1993). In other words, children are in fact able to entertain beliefs about others, unless those beliefs describe a counterfactual state of affairs. If this were the case, children might want to answer the question posed by the experimenter in the following way:

- (4) PrS_[no-fb]: IF WANT(sally, marble) AND IS-IN(marble, box) AND BELIEVE(sally, IS-IN(marble, box)) THEN LOOK FOR(sally, marble, box).

If it is the case that they can't entertain a false belief, then *mutatis mutandis*, they should be able to entertain someone else's true belief about where the marble is or might be. Given the situation, the only true belief that they can ascribe Sally at T_{end} is the belief that the marble is in the box, something they know to be true. Notice here, by the way, that this doesn't mean that the child is just answering with his own belief; for the first argument of the 'believe' predicate is 'sally' not 'self'. The child is, in fact, ascribing a belief to Sally. Granted, a belief with a propositional content that the child him/herself has been entertaining, but from *that* it doesn't follow that the child is answering the belief question with his own belief. Actually, this last option would be too far fetched in my formalism: why would the child even entertain [BELIEVE(self, IS(marble, box))] when the question is about Sally? This would imply that three-year-olds don't know the difference between self and other, and we know that not to be the case. This view is also supported by the developmental literature (see Astington, Harris, & Olson, 1988; Fodor, 1992) and references cited therein).

So, question: is it the concept of BELIEF or the concept of FALSE-BELIEF that explains three-year-olds performance in the F-BT?

Possibility 3: No Tolerance for 'False Thoughts'³

A third way of explaining children's failure in the false belief task -and one that has not, to my knowledge, been specifically addressed, if it ever can be- has to do with children's inability to even entertain false thoughts in general, let alone false beliefs. Said formally:

- (5) PrS_[no-ft]: IF WANT(sally, marble) AND IS-IN(marble, box) AND BELIEVE(sally, [empty]) THEN LOOK FOR(sally, marble, box).

where [empty] stands for [IS(marble, basket)], a thought that is blatantly false and that children don't (or can't) even entertain, neither for Sally nor for themselves. However, these children still have to answer the question posed by the experimenter, and they do so by using an immediate 'replacement' thought, one that seems similar and one they are definitely entertaining; namely, [IS(marble, box)]. By answering like this, children may just be stating where the marble actually is, with no reference to anybody's mental state (neither Sally's nor their own).

So, question: is it the concept of BELIEF, the concept of FALSE-BELIEF or three-year-olds' inability to entertain false thoughts that explains their performance in the F-BT?

Possibility 4: The Memory Explanation⁴

Researchers have always wondered whether there is something to be said about the role of memory in the F-BT. Indeed, this was one of the main concerns in Wimmer & Perner's (1983) seminal paper. They would control for this memory variable by asking the child 'Do you remember where Maxi put the chocolate in the beginning?' Substitute 'sally' and 'marble' for 'maxi' and 'chocolate' respectively, delete the 'do you remember' part of the question, which I think changes nothing, and you have a memory question in the terms of our discussion here. How would the child try to answer this question? Well, just by retrieving a fact from somewhere in the model; more specifically, T_5 [PUT(sally, INTO(marble, basket))]. That does tell us that the child remembers the step in which Sally put the marble in the basket, but there are other (more subtle) details that the child may be missing (recall, also, that the child is asked the M-Question at the end of the experiment, when he or she has already answered the B-Question). For example, what if the child doesn't remember who put the marble where. In our system, this hypothesis can be formally stated as (see, for example, Davis & Pratt, 1995):

- (6) PrS_[mj]: IF WANT(sally, marble) AND IS-IN(marble, box) AND BELIEVE(x, IS-IN(marble, basket)) AND PUT(x, INTO(marble, basket)) AND PUT(x, INTO(marble, box)) THEN LOOK FOR(x, marble, box).

where x = an unrealized (forgotten) argument. Notice that now the child does not know who's belief/false-belief he or she should be entertaining. Basically, the question the child is facing now is: 'where did *who* put the marble again? Did Sally put the marble in the basket and Anne in the box or vice versa?' Again, the child is pressed by the experimenter's question, so he or she has to answer it. My own explanation of why children answer incorrectly under these circumstances is the following: children will answer 'Sally will look in the box' (rather than the basket) because they forget where each of the puppets put the marble and the piece of information they have more readily available is that

³ Sam Scott suggested this hypothesis to me.

⁴ Thanks are due to Kelly Banks and David Coupland.

someone put the marble in the box, and that that *someone* may well be Sally. This is easily testable in an experiment, of course, you just ask the child, after she or he's answered incorrectly: 'who put the marble in the basket and in the box?' Nobody, to the best of my knowledge, has done this. But even if they have, this is just one (albeit the more obvious) piece of information that children may be forgetting. I could definitely give other possible hypotheses about what children may be forgetting, but I do yearn for brevity. I hope researchers will address these non-explicit hypotheses as well further down the road.

So, in the spirit of being consistent, the question has now become: is it the concept of BELIEF, the concept of FALSE-BELIEF, three-year-olds' inability to entertain false thoughts or the selective pieces of information being forgotten that explains children's performance in the F-BT?

Possibility 5: The Non-Belief Explanation

I have a scarier story to tell about the F-BT. What if the child is actually not even entertaining the concept of belief when he or she answers the B-Question; that is, even if they answer it correctly? Consider the following strategy that would actually render a correct answer to the B-Question:

- (7) PrS_[correct-nb]: IF WANT(sally, marble) AND IS-IN(marble, box) AND PUT(sally, INTO(marble, basket)) AND PUT(anne, INTO(marble, box)) THEN LOOKFOR(sally, marble, basket).

Notice that nowhere in this possible explanation is there even a mention of the concept of belief. Children are just entertaining the different steps in their minds as to *who* put the marble *where*. Arguably, it is even a better story to tell because children need not have access to the concept of BELIEF or any other mentalistic concept except maybe for WANT. They only need to remember the different steps in the F-BT (formalized in Table 1 above). Children may just be recalling the bits of information at times T_5 and T_8 . Of course, since the question is about Sally, then children choose the piece of information with 'sally' and not 'anne' as the argument of 'put'.

Very nice. But it is not enough for me to give you an account of why children pass the F-BT using this strategy. I also need to tell you why younger children fail this task. Obviously, I think that, not unlike the 'belief' explanation of performance, there are many ways to account for children's failure under this new syllogism. Here is my favorite one, which draws from Possibility 4 above. Suppose (8) below:

- (8) PrS_[incorrect-nb]: IF WANT(sally, marble) AND IS-IN(marble, box) AND PUT(x, INTO(marble, basket)) AND PUT(x, INTO(marble, box)) THEN LOOKFOR(x, marble, box).

where x = an unrealized (forgotten) argument. The careful reader may be wondering why would the child choose the entity 'box' to answer the question posed by the

experimenter (and children do say only 'box', see (Wellman et al., 2001)); why not 'basket' if they are keeping both propositions in mind. I could give two different explanations about this: E1) because when children backtrack, since they don't remember who put the marble where, and since the most recent event is T_8 and not T_5 , they will choose the latter one; E2) without referring back to the different stages, children are entertaining three very similar propositions as to the location of the marble: two of these propositions point at the entity 'box' as the location and just one of these propositions point at the entity 'basket'. Children may just have strong evidence about the marble being in the box and that's why they choose it as the correct location for the question (see Emond & Ferres, 2001).

Remember that the M-Question, at least in Wimmer & Perner's (1983) paper, is asked *after* the B-Question. Therefore, we are not sure whether children remember who put the marble where, even though children answer it correctly 80% of the time when they give incorrect responses to the B-Question. But then again, I could tell you other stories about children's failure using the syllogism in (8). Again, that will be left for another paper. As I said, my aim here is to formally present the problem, not to solve it.

So, in the spirit of being *extremely* consistent, the question has now become: is it the concept of BELIEF, the concept of FALSE-BELIEF, three-year-olds' inability to entertain false thoughts, selective pieces of information being forgotten that explains children's performance in the F-BT or, to put it very strongly, is it that there is no such thing as the F-BT?

Conclusions

What is scary about the different stories that I have told you in the previous pages is that I can tell them... and get away with it. The lesson to be learned from the formalism that I have proposed is that there's a lot that could actually be going on in the F-BT. And maybe none of these 'going-ons' has anything to do with testing the concept of BELIEF.

I think I've done my share to give you the tools to propose testable hypotheses about the F-BT. So my first general objective (Objective1) has been achieved. With regards to Objective2... Well, my dear Psych students, the answer to your questions is: there's a lot to be done to answer your questions and we'd better get to it. Soon.

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