Brief Report: Removing shared information improves 3- to 4-year-olds' performance on a change of location explicit false belief task

Keywords: Theory of mind, False belief task, Shared information

Introduction

Developmental research on Theory of Mind (ToM) originated with the classic change-of-location, explicit false belief task (EFB). This was first implemented by Wimmer and Perner (1983), who found that children up to four years are unable to say how an agent with a false belief will act, predicting instead the agent will act based on the child's own belief. Wimmer and Perner's work was replicated by a large number of EFBs conducted with slight modifications and in new cultural and clinical contexts (Wellman, Cross & Watson, 2001). However, several researchers have suggested that the EFB in its change-of-location form is cognitively challenging in a number of ways (Bloom & German, 2000; Rubio-Fernández & Geurts, 2013; Setoh, Scott & Baillargeon, 2016; Helming, Strickland & Jacob, 2016). New EFBs have been designed that address these difficulties.

Setoh and colleagues (2016) found that 2.5-year-old children succeeded in a modified EFB. They targeted the response-generation process as a source of difficulty in the tasks, arguing that being forced to produce a response to the story is a key aspect of difficulty in EFBs. By providing children with practice trials where they answered questions about relevant objects in the story at different stages of the narrative, they found that children were more successful at choosing the target location in a false belief task. Grosso and colleagues (2019) have also replicated this procedure in a different cultural context.

Rubio-Fernández and Geurts (2013; 2016) developed the "Duplo Task", which provided evidence that 3-year-olds can pass a modified version of the EFB. They argue that EFB complexity

stems from the pressure it places on children's attentional and inhibitory resources and the ability to track others' perspectives. They introduced a number of modifications that together improved task performance: keeping the agent in view at all times, emphasising the secretive character of the task, and making the agent's perspective explicit by asking questions about what she could and could not see. Various follow-up studies have been published that both support (Białecka-Pikul, Kosno, Białek & Szpak, 2019) and question (Dörrenberg, Wenzel, Profta, Rakoczy & Liszkowski, 2019; Kammermeier & Paulus, 2018) the results of the Duplo Task.

Whilst some issues remain, the emerging picture is that the EFB is a challenging task for children as it simultaneously draws upon a number of different cognitive processes. Our contribution to these discussions is to introduce and examine an important and often neglected aspect of discussions of the EFB: the role of *shared information*.

Shared information and the "where-prediction" question

Work by Rubio-Fernández and Geurts on the Duplo Task (2013; 2016) has highlighted the difficulty of the standard where-prediction question, of the form "Where will [agent] look for [object]?" Use of the where-prediction question caused success rates on the task to fall to 22.2% compared to 80% success when an active response approach (where the child was allowed to actively guide the agent to a target location) was used. A follow up study (Rubio-Fernández & Geurts, 2016) examined the test question in more detail. This study found that omitting mention of the target object from the test question ("Where will Lola go now?'') led to a success rate significantly above chance (80%), whereas two conditions that included mention of the target object even just prior to test question led to low success rates (5% in both conditions).

The where-prediction question is especially (and perhaps only) difficult when directly addressed to the child. He and colleagues (2012) investigated 2.5-year-olds' anticipatory looking behaviour on a change of location false belief task, examining the effect of directly addressing the child with the test question versus self-addressing the test question. They found that performance improved significantly when the test question was not directly addressed to the child.

Why might where-prediction questions directly addressed to the child be a source of difficulty? Work in language processing (Horton & Gerrig, 2005; Brown-Schmidt, Yoon & Ruskin, 2015) has shown that simple memory-based mechanisms enable rapid recall of shared information. In particular, it has shown that interlocutors form strong, speaker-specific memory associations that include a linguistic expression and referent and that these persist and become reactivated in later interaction with the same interlocutor. Thus, language processes are biased to prioritise referential information that has been shared with one's interlocutor.

Evidence suggests that these biases are active through childhood. For example, 1-year-olds are able to track which of two adults they have engaged in one of two different activities (Liebal, Carpenter & Tomasello, 2010). Moll and Tomasello (2007) show that 14- and 18-month olds are better able to determine what is novel for an interlocutor when old information is previously shared in joint engagement with the adult (see also Moll, Carpenter & Tomasello, 2007). Yoon, Johnson and Csibra (2008) suggest that even younger infants are biased to recall information differently, depending on whether it was previously communicatively shared. The bias for memory mechanisms to prioritise information previously shared in communicative engagement is quite probably linked to the bias to for communicative engagement to create expectations of relevance, resulting in deeper processing of stimuli and a greater liability for cued retrieval (Yoon et al., 2008).

Thus information that is processed in shared, communicative engagement is particularly salient in subsequent interactions with the other sharing agent. In the case of the EFB, the child and experimenter have most recently jointly attended to the target object in its switched location. This means that during the procedure, particularly at the point of the where-prediction question, the child's ability to access relevant information about the protagonist's beliefs faces interference from a memory association between the experimenter and the target object, triggered by linguistic reference to that object. This adds to the inhibitory demands faced by the participant in the task.

Our view is similar in spirit to that of Helming and colleagues (2016), who argue that the child's second person engagement with the experimenter interferes with the need to take a third

person perspective on the character's instrumental activity. Specifically, the where-prediction question includes linguistic reference to the hidden object, and children process this expression while communicatively engaged with the experimenter. The EFB sets up a conflict between responding according to the experimenter's epistemic perspective on the object's current location and the agent's incorrect perspective. For Helming and colleagues, children have a bias towards the experimenter's epistemic perspective. Our approach offers a further specified account of this bias and why it is only triggered when children are addressed by the experimenter, who refers to the target object.

The main proposal of this paper is thus based on both adult and child language research, and states that a "where-prediction" questions that mentions the target object, when addressed to the child, causes increased activation in memory of the actual location of the target, making it harder for them to inhibit their knowledge of the actual state of affairs. Thus, an important element of difficulty for children in the EFB comes from the fact that the actual location of the target object is *shared* information between the child and the experimenter who addresses the question to the child. Task difficulties are not solely caused by a reality bias (e.g., Carlson & Moses, 2001) but by a bias for shared information between two agents to become highly activated when those agents are interacting. We test these hypotheses in the experiment reported below.

If shared information is especially salient, there are two ways to reduce the difficulty of the EFB (Helming et al., 2016). Firstly, the test question can be changed so that it does not refer to the hidden item, thereby ensuring the shared information is less activated. This has already successfully been tested by Rubio-Fernández and Geurts (2013; 2016). The other option is to ensure that when the target object is mentioned, it is not shared information between the child and the experimenter asking the question. The present study investigated this hypothesis by ensuring that the experimenter who performed the switch and the experimenter who asked the test question were different people. It also made use of the elements that facilitate perspective tracking seen in the studies of Rubio-Fernández and Geurts (2013; 2016). These included keeping the agent in view of the child, emphasising the secretive nature of the task and making the agent's perspective explicit with questions about what she could and could not see at different stages of the task. In those studies, these modifications improve

task performance, but not when the target object is mentioned. Additionally, a test of conflict inhibitory control, previously highlighted as an important executive function in EFBs (Carlson & Moses, 2001), was administered in order to account for the influence of children's inhibitory control and working memory in the regression model.

Material and methods

Participants

A total of 38 participants were recruited from schools and nurseries in London and the Midlands, who were compensated for their help. The children were typically-developing English native speakers aged 3 or marginally 4. (Control group: 19 members, 13 Female 5 Male, 3.0 years to 4.25 years, M_{age} = 3.66 years, SD = 0.34; Experimental group: 19 members, 11 Female 8 Male, 3.0 years to 4.17 years, M_{age} = 3.61 years, SD = 0.36).

Method

The experiment featured three stages. The session began with a warm-up, where the child played a game with two experimenters (E1 and E2) which involved decorating an envelope with stickers. The game served to familiarise the child with both experimenters. After decorating for a few minutes, E2 would pretend to answer a phone call, providing a plausible reason for them to leave the room. E1 would explain to the child "E2 is outside on the phone; we'll carry on playing without her". The door was always behind the child and closed, though the testing room always had a means by which E2 could observe in order to re-enter the room at the appropriate point and to observe children's responses. After briefly continuing the warm-up game, E1 would begin the second stage, the false belief task.

The false belief task

E1 introduced the scene. They showed the child the protagonist, a toy elephant. E1 explained that the elephant loves carrots, showing the child the elephant's toy carrots. They also showed the child two different coloured boxes, which they explained were cupboards in the elephant's kitchen. E1 demonstrated that the boxes had doors that could be opened and closed, fully concealing the contents. E1 showed the child that the cupboards were empty and then explained that the elephant was going to store her carrots in one of the cupboards before going for a walk. After placing the carrots in a cupboard, the elephant was moved to the edge of the table, facing away from the cupboards but remaining in view of the child. At this point, E1 turned to the child and, in a lowered voice, asked "Can the elephant see me?" If the child said no, the next step would begin. If the child said yes, E1 would correct them, saying "No, she can't see me because she's looking away" and then continued. The next step was to quietly and secretively move the carrots from their initial location to the other box. After doing this, E1 would ask "Did she see what I just did?" Again, if the child said no, the next stage would begin. If the child said yes, E1 corrected them, saying "No, she didn't see what I did!" If the child did not give a response either before or after the switch, E1 would provide the answer for them.

Control condition

The control condition proceeded in a similar fashion to the standard EFB as seen in experiment 2b of the Duplo task (Rubio-Fernández & Geurts, 2013), with one difference: E1 would tell the child that the elephant had finished her walk and wanted to say something. E1 lifted the elephant to his ear to "listen" and told the child "Ah! She says she want to get her carrots! She wants to go back to the kitchen!" They would then walk the elephant back towards the cupboards, placing the elephant facing the cupboards at a point equidistant between them. E1 would then tell the child the elephant wanted to tell him something else. After listening, E1 would place the elephant back in front of the cupboards, saying "She wants to look in one of the cupboards!" and then the test question, "Where will the elephant look for her carrots?" At this point, E1 would look to the child and wait for

her to respond, either verbally or by pointing at a cupboard. If the child did not respond after 10 seconds, the question was repeated. If the child did still not respond after another 10 seconds, the trial was recorded as no response.

Experimental condition

After E1 had made it clear to the child that the elephant had not seen the switch take place, E1 would pretend to notice E2 at the door. At this point, E2 would enter with the phone, saying "She wants to speak to you on the phone now." E1 told the child that he had to leave, but that E2 would carry on playing with her.

E2 would sit down, first saying "Oh look! An elephant!" before continuing "Oh! She says she wants to say something to me!" E2 would then lift the elephant to her ear, pretending to listen. Placing the elephant down, E2 would say "She says she has some carrots, and she wants to go and get them! She says she wants to go to the kitchen!" The final part took place in the same manner as the control condition, with the elephant being placed in front of the cupboards and the same test question being used- "Where will the elephant look for her carrots?" As before, if the child did not respond after 10 seconds, the question was repeated. If the child did still not respond after another 10 seconds, the trial was recorded as no response.

The two experimenters were different genders. The role of E1 and E2 and the initial location of the carrots were randomised across trials. In each condition, choosing the empty box (verbally or by a gesture) was coded as a pass, and choosing the actual location of the carrots or no response was coded as a fail.

The Bear/Dragon task

The third and final part of the procedure was the "Bear/Dragon task" (Reed, Pien & Rothbart, 1984) which tests conflict inhibitory control (Carlson & Moses, 2001). The child was introduced to two puppets, and encouraged to greet them. One, a friendly looking orang-u-tan, was nice to the child in response and used a friendly tone of voice. The other, a mean looking crocodile, responded

negatively to the child's greeting and used a gruff voice. The child was told that each puppet would ask her to perform different actions. She was invited to follow what the nice puppet said, whilst ignoring what the mean puppet said.

The child had to first correctly respond to an instruction from each puppet. If the child failed 5 of these test trials with either puppet they were assigned a score of 0. If they successfully completed the test trials, the experimenter would start the main procedure. A total of 10 instructions were provided in a randomised order, 5 from each puppet. After 5 trials, whatever the child's performance, the experimenter would provide a reminder of the rules before proceeding with the second 5 trials.

The responses to the mean puppet were scored on a scale of 0 to 3 (0 = the child fully performed the action, 1 = the child began the action and then ceased, 2 = the child flinched or made a slight movement, and 3 = the child completely ignored the instruction). One experimenter performed the task while a second experimenter coded the responses, with the scores discussed and agreed immediately after the session. Responses to the nice puppet were used as a control to ensure that the child comprehended the instructions that were being given and was not simply ignoring all commands.

Results

All children in each condition produced a valid response. In the Control condition, 6 children passed the task while 13 failed (32% success rate). In the Experimental condition, 12 children passed the task while 7 failed (63% success rate). There was no significant difference between the Inhibitory Control performance in the Control group (μ = 8.26) and the Experimental group (μ = 6.89), as revealed by an independent samples t-test (t(36) = .680, p = 0.501).

A logistic regression was conducted with False Belief Task Score as the dependent variable and Inhibitory Control, Age and Condition as independent (predictor) variables. The model fitted the data well (*Hosmer-Lemeshow*, $X^2(7) = 7.404$, $p = 0.388$). The only variable found to predict false belief task performance was Condition (*Nagelkerke's* $R^2 = 0.17$, *Wald* = 4.10, $p = 0.043$).

Discussion

Overall, these results show that whether the experimenter asking the test question has shared the change of the location is a significant predictor of children's performance on the EFB. In other words, the experimental manipulation had a significant effect on children's performance.[1] The results could not be explained by differences in inhibitory control score between the groups.

The results were unable to reach the effect generated by removing the target object entirely from the test question (e.g. Rubio-Fernández & Geurts, 2013; 2016), with a pass rate not significantly above chance (two choice binomial test, two tailed, $p = 0.359$). One part of the explanation might be that replacing E1 with E2 removes the shared goal of deceiving the agent, thereby removing one of the elements helping the child understand that she must select the empty container. This reasoning is plausible given the recent findings of Białecka-Pikul and colleagues (2019), who found 3.5 year olds successfully passed a version of the Duplo task that mentioned the target object in the test question when the interactive and secretive dimension of the task was emphasised. Another possible part of the explanation is that the procedure is unable to avoid some degree of perspective tracking disruption at the point that E1 and E2 exchange positions. On the other hand, performance in each condition may have been facilitated by the design feature whereby the experimenter would "talk" to the elephant. It is possible that this made the protagonist's perspective more salient just before the test question.

Finally, it is plausible that the reality bias is still an important factor, and that the effect of shared information and the reality bias combine to cause inhibitory difficulties when the standard "where-prediction" question is asked. Under the "representation competition" account (Altmann & Kamide 2009; Ferguson & Breheny, 2012), representations of alternative states of affairs compete, with different factors making one option more salient than the other. In these accounts, information

[1] We note that in addition to a difference in sharedness of information, the pragmatics of the critical question differs between our two conditions. In the replication condition, the experimenter's question would be construed by the participant as a kind of "test question" where the speaker is assumed to know the answer. In the Experimental condition, the second experimenter may be understood to be asking a "request for information question". While there is this difference in status of speaker between conditions, both kinds of question require the child to draw on their ToM abilities in the same way to provide an answer and so it is not clear whether this pragmatic difference is relevant. Nevertheless, it is a question for future research whether the pragmatics of the question can impact on EFB performance. We thank an anonymous reviewer for pointing this out to us.

about others' beliefs is involved in the early stages of processing, rather than necessarily taking place after an egocentric processing stage (see also Nadig & Sedivy, 2002; Heller, Parisien & Stevenson, 2016). Similarly, Moll and colleagues (2013) propose that children younger than 4 to 5 years struggle in cases that they are forced to make explicit judgements involving mutually exclusive perspectives, whether perceptual or epistemic. They argue that the issue is not that the egocentric response is the default, but that it is generally the more "obvious" choice of the two competing states of affairs. In our view, shared information enhanced competition from the reality perspective.

Conclusions

This study has highlighted the influence of shared information in the EFB. It provides evidence that one reason why the standard procedure is challenging for children is that it requires inhibiting shared information, a task that is difficult due to children's bias to treat shared information as highly relevant in comprehension.

The picture we present suggests that the cognitive mechanisms involved in processing shared information need not be cognitively costly. Perspective tracking and the registering of shared information are all well within the capabilities of 3-year-old children. However, the explicit task pits these abilities against each other, creating high pragmatic and executive function demands (Helming et al., 2016).

Future work could attempt to use shared information to "boost" children's performance. For example, the procedure could have the second experimenter witness the initial placement of the target object, rather than being ignorant of the state of affairs, this would serve to align the perspective of the questioner with that of the character with the false belief. However, such a procedure would have to be sensitive to the fragile nature of children's perspective tracking (Rubio-Fernández & Geurts, 2016). Having experimenters entering and leaving the room repeatedly may only serve to disrupt children's attention.

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