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Analogical comparison aids false belief understanding in preschoolers

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Abstract

Analogical comparison has been found to promote learning across many conceptual domains. Here, we ask whether this mechanism can facilitate children's understanding of others' mental states. In Experiment 1, children carried out comparisons between characters' thoughts and reality and between characters with true beliefs vs. those with false beliefs. Children given this training improved from pre- to post-test. In Experiment 2, we used a more minimal comparison technique. Children saw a series of three stories involving true or false beliefs. There were two between-subjects conditions that either facilitated (High Alignability) or impeded (Low Alignability) comparison across stories. We found that children made more gains from pre- to post-test in the High Alignability condition than in the Low Alignability condition. We also found effects of production of mental state verbs, as assessed in an Elicitation Task. These results provide evidence for the role of analogical comparison in theory of mind development.

Keywords: analogy; comparison; theory of mind; false belief; cognitive development; social cognition

Background

Theory of mind (ToM) refers to the ability to reason about the mental states of others and oneself, including desires, beliefs, emotions, intentions, and knowledge. Understanding how children arrive at this ability has been a central topic within cognitive science for decades. The aim of this paper is to elucidate the cognitive processes that contribute to this development. Specifically, we propose that analogical comparison processes contribute to ToM development. We describe two experiments that provide evidence for this claim.

In our research, we test children on a set of standard ToM tasks, then expose them to comparison-based training, and then test them on new versions of the ToM tasks. We chose a set of false belief tasks as the pre- and post-tests because false belief understanding is considered the litmus test for measuring children's ToM. The ability to pass false belief tasks is taken as an indication that children are acquiring a representational understanding of mind (Perner, 1991).

Although some recent research suggests that some aspects of false belief understanding emerge very early (Leslie, 1987; see Baillargeon, Scott, & He, 2010 for a review), there is considerable evidence that substantial gains in ToM occur between 3 and 5 years of age (Wellman, Cross, & Watson, 2001). Further, a comparison of different ToM tasks tapping into different types of mental states (e.g., desires, beliefs, emotions) suggests that false belief understanding is part of a stable developmental trajectory of increasingly sophisticated reasoning about mental states (Wellman & Liu, 2004). Thus, it appears that children's performance on false belief tasks is a good indication of a conceptual understanding of others' mental states.

Approaches to ToM Development

What happens between 3 and 5 years of age that allows children to understand others' mental states? Several answers to this question have been proposed. One proposal emphasizes the link between ToM and executive function (Perner & Lang, 1999). Another proposal ("theory-theory") emphasizes changes in children's theories, while a third proposal emphasizes the role of language. Here, we focus on the latter two approaches to ToM development.

Under the theory-theory approach, children undergo a revision of their folk psychological theories between 3 and 5 years of age that allows them to consider false beliefs (Gopnik & Wellman, 1994). Here, *theory* refers to interconnected concepts in the child's mind that can be used to form predictions or expectations about the environment. When children are confronted with evidence that contradicts or cannot be explained by their current theory, they resolve the conflict by revising these theories to account for the new evidence. Theory-change is thus an experience-dependent process.

Research on the influence of language on ToM has examined several aspects of linguistic knowledge and experience, including acquiring sentential complement syntax (de Villiers & Pyers, 2002), acquiring mental state verbs, and exposure to discourse (Lohmann & Tomasello, 2003). Lohmann and Tomasello (2003) developed a training study in which they found that discourse and sentential complement syntax on their own improved false belief understanding. However, the greatest gains in performance occurred in a condition that provided children with a combination of discourse, sentential complement syntax, and mental state verbs. A meta-analysis also indicated that multiple elements of language contribute to false belief understanding (Milligan, Astington, & Dack, 2007). On this evidence, language provides an important set of tools through which children can consider others' perspectives.

In sum, theory-theory emphasizes the importance of learning from experiences, but does not explain how children arrive at meaningful insights from those

experiences. And while the language account is also compelling, it does not specify how children combine language with their experiences in the world to produce false belief understanding. We propose that analogical comparison processes can help fill in these gaps. In the experiments reported here, we designed specific training experiences designed to facilitate key analogical comparisons and thereby provide children with a stronger grasp of mental states.

Analogical comparison has been shown to be a powerful learning process that can reveal similarities and differences between entities, give rise to new inferences, and uncover deep relational structure (Christie & Gentner, 2010; Doumas & Hummel, 2013; Gentner, 1983, 2010; Gentner & Markman, 1997; Holyoak & Thagard, 1989). One reason to think that analogical processes can promote ToM is that false belief understanding depends on understanding key similarities and distinctions between representations. For instance, children must acknowledge that one's mental contents may differ from reality, and that two people may hold different mental states concerning the same experience. Beyond identifying important commonalities and differences, engaging in analogical comparison may give rise to abstract relational structures that provide the child with a more general understanding of beliefs.

The proposal that analogical processes can aid in ToM development has been made before (Baldwin & Saylor, 2005; San Juan & Astington, 2012; Bach, 2014; Pham, Bonawitz, & Gopnik, 2012). However, empirical evidence on these claims is lacking. Our goal here is to test whether analogical processes can foster children's ToM understanding.

Experiment 1

In Experiment 1, we developed a training procedure using comparative questioning to examine whether analogical comparison may aid children's understanding of false beliefs. During this training procedure, we modified the *unexpected contents* task (Perner, Leekam, & Wimmer, 1987) to allow for a comparison between characters who held true and false beliefs. Characters' thoughts were displayed in thought bubbles so as to facilitate children's comparisons across entities. Our hypothesis is that with this type of explicit comparative questioning, differences between characters' mental states and between mental states and reality will become more apparent, allowing children to then generalize from these instances to other situations.

Because this was a novel training approach, whether children could make gains in false belief tasks in a single session was unclear. Thus, as a first pass, we developed a very strong intervention, as described below. There were three conditions: the key *Compare Thoughts* condition and two control conditions. In the *Baseline* condition, children received no intervening training between pretest and posttest. In the second control condition (the *Compare Items* condition), children answered comparative questions (as in the key experimental condition), but these questions had nothing to do with mental states. If mental comparisons provide children with relational knowledge about mental states, children should make gains solely in the Compare Thoughts condition.

Wellman and Liu (2004) reported that the average age of children failing the false belief task was about 4 years 6 months and the average age of children passing this task was about 4 years 11 months. We thus focused on the 4;6-to-5;0 age range since it is an age at which children may be especially ready to gain insight about mental states. In addition, given previous work showing possible gender differences in ToM tasks (Charman, Ruffman, & Clements, 2002), we will also compare performance between males and females.

Methods

Participants One hundred ten 4.5- to 5-year-olds from the greater Evanston/Chicago area participated. The racial and economic composition of the sample reflected those of the local population, with the majority coming from European American, middle- and upper-middle-class families. Children received small gift for their participation.

Nine children were excluded for not finishing the experiment, lack of engagement during experiment, or not understanding English. Another eighteen children (18%) were excluded for ceiling performance in the Pretest. A total of eighty-three children were included in the subsequent analyses (40 females, mean age 4 years 8 months).

Materials The false belief tests were displayed on a laptop. Simplified images of characters and events were displayed in semi-animated fashion using PowerPoint.

Procedure The experiment was run at Northwestern University or at the child's preschool. Children first completed the *diverse desires* task (Wellman & Woolley, 1990; Repacholi & Gopnik, 1997)—an easy task for 4-year-olds. Then children completed the Pretest, comprised of three different false-belief tasks. These included the *change of location* task (Wimmer & Perner, 1983; Baron-Cohen, Leslie, & Frith, 1985), the *unexpected contents* task (Perner et al., 1987), and a *verbal false belief* task (Wellman & Bartsch, 1989; Siegal & Beattie, 1991). In all tasks, children had to answer both a target and memory question correctly in order to pass each task. For instance, in the *change of location* task, children were asked where the character will look for a given object, and where the object actually is.

Following the Pretest, children were given brief training on thought bubbles, adapted from Wellman, Hollander, and Schult (1996). All children received thought-bubbles training, regardless of condition; however, only children in the experimental condition (Compare Thoughts) saw thought bubbles during subsequent training. No thought bubbles were used in the Pretest and Posttest.

After the thought bubbles training, children were randomly assigned to one of three training conditions: Compare Thoughts, Compare Items, or Baseline. In the Compare Thoughts condition, children saw two boxes and two characters involved in an *unexpected contents* situation.

In the classic version of the task, children are shown a box that appears to contain one thing but contains something different. After the child is shown the box's true contents, they are introduced to a character who has never seen inside the box, and asked what the character thinks is inside the box. Young children often incorrectly answer that the character will already know what the box contains. In our version, thought bubbles displayed what the character thought was inside the box. This allowed us to ask children to compare mental states as well as states of the world.

Children initially saw two cereal boxes, which opened to reveal that one contained cereal and the other did not. Then the boxes were closed and two characters were introduced. Thought bubbles showed that each character thought his box contained cereal (see Figure 1). The child was asked to directly compare the characters' mental states: "Are Jay and Luke thinking the same or different?" Then they were asked to contrast the actual contents of the boxes: "Do the boxes contain the same or different things?" Next, the contents of the boxes were revealed to the characters. For each character, we asked: "Was he thinking the same or different than what was inside the box?" This question was intended to prompt the child to compare mental states with reality—revealing either a true belief or a false belief. Nearly all children answered these questions correctly.

After this, children were presented with a new *unexpected contents* scenario, parallel to the first scenario but with new boxes, contents and characters. The same sequence of questions was repeated for this scenario. After this second scenario was completed, the two scenes—each with its own boxes and its own characters—were shown simultaneously, and children were asked to identify what was the same between the two stories: "Remember these two stories? Can you tell me what's the same between these two stories?" The goal was to promote structural alignment between the situations and thereby foster noticing the common relations.

The Compare Items condition was designed to test whether any gains in the experimental condition could be due to comparison itself. In this condition, for example, children were shown two characters, each of whom had brought various items to a picnic. The child was asked to make comparisons between the items. This training procedure had a similar number of comparison questions to the Compare Thoughts condition.

The Baseline condition had no intervening task between the Pretest and Posttest; children went directly from the thought-bubbles training procedure to the Posttest.

We predicted that children who made comparisons between mental states and reality and between characters' mental states in the Compare Thoughts condition would make more gains from Pretest to Posttest than children in either the Compare Items or Baseline conditions.

Results and Discussion

A difference score was calculated for each child, subtracting the number of tasks the child passed in the Pretest from the number of tasks they passed in the Posttest. Because children with perfect Pretest scores were excluded, the difference scores could theoretically range from -2 to 3; however, the actual range of scores was from -1 to 3.

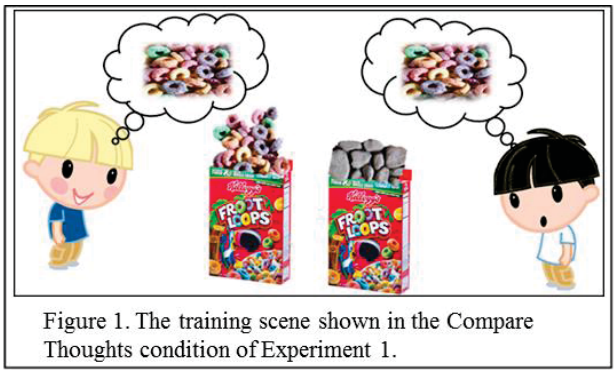

Figure 1. The training scene shown in the Compare Thoughts condition of Experiment 1.

An ANOVA with difference score as the dependent variable and condition and gender as between-subjects factors showed a significant main effect of condition, $F(2,77) = 5.30$, $p < .01$, $\eta^2 = .10$. Planned comparisons indicated that children in the Compare Thoughts condition ($M = .75$, $SD = 1.00$) made more gains in false belief understanding than children in either the Compare Items condition ($M = .19$, $SD = .68$, $p < .01$) or the Baseline condition ($M = .25$, $SD = .70$, $p < .01$). We then compared these means to zero. We found that the mean gain in the Compare Thoughts condition was significantly greater than zero, $t(27) = 3.95$, $p = .001$, whereas the gains in the Compare Items and Baseline were not reliably greater than zero, $t(26) = 1.41$, *n.s.*, $t(27) = 1.89$, *n.s.*

Interestingly, there was also a significant main effect of gender, $F(1,77) = 11.13$, $p = .001$, $\eta^2 = .11$. Across condition, females ($M = .675$, $SD = 1.00$) made more gains from Pretest to Posttest than males ($M = .14$, $SD = .56$, $p = .001$). There was also a marginal interaction between condition and gender, $F(2,77) = 2.93$, $p = .06$, $\eta^2 = .06$. Bonferroni post hoc tests showed that females made more gains in the Compare Thoughts condition ($M = 1.31$, $SD = 1.11$) than in the Compare Items condition ($M = .46$, $SD = .78$, $p < .05$) and the Baseline condition ($M = .29$, $SD = .83$, $p < .01$). Males did not differ in their performance across the three conditions; surprisingly, they showed no significant gains in performance in any condition, all *n.s.*

Children made significant gains from Pretest to Posttest after making mental state comparisons. These results provide evidence that comparison between and among thoughts and states of the world can help children understand others' mental states.

Experiment 2

Although the results of Experiment 1 provide support for the hypothesis that analogical comparison can facilitate false belief understanding, it left some open questions. First, the Compare Thoughts condition was extremely rich. Children compared mental states to states of the world, mental states to other mental states, and whole situations involving true and false mental states to each other. Clearly, this level of intensive comparisons is not likely to happen in real life. In Experiment 2, we aimed for a more naturalistic experience. We showed children one true/false belief story

at a time, but varied how easy they were to compare. The prediction is that children will gain insight when comparison across the stories is easy. This approach better matches real life experience, in which children can and do spontaneously compare across similar instances if they are not too distant in time.

Another concern is that children in the Compare Thoughts training received more exposure to mental states than those in the other conditions. In Experiment 2, we equated exposure to thought-bubbles and mental state depictions. We varied only the ease with which children could compare across instances. If we see more gains when comparison across instances is facilitated, this will provide evidence that comparison can support false belief understanding.

Finally, to test the possibility that gains in this task could also be related to children's command of mental state language, we included a story-telling task in which we measured children's production of mental state verbs. We predicted that children who produced mental state verbs would benefit more from training than those who did not.

In Experiment 2, we again used a Pretest-Training-Posttest structure. The training was again focused on the *unexpected contents* task. Our goal was to increase children's sensitivity to the match (or nonmatch) between mental expectations and reality. To do so, we adapted Loewenstein and Heath's (2009) *repetition-break* pattern, in which two parallel (and readily alignable) situations are presented sequentially, followed by another (alignable) situation that differs in an important way. The idea is that the alignment between the first two situations renders their common structure salient, so that the learner readily notices the change in the last scenario.

In our procedure, children saw a series of three stories. In each story, a character looked at a box—for example, a crayon box—and a thought bubble appeared with the character's belief about its contents (e.g., crayons). Then the contents of the box were revealed. In the first two stories, the character's guess was correct (True Belief; TB). In the third story, the character's belief was shown to be incorrect (False Belief; FB). If children can align the first two stories, the contrast between TB and FB should stand out.

There were two conditions that varied the predicted ease of alignment across the stories. In the *High Alignability (HA)* condition, the three stories were similar in characters and objects; this should facilitate aligning the two stories and noting their common structure. The *Low Alignability (LA)* condition showed the same sequence (two TB and then a FB story), but the characters and objects differed across the stories, making it harder for children to align the stories. Thus, we predicted that children in the HA condition would show more gains than those in the LA condition.

In addition to equating exposure to mental states, this simpler method was intended to reduce demands on attention. For each scenario, children attended to a single character and container, and there were fewer questions. Because the procedure was less demanding, we extended the age range to the whole 4-5 period.

Methods

Participants A total of 137 4- to 5-year-olds were recruited from the greater Evanston/Chicago area. The demographic make-up was similar to that of Experiment 1.

Seven children were excluded for bringing a distracting toy into the testing area, not answering questions during the study, or experimenter error. Another 50 children were excluded for ceiling performance in the Pretest (38%). A total of 80 children were included in the subsequent analyses (38 females, mean age 4 years 6 months).

Materials The false belief Pretest and Posttest were identical to those of Experiment 1, except that we included an extra task: a story-telling task in which two brothers engaged in deception. This was used to measure children's production of mental state words.

Procedure The overall procedure was similar to that of Experiment 1. After completing the diverse desires warmup task, children completed the story-telling task. Their utterances were transcribed and we coded whether children used mental state verbs to describe the scenes.

Following the story-telling task, all children completed the Pretest, followed by the thought bubbles training procedure. Then children were randomly assigned to either the HA or the LA condition. In both conditions, children saw three stories presented sequentially: two TB stories followed by a FB story. Specifically, the first two stories showed 'expected contents' situations; the third showed the classic 'unexpected contents' situation.

In each of the three stories, children saw a box with obvious contents (such as crayons) and a character who had not yet seen inside the box. A thought bubble appeared, depicting the character's belief about the contents of the box. Then we revealed the contents of the box. The child was then asked "Was she right?"—that is, did the character's thought bubble match reality. The child's answer was confirmed by the experimenter, and then they moved onto the next story. The idea was to elicit a comparison between the character's mental belief and the true contents of the box. The first two stories depicted TB, the characters' predictions were right. The third story depicted an FB: the character's prediction was wrong. The idea was that if the child had successfully aligned the first two TB scenarios, then the contrast with the FB scenario in the third story should be highly salient.

We manipulated the alignability of the stories in two ways: (1) the characters and objects were highly similar in the HA condition and much less similar in the LA condition; (2) the same mental verb "think" was used to describe each story in the HA condition; in the LA condition, "think" was used in stories 1 and 3 and "believe" was used in story 2. These dissimilarities were predicted to make alignment more difficult in the LA condition. Thus we predicted that the HA group would be more likely to align the first two stories and extract their common relational structure, and therefore to notice the difference between TB and FB.

Results & Discussion

A difference score (gain) was calculated for each child, subtracting the number of FB tasks passed in the Pretest from the number of FB tasks passed in the Posttest. These scores ranged from -2 to 3. For the story-telling task, we measured whether children produced a single mental state verb (*want, believe,* or *know*).

An ANOVA with gain as the dependent variable and condition, gender, and mental state language as between-subjects factors revealed a main effect of condition, $F(1,72) = 3.50$, $p = .03$, $\eta^2 = .05$. Bonferroni post-hoc tests indicated that children in the HA condition ($M = .75$, $SD = .84$) made more gains from Pretest to Posttest than children in the LA condition ($M = .29$, $SD = .93$). We also compared these means to zero. We found that the gains in both the HA and LA conditions were significantly above zero, $t(39) = 5.65$, $p < .001$, $t(40) = 2.02$, $p = .05$, respectively.

We did not find a significant difference in gains between children who produced mental state language and those that didn't, $F(1,72) = 2.31$, $p = .13$, $\eta^2 = .03$, nor was there a significant interaction between condition and mental state language, $F(1,72) = 1.68$, $p = .20$, $\eta^2 = .02$. However, when we compared these means to zero, we found an effect in the LA condition: only children who produced mental state language made significant gains ($M = .60$, $SD = .68$), $t(19) = 3.94$, $p = .001$. Children in the LA condition who did not produce mental state language did not make gains ($M = 0$, $SD = 1.05$), $t(20) = 0.00$, $p = 1.00$. This difference did not hold for the HA condition, who showed significant gains whether they produced ($M = .77$, $SD = .90$) or did not produce ($M = .73$, $SD = .83$) mental state language. Controlling for language, we found a marginal interaction between gender and condition, $F(1,72) = 2.13$, $p = .09$, $\eta^2 = .03$. Bonferroni post hoc tests revealed that while females made similar gains in both the HA and LA conditions, males made more gains from the HA condition than the LA condition ($p < .01$).

As predicted, we found that children made more gains from the HA condition than the LA condition. It appears that sequential comparison of alignable situations can increase children's insight into mental states.

General Discussion

Theories of ToM development have not typically considered analogical processes as important to children's developing understanding of others' minds. Here we provide evidence that these processes can be a route to understanding mental states. In Experiment 1, asking children to explicitly compare across mental states and between mental states and states of the world allowed them to see what was similar or different between these elements across different characters. Children who received this training showed gains on false belief tasks. In Experiment 2, we used a more naturalistic procedure. Both groups of children received three stories depicting mental states (TB, TB, and FB). But we varied how easy it was for children to compare across instances by varying their alignability. When comparison across stories was easy (HA condition), children made more gains in false belief understanding than when it was difficult (LA). These large difference in gains is noteworthy, given that the two groups received the same kinds of stores in the same order, varying only in the similarity of characters and objects.

Interestingly, children who produced mental state verbs in the story task made gains in both conditions, whereas those who did not made gains only when comparison was easy (HA). This suggests that greater knowledge of mental states (as indexed, and, possibly, abetted by production of mental state language) may facilitate analogical comparison across mental state scenarios. Such an effect would be consistent with previous findings. Evidence suggests that less sophisticated learners (in this case, children who did not produce mental state language) require closely aligned situations in order to benefit from comparison; but with increasing domain knowledge (here, producing mental state language) learners can align relationally similar situations even when the situations lack concrete similarity (Gentner, 2010; Kotovsky & Gentner, 1996). Thus, children who grasp these verbs may be in a better position to notice relational similarities across instances and extract underlying regularities about beliefs.

The findings also suggest possible effects of gender in the ability to gain from these experiences. In Experiment 1, only females showed specific gains from the Compare Thoughts training. In Experiment 2, there was a suggestion that females gained from both high- and low-alignability comparison, while males required high-alignability comparisons. Gender differences in mental state understanding have been reported in prior work (Charman et al., 2002). Future work should clarify the nature and extent of these differences.

How might these kinds of analogical processes influence children's ToM development in everyday life? We believe that the training in Experiment 2 simulated events that children are likely to encounter. Children spontaneously compare between similar situations in their everyday experience. We suspect that this is particularly likely when similar language is used across them. Evidence suggests that common language invites comparison (Gentner & Namy, 1999). For instance, when children hear the same mental state verb used across different situations, they may seek commonalities across those situations (Baldwin & Saylor, 2005). Children from the age of 2 are capable of producing contrastive statements that explicitly compare mental states (Bartsch & Wellman, 1995), such as "You like it, but I don't like it."—suggesting that children compare at least some aspects of mental states even at an early age.

Of course, thought bubbles do not exist in the real world. Nonetheless, children can infer some aspects of mental states through the language and affective reactions of the people around them. And as children learn mental state verbs, they should make gains in the ability to track and compare other's mental states.

In sum, we propose that analogical comparison processes operating over social experiences are instrumental in

children's understanding of mental states and their relation to the factual world.

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