

# The Effect of Language on Mindreading Processes in Children

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# The Effect of Language on Mindreading Processes in Children

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**Abstract** : To understand the impact of language processing on mindreading tasks, the present study compared eye-gazing behaviours observed both with and without false-belief scenarios, using the anticipatory-looking paradigm. 93 5-year old children participated in this study. The children who saw the false-belief event presented without a verbal scenario showed anticipatory-looking that supported their understanding of false-belief. In contrast, the children who saw the false-belief event which was accompanied by a verbal scenario did not show such trend. These findings were discussed with reference to the cognitive load that may have interfered with the implicit processing of the false-belief task.

**Keywords** : Theory of mind, eye-tracking, linguistic processing, mindreading

## 1. Introduction

Mindreading is defined as an ability to impute mental states of other people. One of the signature tasks that measures this ability is called the false-belief task. The false-belief task tests one's understanding of a typical event in which a protagonist accidentally comes to hold a belief that is not true. The task is normally presented by a puppet enactment together with a verbal scenario, as used by Baron-Cohen, Leslie, and Frith (1985). In this scenario, the doll, Sally, puts her marble into a basket. While she is away, another doll, Ann, comes and moves the marble into a box. The main question of the task is to ask the children "where will Sally look for her marble, either in the basket or in the box?" The correct response is that Sally will look in the basket because she has a false-belief that her marble is still in the basket where she put it. However, children at or below 5 years of age normally answer incorrectly as they know that the marble is in the box. This developmental shift of mental representation has been supported by mounting evidence, including a meta-analysis (Wellman, Cross, & Watson, 2001).

More recent studies using a nonverbal version of the false-belief task investigated children's anticipatory looking behaviours. The findings suggest that some

form of mental representation is in place before two years of age (Southgate, Senju, & Csibra, 2007; Surian & Geraci, 2011). Mindreading ability that has been studied using two forms of the false-belief tasks called for further clarification of these relationships. The classic false-belief scenario, described above, is presented mainly with an accompanying verbal description and the task requires verbal responses to answer the question; therefore, it is often referred to as the explicit false-belief task. On the other hand, the recent studies, measuring anticipatory-looking behaviours with an eye-tracking method, do not use a verbal scenario for the false-belief event, and the task requires the processing of perceptual information; therefore it is referred to as the implicit false-belief task. In this implicit false-belief task, the true belief location (such as "the marble was moved into the box") was made unambiguous by totally removing the object from the scene. Grosse Wiesmann, Friederici, Singer, and Steinbeis (2017) found that three-year-old children who failed a verbal version of the false-belief task showed correct anticipatory-looking behaviours, which qualified as a success for a nonverbal version of the false-belief task, i.e. implicit false-belief task. These results suggest that the implicit (non-verbal) version of the false-belief task and the explicit (verbal) version of

the task are not measuring the same thing. Grosse Wiesmann et al. further provided evidence that only the verbal version of false-belief task required syntactic and executive processing to succeed. In contrast, in their longitudinal investigation, Thoermer, Sodian, Vuori, Perst, and Kristen (2011) found that infants' correct anticipatory looking at a false-belief event at 18 months predicted a success with the verbal version of false-belief reasoning at 48 months. In an attempt to resolve this puzzle, Saxe (2013) provides useful explanations in that infants' attribution of false-beliefs and desires are limited to the context in which the stimuli are presented, and lacked flexibility thus showing some basic understanding of false-beliefs. From this interpretation, it is possible that when children pass the explicit false-belief task, they are likely to be more flexible in ways of imputing mental states and encoding linguistic information.

Language processing is one of the key elements for imputing the mental state of the agent in the task. Achim, Guitton, Jackson, Boutin, and Monetta (2013) provided a useful framework for which the difference in demand of processing linguistic/perceptual information in the mindreading tasks may bring about different outcomes in children's performance. They argue that the aspects of processing involved in the task need be addressed when addressing the performance of mindreading. From this perspective, the task with anticipatory-looking paradigm relies on the perceptual level of processing, whereas the explicit false-belief task with a puppet enactment requires children's constant monitoring of perceptual and linguistic information in order for them to respond correctly to the protagonist's false-belief.

The explicit and implicit tasks for mental state attribution have used different formats to present the false-belief event and for the responses. Therefore it is difficult to compare directly the performances of the two tasks. For example, a lack of association between verbal and nonverbal tasks as reported by Grosse Wiesmann et al. may be due to the difference in task format but not to the difference in the aspect of processing needed for the task. To untangle this situation, this study compared the anticipatory-looking paradigm with and without language

processing for false-belief events. The main question is what effect language processing placed on anticipatory-looking behaviours. There is evidence that adults who were subjected to extra cognitive load in the dual task condition had a lower level of accuracy in showing the correct anticipatory-looking behaviours (Schneider, Lam, Bayliss, & Dux, 2012). It is therefore possible that when the participants are faced with linguistic information, that they spontaneously process such information. Thus if the narratives are accompanied with false-belief events in the anticipatory-looking paradigm, such linguistic information may facilitate or hinder the participants' perceptual processing of false-belief events when compared with the case when no linguistic information was present.

The present study compares two conditions using the anticipatory-looking paradigm to examine the effect of processing linguistic information on children's reasoning of false-beliefs.

## 2. Method

### 2.1. Participants.

93 preschool children (42 girls) aged between 4 and 6 year olds ( $M = 60.1$  months,  $SD = 9.6$  months) participated in the study. They were from the mid- to lower-middle socioeconomic status backgrounds located in the Kansai area of Japan. Parental consents were obtained prior to the study and the study design was approved by the ethical committee of the author's institution.

### 2.2. Design.

Two conditions were prepared for the mindreading task. The non-verbal condition included a video clip depicting the protagonist holding a false-belief because of the unexpected transfer of a ball by the puppet (bear), whereas the verbal condition included an additional audio narration which was played simultaneously with the video-clip. This study is a part of a larger project investigating preschool children's development of theory of mind, which included several additional measures of explicit false-belief tasks, executive functions and picture-sequencing tasks (Baron-Cohen, Leslie, & Frith, 1986).

### 2.3. Stimuli in the mindreading tasks

The video clip depicting the protagonist who came to hold a false-belief was created based on the work of Southgate et al. (2007). The task has two phases: the first phase is familiarising the participants with the

context by showing the puppet (bear) putting the ball into one of the two boxes which were aligned horizontally. The female protagonist watches the bear's actions, then she retrieves the ball by opening the box in which the bear put the ball. Two

#### Familiarisation

	1	2	3	4
				
言語刺激	1. クマさんが、ボールをもっています。 2. クマさんは、お姉さんの前にある缶にボールをいれます。			7. お姉さんは、ボールを取ります。

#### False-belief task 1

	1	2	3	4	
					
言語刺激	1. クマさんが、ボールをもっています。 2. クマさんは、お姉さんの前にある缶にボールをいれます。		3. あっ！電話がなっています。 4. お姉さんは電話の音をする方を見ます。 5. その間に、クマさんは、ボールをもう一つの缶にうつします。		6. それからクマさんは、缶からボールをとりだします。 7. お姉さんは、ボールを取ります。

#### False-belief task 2

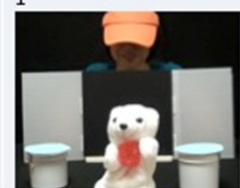


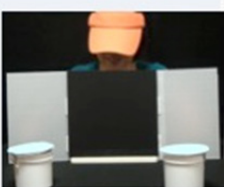
	1	2	3	4	
					
言語刺激	1. クマさんが、ボールをもっています。 2. クマさんは、お姉さんの前にある缶にボールをいれます。		3. それから、クマさんは、ボールをもう一つの缶にうつします。 4. あっ！電話がなっています。 5. お姉さんは電話の音をする方を見ます。 6. その間にクマさんは、缶からボールをとりだします。		7. お姉さんは、ボールを取ります。

Figure 1 Schematic images of the experimental task. The Japanese text describes the narrations which were played back simultaneously with the video in the verbal task only condition. The nonverbal condition was identical, but with the absence of Japanese narrations.

familiarisation trials in which the bear placed the ball in one of the boxes were presented in a counterbalanced way. After the familiarisation phase, the main test phase began. The main false-belief event was displayed as follows: the bear puppet used in the familiarisation phase puts the ball into one of the two boxes while the female protagonist was looking at the scene. When the telephone rang, the female protagonist turned away. While she was looking away, the bear moved the ball to the other box and then took the ball totally away from the scene. The main false-belief task included one of the two versions of the false-belief events, which differed in the timing of movements of the ball. The schematic images of the task are presented in Figure 1.

#### 2.4. Apparatus

The Eye-tracker (Tobii X-60) tracked the participants' eye-movements to measure fixation durations. The eye tracker was attached to the bottom of a 17-inch screen of a laptop computer (DELL, Precision 7710). The equipment was placed in a quiet room.

2.5. Procedure. The children were tested individually. Each child sat on a chair that was situated at a viewing distance of approximately 50 cm away from the computer screen and eye-tracker. After a 9-point calibration of the eye tracker, the experiment was conducted.

### 3. Results

#### Area of Interest (AOI)

In this study the child participants' eye movements were tracked to see if they would look at the box that the protagonist wrongly believed she would find the ball. The AOI was set when the protagonist turned back towards the box and the chime sounded until the video ended. The proportion of the fixation duration was calculated for each test and was used for the analyses.

#### Analyses of overall design.

The proportion of fixation was compared for the two versions of the false belief video. There was no significant difference in the proportion of fixation duration for each location between the two versions of

false-belief task for: verbal condition:  $t(49) = 1.00$  and  $t(49) = .89$ ,  $ps > .1$ , and for nonverbal condition  $t(40) = 1.3$  and  $t(40) = .13$ ,  $ps > .1$ .

A mixed ANOVA for 2 locations (correct/ incorrect) x 2 experimental conditions (verbal/ nonverbal) was conducted for the proportion of fixation duration (Figure 2). There was a significant main effect for the two conditions:  $F(1,91) = 5.09$ ,  $p = .03$ . However, there was no significant main effect for location:  $F(1, 91) = 2.34$ ,  $p = .13$ ; also there was no significant main effect for the interaction between locations and conditions:  $F(1, 91) = 1.39$ ,  $p = .24$ . Planned comparisons for the level of experimental conditions were conducted to investigate whether correct anticipation was made under the experimental conditions. For the nonverbal condition, there was a trend that the child observers looked for a longer period of time at the correct location than the incorrect location:  $F(1, 91) = 3.38$ ,  $p = .069$ , whereas no difference was found between these locations under the verbal conditions. The correct location is location where the protagonist believes that the ball is located, which maybe a false belief.

To better understand the significant condition effect, the measures for explicit false-belief tasks, picture-sequencing tasks, executive processing as measured by digit span, Dimensional Card Change Sort tasks and receptive language were also examined and no difference was found between these conditions (all  $ps > .1$ ), suggesting that the random assignment of these two conditions was not skewed by the processing abilities of the children.

#### Analyses of the explicit FB task

The previous section examined the difference between the experimental conditions with and without language processing. It was found that the children under the condition that involves language processing did not make any preferential anticipation in their eye-movements. In the present analysis, the children were then split into two groups. The first group included the children who passed the explicit false belief task and the second group included the children who did not pass the task. It is possible that under the verbal condition, the children who passed the explicit FB task were able to perform well on the FB task assessed by

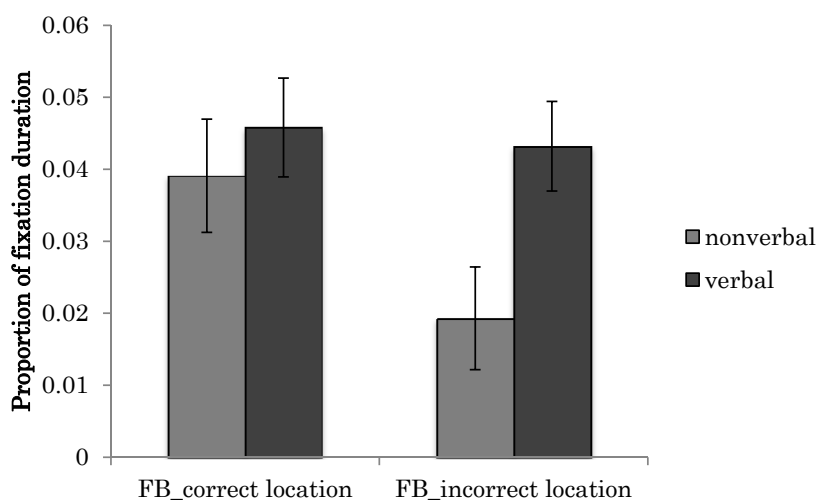


Figure 2 Proportion of fixation duration for gazing at the location in two conditions

anticipatory looking, whereas the children who did not pass the explicit FB task might have failed to anticipate the correct location because of the required language processing.

Children's scores for the explicit FB task were used to make two explicit FB performance groups (explicit FB task passed:  $n = 47$ ; explicit FB not passed:  $n = 46$ ). Mixed ANOVAs for 2 locations (correct/ incorrect)  $\times$  2 experimental conditions (verbal/ nonverbal) were conducted separately for these groups. For the group that did not pass explicit FB task, there were no significant main effects for condition  $F(1, 44) = .50$ ,  $p = .48$ , or for interactions between locations and conditions:  $F(1, 44) = .08$ ,  $p = .78$ . For the locations, there was a trend for a significant effect of locations for preferential looking at correct locations:  $F(1, 45) = 3.46$ ,  $p = .07$ .

For the group that passed the explicit FB task, there was a significant main effect for the condition  $F(1, 45) = 5.70$ ,  $p = .021$ , but not for the locations  $F(1, 45) = .06$ ,  $p = .81$  or for the interaction between locations and conditions:  $F(1, 45) = 1.91$ ,  $p = .17$ . The follow-up analysis suggests that the significant effect of condition was due to the significantly longer looking at the incorrect location in the verbal condition than in the nonverbal conditions:  $F(1, 45) = 7.44$ ,  $p < .01$ .

#### 4. Discussion

The present study examined the effect of processing linguistic information while viewing a false-belief event

under the condition of with or without simultaneous verbal inputs about the false-belief scenario. When the verbal inputs were presented, the child perceivers looked longer at the AOIs. This result suggests that the child perceiver was influenced by such verbal inputs when viewing the false-belief event. When the location of eye-gaze was considered, the perceivers under the nonverbal condition made anticipatory-looking based on the protagonist's false-belief, whereas those in the verbal condition group gazed equally at both locations. Although the statistical analyses suggest that this trend needs to be interpreted with caution, the processing of linguistic information played a role that resulted in looking at both locations equally longer. When the perceivers' performance on the explicit false-belief task was considered, the children who had demonstrated a full understanding of explicit false-belief, looked significantly longer at the incorrect location in the verbal condition than in the nonverbal condition.

Why did some of the perceivers who had a full understanding of false-belief not look at the AOI as expected? One possibility is that these children engaged with the scenario while looking at the scene and monitoring the movement of the bear puppet and the protagonist carefully. In this false-belief event in this implicit FB task a hidden object was removed from the scene while the protagonist was not looking and before the protagonist reached for it. The perceivers had experienced the false-belief event in

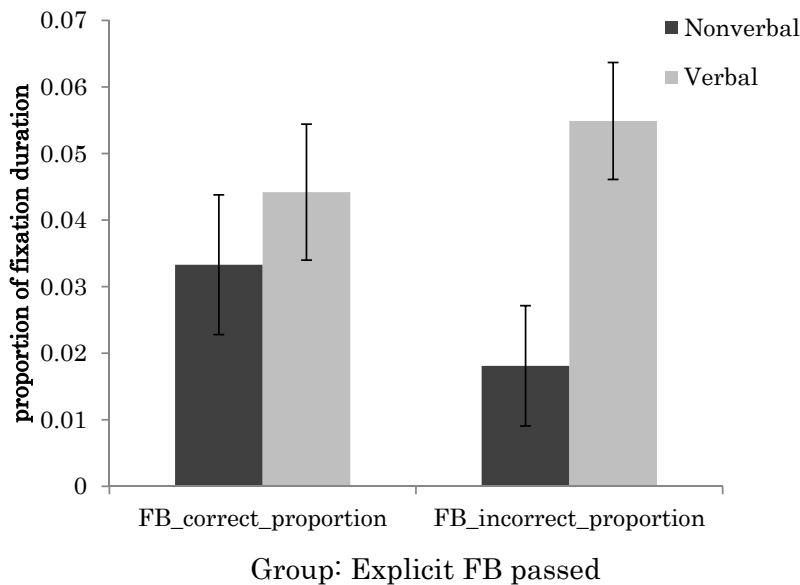
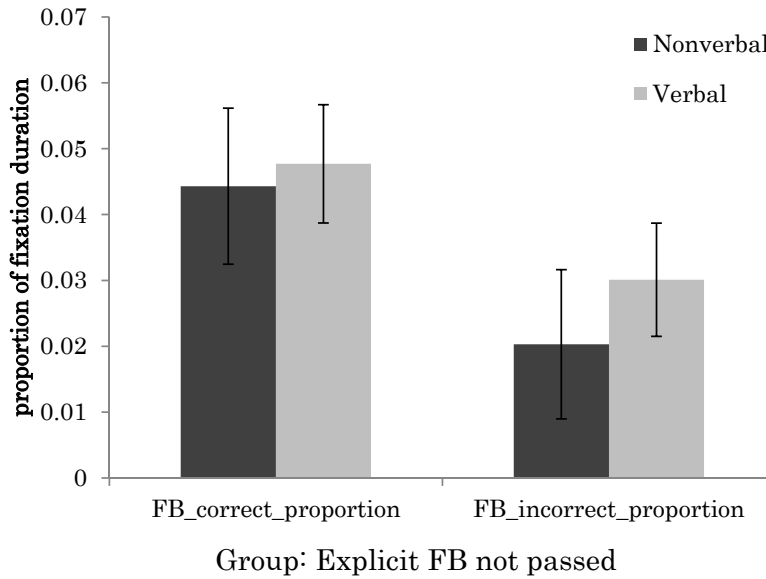


Figure 3 Proportion of fixation duration for gazing at the location in two conditions when analysed by the groups that passed explicit FB task and that did not pass.

which the hidden object remained at the scene in the explicit false-belief task. Thus when the verbal information was accompanied with the implicit FB task, the perceivers might have been confused by what they expected to see in the location as in the explicit FB task. In the nonverbal condition, because the information related to false-belief event was presented only perceptually, the perceivers might not be aware of such a difference. In the verbal condition, albeit the perceptual and linguistic information are both related to the false-belief, additional linguistic processing might have hindered the perceivers in responding in a way that even infants were able to do

when only perceptual processing was required. The adults in the anticipatory-looking paradigm under the extra cognitive load condition, such as listening to a series of letters or even a higher cognitive demand such as 2 back letter repetition, affected their gazing at correct locations (Schneider et al., 2012). These findings support the possibility of the interpretation of the present study that the children were influenced by the extra linguistic information even though it was coherent with the perceptual information.

In terms of the framework of Achim et al, the distinction between the information presented linguistically and perceptually in the task is important,



and it resonates with the present approach that compared the same anticipatory-looking behavior while controlling for the presentation of linguistic information. The implicit false-belief task that employed eye-gaze measurement has been assumed to differ from the standard explicit false-belief task in terms of executive demands and that there was minimal association between the two tasks (Grosse Wiesmann et al., 2017). It is possible to suggest that such differences in executive demand may be derived from how the task is presented through different channels such as linguistic and perceptual levels. The task required for multiple levels of processing may inherently require a greater degree of resources in processing each channel.

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# 子どものマインドリーディング処理過程における言語の影響

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## 要 旨

本実験は、言語処理がマインドリーディングに与える影響を検討するため、ナレーションの有無条件において登場人物の誤信念の理解課題を暗黙的に正しく処理できるかどうか、視線注視行動を測定した。93名の5歳児の協力者がどちらかの条件で登場人物の誤信念を理解しているかどうかを検討する課題ビデオを視聴した。ナレーション無し（言語処理無し）条件では、協力者の視線注視行動は、登場人物が誤信念にしたがって行動をすることを予期した動きをみせ、誤信念を暗黙的に理解している傾向を示す結果が得られた。一方、ナレーション有り（言語処理有り）条件において、同じ課題ビデオを視聴した協力者の視線注視行動は、登場人物の誤信念に関係なく、ランダムな動きをみせた。これらの結果について、言語処理の負荷とマインドリーディングとの関係について考察した。

キーワード：心の理論、アイトラッカー、言語処理、マインドリーディング