

Perspective Taking about Interacting Characters: Detecting Theory of Mind Inferences from Eye Movements

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ABSTRACT

In 2 experiments, eye-movements were recorded from 60 subjects viewing complex pictures and listening to complex stories about interacting characters. Each story was presented with a single image, but told from the perspective of Character A (the person depicted on the left), Character B (the person on the right), or a Neutral perspective. Each story was in one of two Theory of Mind (ToM) categories (Baron-Cohen et al., 1999): 1st-order (in which understanding the story required inferences about the perspective of the given character) or 2nd-order (in which understanding the story required inferring the given character's inferences about the perspective of the other character). The predicted Perspective X ToM interaction was found; at a critical point in the story, listeners looked at the character from whose perspective the story was told during 1st-order stories, but at the other character during 2nd-order stories.

BACKGROUND

Perspective taking, or processing information according to another's point of view, is related to *Theory of Mind*, the ability to attribute mental states to others (Baron-Cohen et al., 1999; Premack & Woodruff, 1979). This ability is the foundation of successful communication and language understanding, as well necessary for effective collaboration; it includes the ability to reason about others' beliefs, emotions, thoughts, desires, goals, and intentions. ToM inferences can be made about what a person is thinking, or about what they think about what another is thinking (Baron-Cohen, 1989; Happe, 1993; Perner & Wimmer, 1985).

Recent ToM studies have found that looks to appropriate regions signal understanding of another's beliefs, and that anticipatory eye-movements are even more informative than verbal responses about whether a person can take the perspective of a character (Southgate et al., 2007). The goal of the current project is to non-invasively measure social inferences in real-time while subjects are engaged in thinking about complex social scenarios.

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PROJECT

- This project develops a novel paradigm for relating listeners' eye gaze to their interpretation of the perspectives of interacting characters in an illustrated story.
- Listeners were not informed explicitly about characters' mental states (as in previous studies), but made their own *Theory of Mind* (ToM) inferences.
- Complex stories and illustrations were used.

PREDICTIONS

- At a critical point in the story, listeners should look at the character whose perspective is most relevant.
- For 1st-Order ToM stories (told from Character A's or Character B's perspective), listeners should look at the character from whose perspective the story was told.
- For 2nd-Order ToM stories (which require inferences about that character's thoughts about the mental state of the other character), listeners should look at the other character.
- This pattern should be reflected in an interaction between *Perspective* and ToM story type.



1ST-ORDER ToM STORY

SETTING THE SCENE: "Eliza and Raymond are expecting a baby. They are attending a Lamaze childbirth class, sitting on the floor and practicing breathing exercises."

PERSPECTIVES (One of these; played during blank screen):

- Character A:** "Eliza is excited about her pregnancy, but she's also very worried, so she's doing everything she can to prepare. She is committed to doing exactly what her doctor says, which meant having to change her diet and kick some bad habits. This breathing thing had better work!"
- Character B:** "Raymond is here to support his wife, but he hates to miss his Sunday football game; he can't wait to get back home to see who's winning. Will this class really matter? It certainly doesn't seem to be calming him down!"
- Neutral Perspective:** "The class hasn't been much fun so far, and the exercises seem kind of pointless. Sitting on the cold hard floor is neither comfortable nor sanitary. And the hideous maternity clothes aren't very inspiring either!"

WRAP-UP (Image reappears): "One can only imagine what it's going to be like when the baby gets here."



2ND-ORDER ToM STORY

SETTING THE SCENE: "Randy and Maya are high school students who have been dating for a year. They are hanging out on the train tracks in the middle of the woods, discussing their relationship."

PERSPECTIVES (One of these; played during blank screen):

- Character A:** "Randy is a loyal boyfriend, with no interest in dating other girls. Even though they're both only 16, he's thinking ahead and wants them to apply to the same colleges. He has just asked: Wouldn't it be great to be together through all of life's exciting experiences?"
- Character B:** "Maya is a popular girl, with many other boys interested in her. She isn't yet sure what she wants in a partner, the only way to find out is to date other people. She has just delivered the news that she wants to be just friends."
- Neutral Perspective:** "Their parents think they are much too young to be seriously involved. So Randy and Maya have been forbidden to see each other outside of school, and the only place they can meet is by the tracks. Deep in conversation, they fail to notice that a train is approaching."

WRAP-UP (Image reappears): "Who knows what the future will bring?"

EXPERIMENTS 1 & 2

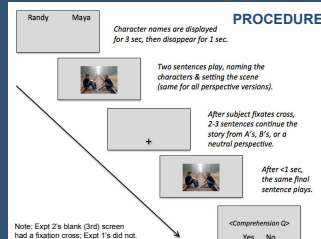
Design and Subjects

- 20 (Expt 1) and 40 (Expt 2) undergraduates listened to 20 critical stories about situations involving two characters, while viewing a photograph depicting the situation (with Character A on the left and B on the right).
- Each critical story had 1 of 3 **Perspective** versions: one told from Character A's perspective, one from Character B's perspective, and one from a neutral perspective, counterbalanced across 3 lists with each listener hearing one version.
- Each critical story required 1 of 2 types of **Theory of Mind** (ToM) inferences about the reactions or emotions of the character from whose perspective it was told (1st-Order) or about the other character's reactions or emotions (2nd-Order).

Materials

- All scenes were complex naturalistic photos unaltered from Internet databases.
- 1st-Order stories were free of surprise events, false belief, or deception, and required no predictions about the other character's mental state. In 2nd-Order stories, the character whose perspective the story took was concerned with the mental state of the other character. 2nd-order stories often involved deception or sharing surprising or important news.
- 20 filler stories were about images of animals, objects, one person, or groups.
- Listeners' eye positions were sampled at 500 Hz by an EyeLink II eye-tracker.

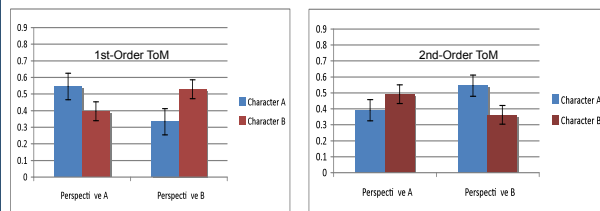
PROCEDURE



Critical measure: The listener's first look when the image reappeared (see Altman, 2004).

RESULTS - EXPERIMENT 1 (hand coding)

Proportions of First Looks to Characters



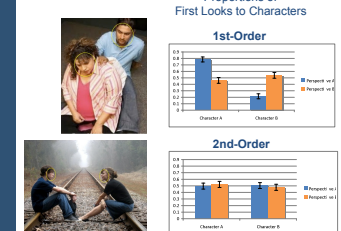
During the blank screen in Expt 1, some listeners kept their gaze steady, while others looked around, perhaps exploring a mental record of the empty space as the story continued (see Altmann & Kamide, 2003). 37% of the time, they were already looking at a character when the image reappeared; this made it difficult to detect their first looks and code them automatically.

In order to make the direction of the first looks more meaningful, we ran Expt 2, with a fixation cross during the blank screen that accompanied the distinctive perspectives to prevent listeners from using different strategies. We also used heat maps from Expt 1 to more precisely define the regions-of-interest targets for Expt 2.

RESULTS - EXPERIMENT 2 (automated coding)

Experiment 2's automated coding replicated the predicted *Perspective X ToM* interaction. The effect was stronger for 1st-Order stories than 2nd-Order stories.

Proportions of First Looks to Characters



DISCUSSION

- This paradigm succeeded in measuring perspective-taking inferences on-line. We found the predicted *Perspective X ToM* interaction.
- This was the case despite the fact that the stories and images were complex and many aspects were uncontrolled, such as color and luminance values, the emotional expressions on characters' faces, the distance between them, and their direction of regard (which is known to affect observers' gaze). Some characters faced each other, which may have led to back-and-forth looks, and others faced the same direction or toward the same object, which may have drawn looks as well.
- Other approaches have not measured subjects' inferences on-line as we aimed to do here, but explicitly informed subjects about characters' mental states with verb changes (e.g., *thinks* vs. *feels* vs. *sees*; Saxe et al., 2006; Zaitchek et al., 2010). This project used realistic, engaging stimuli that captured reasoning about social nuances in a way previous studies have not.
- Follow-up work will focus on dynamic gaze signatures, successfully detecting and making inferences about characters' goals, and joint attention between collaborating people.

CONCLUSIONS

- These findings establish that eye gaze can be guided by inferences about the perspectives of interacting characters. Listeners' inferences about characters' mental states were reflected in distinct patterns of eye movements over the same image.
- The current approach, which required subjects to make inferences on their own about complex social scenarios, has the potential to improve measures of ToM and perspective-taking in socially embedded cognition and social cognitive neuroscience.