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Children's Use of Triadic Eye Gaze Information for "Mind Reading"

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Five experiments examined children's use of eye gaze information for "mind-reading" purposes, specifically, for inferring another person's desire. When presented with static displays in the first 3 experiments, only by 4 years of age did children use another person's eye direction to infer desires, although younger children could identify the person's focus of attention. Further, 3-year-olds were capable of inferring desire from other nonverbal cues, such as pointing (Experiment 3). When eye gaze was presented dynamically with several other scaffolding cues (Experiment 4), 2- and 3-year-olds successfully used eye gaze for desire inference. Scaffolding cues were removed in Experiment 5, and 2- and 3-year-olds still performed above chance in using eye gaze. Results suggest that 2-year-olds are capable of using eye gaze alone to infer about another's desire. The authors propose that the acquisition of the ability to use attentional cues to infer another's mental state may involve both an association process and a differentiation process.

A pair of eyes is a relatively simple stimulus that involves only two dark dots encircled by surrounding white areas. Yet, it conveys strong directional information that is unparalleled by any other dark–white contrasts (Cline, 1967; Gibson & Pick, 1963). Ethologists and other behavioral scientists have noted the important and unique role that eye gaze plays in inter- and intraspecies interactions. For many animals, eye gaze establishes dominance, initiates and terminates aggression and mating behaviors, and sometimes indicates the location of food and signals the direction of an approaching predator (Argyle & Cook, 1976; Eibl-Eibesfeldt, 1989; Gomez, 1994b; Povinelli & Eddy, 1996a, 1996b; Rutter, 1984).

Humans have extended the use of eye gaze to many other situations (for a review, see Kleinke, 1986, and Rutter, 1984). One of the main uses of eye gaze that appears to be unique to humans is to reveal another person's mental activities, or "mind-reading" (Baron-Cohen, 1994, 1995a). Eye gaze may be used to determine another individual's state of mind (e.g., focus of attention, knowledge, desire, and belief). Baron-Cohen (1995a, 1995b) theorized that the ability to use eye gaze is crucial to the development of a theory of mind, and that the lack of the sensitivity to eye gaze is related to impairments in social and cognitive abilities such as autism (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995; Phillips, Baron-Cohen, & Rutter, 1992).

In the past two decades, it has been found that the development of theory of mind undergoes a dramatic shift around 4 years of age (Perner, 1992; Wellman, 1990). Four-year-olds rapidly develop the ability to represent others' beliefs, and to understand representational change of their own beliefs, whereas 3-year-olds have difficulty with such concepts. This developmental pattern has been found in numerous studies (see Astington & Gopnik, 1991, for a review), although a few investigators have claimed that 3-year-olds have a fledgling understanding of others' beliefs (e.g., Chandler, Fritz, & Hala, 1989; Siegal & Beattie, 1991).

Many researchers believe that the rapid development in children's understanding of belief and false beliefs around 4 years of age is an outcome of many earlier developments. Wellman (1990) suggested that one of the precursors to the development of the understanding of beliefs is the understanding of another's desire. Baron-Cohen (1994) added to Wellman's model a Shared Attention Mechanism (SAM) that enables children to infer others' desire through the use of eye gaze information. According to Baron-Cohen (1994, 1995a), SAM evolves from two mechanisms, an intentionality detector and an eye direction detector, which both emerge during the first year of life. The Shared Attention Mechanism allows children to determine the object of a person's attention and, when combined with other information, why the person is attending to the particular object. The Shared Attention Mechanism forms the basis for the later development of a theory-of-mind mechanism, the mechanism responsible for understanding beliefs (Leslie, 1994).

To date, little empirical evidence exists to substantiate Baron-Cohen's claims regarding the SAM and young children's use of eye gaze information for "mind-reading" purposes. Nevertheless, extensive studies have been conducted to examine the early development of children's sensitivity to eye gaze and their use of eye gaze information during face-to-face interaction, joint attentional activity, and referential communication (for a review,

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see Baldwin & Moses, 1994). These studies can be divided into two categories: One addresses the issues involving dyadic eye gaze and the other addresses the development of triadic eye gaze use. Behavioral and neurobiological evidence to date suggests that it is necessary to differentiate between these two types of eye gaze because of differences between them in information processing requirements, function, ontogeny, and underlying neurological mechanisms (Argyle & Cook, 1976; Baron-Cohen, 1995a, 1995b; Perrett & Mistlin, 1990; Perrett, Mistlin, & Chitty, 1987).

Dyadic eye gaze involves a relatively simple information processing mechanism. It only requires the perceivers to identify whether two eyes have the same dark–white configuration and then use the information to determine whether an individual's eyes are directed at them or averted. The main function of dyadic eye gaze is to regulate face-to-face social interaction (Argyle & Cook, 1976; Eibl-Eibesfeldt, 1989; Hains & Muir, 1996; Kleinke, 1986; Rutter, 1984). Infants' sensitivity to adults' eyes emerges as early as 2 to 3 months of age (e.g., Caron, Caron, Caldwell, & Weiss, 1973; Caron, Caron, Roberts, & Brooks, 1997; Maurer & Salapatek, 1976; Vecera & Johnson, 1995). For example, Maurer and Salapatek found that 2-month-olds fixated the eyes longer than other internal features and periphery of the face. Vecera and Johnson showed that infants of the same age are also capable of discriminating between directed and averted gaze. Hains and Muir (1996) further demonstrated that infants between 3 and 6 months of age are sensitive to an adult's gaze aversion during dynamic face-to-face interaction. They smile more when an adult's eyes are fixated on them and less when the adults' eyes are averted (Hains & Muir, 1996; Symons, Hains, Dawson, & Muir, 1996).

Triadic eye gaze, on the other hand, involves a third party (an object or a person) as the focus of the attention of the looking individual. To achieve triadic eye gaze, the perceiver must use the asymmetrical configuration of the dark–white contrast of another individual's eyes, and trace along two invisible sight-lines to their convergent point, that is, the third part of the triad (e.g., an object). Although triadic eye gaze can also be used to regulate one-to-one social interaction, another major and unique function of triadic eye gaze is that it can be used to reveal an individual's focus of attention and internal states (desire, goal, etc.). Current evidence suggests that the use of triadic eye gaze emerges later than that of dyadic eye gaze (at about 6 months), although infants can briefly follow head orientation at an earlier age (D'Entremont, Hains, & Muir, 1997). Butterworth and Grover (1990) showed that infants at 6 months of age orient their gaze to the same side as their mother's gaze but are confused about which object to attend to when several objects are present on the same side. Twelve-month-olds overcome this difficulty (Butterworth, 1991), and also begin to use their own eye gaze to engage their mothers while pointing to objects in the environment (Desrochers, Morissette, & Ricard, 1995; Morissette, Ricard, & Decarie, 1995). Butterworth further indicated that infants at 12 months of age begin to use an adult's eye gaze to establish joint attention with the adult, and by about 18 months, they can accurately determine others' focus of attention (Butterworth, 1991; Butterworth & Jarrett, 1991). However, a recent finding of Corkum and Moore (1995) suggested that this ability may develop at a later age unless infants are reinforced for joint attention response. At about 18 months of age, young children also begin to use triadic eye gaze and other directional cues (e.g., pointing and head orientation) for referential communicative purposes such as learning new words (Baldwin, 1993, 1995).

In contrast to relatively extensive research on the development of the use of dyadic eye gaze during social interactions and the use of triadic eye gaze during joint attentional activity and referential communication, little evidence exists as to when and how young children develop the ability to use triadic eye gaze for "mind-reading" purposes. The only relevant study, to our knowledge, was conducted by Baron-Cohen et al. (1995). In their study, children, with or without autism, were shown a picture depicting a boy named Charlie (the Charlie task) whose eye gaze was fixated at one of four sweets located in each corner of the picture (upper left, upper right, lower left, and lower right). They were asked which sweet Charlie wanted. Most normal 4-year-olds had no difficulty in using Charlie's eye gaze to determine his desired sweet, whereas autistic children failed to do so. Because the main focus of Baron-Cohen et al. was on autistic children, only 4-year-olds were used as a normal comparison group in their study. Hence, the development of the ability to use triadic eye gaze to infer another person's desire is not known.

Five experiments were conducted to replicate and extend Baron-Cohen et al.'s (1995) work and to describe the developmental function of the use of eye gaze information in children between 2 and 5 years of age. In the first experiment, a task similar to the Charlie task was used to determine children's use of eye gaze information for inferring an individual's desire. In addition, we also investigated children's accuracy in determining the individual's eye direction and focus of attention, a factor not tested in the Baron-Cohen et al. study. The remaining four experiments were conducted to further delineate factors that contribute to young children's success or failure in using triadic eye gaze to infer another individual's desires.

Experiment 1

Method

Participants. Ninety-four, predominantly White middle-class children (54 boys) participated in the study after their parents gave informed consent. They were divided by age into four groups: twenty-two 3-year-olds (M age = 3 years 8 months), twenty-six 4-year-olds (M age = 4 years 7 months), twenty-five 5-year-olds (M age = 5 years 6 months), twenty-one 6-year-olds (M age = 6 years 6 months).

Materials. Children were shown color pictures depicting a boy named Larry looking at one of six surrounding objects (see Figure 1a). The pictures were adapted from Baron-Cohen et al.'s (1995) Charlie task. We used six objects in each of the pictures so that Larry could attend to one of six possible locations: right, left, upper-right corner, upper-left corner, lower-right corner, and lower-left corner. Objects were drawn from a variety of categories of items commonly desired by children (e.g., toy items, food, drink), and the objects in one picture differed from those in another. This procedure avoided a possible response bias. If the same type of candy was used, children might either change their choice of candy from one trial to another simply to avoid giving the same answer, or they might choose the same candy to avoid answer switching.

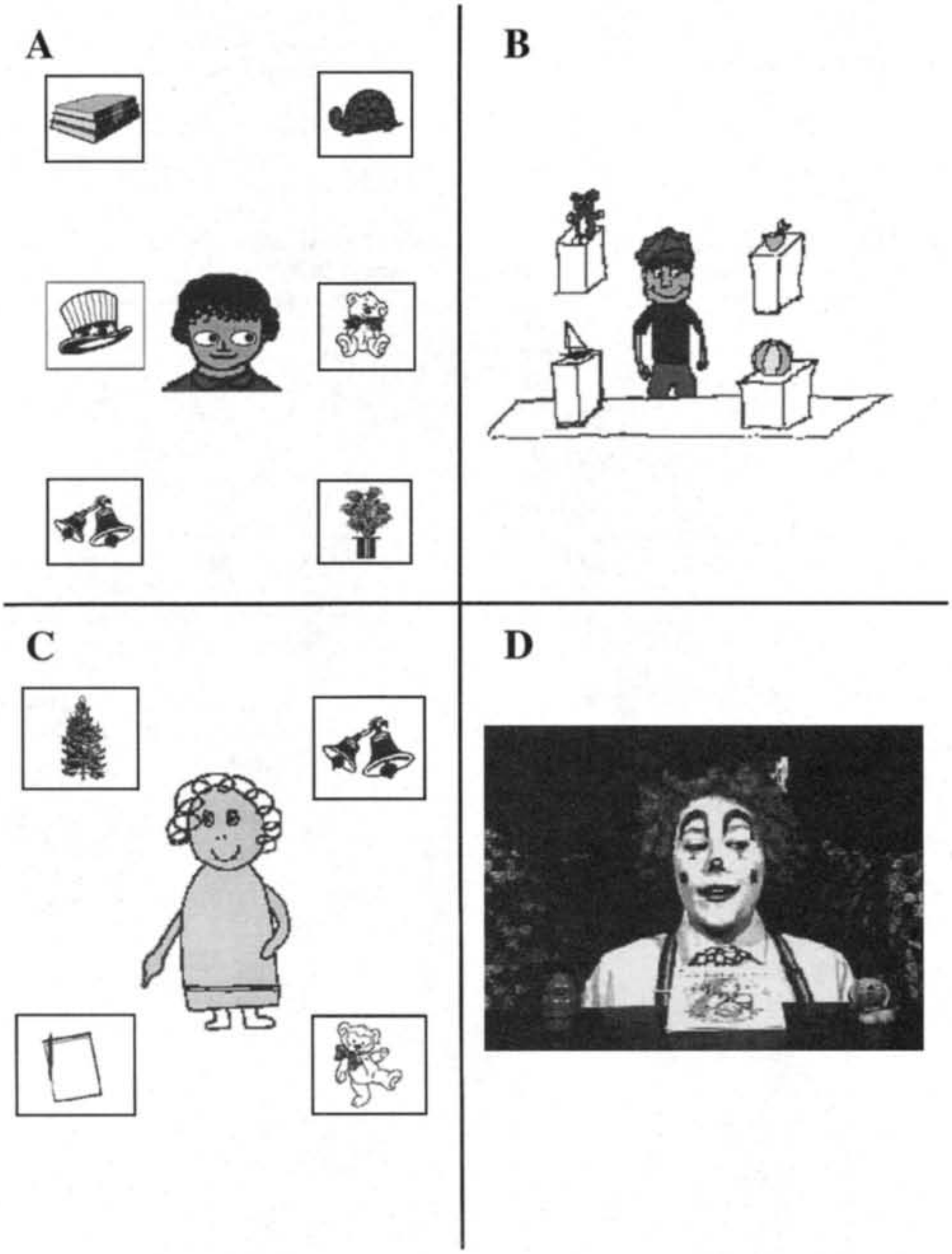

Figure 1. Examples of stimuli used in Experiments 1 through 4. Panel A: the Larry task (Experiment 1); Panel B: the Larry story (Experiment 2); Panel C: the Mary task (Experiment 3); Panel D: the Giggles task.

There were two sets of pictures (Sets A and B), each containing nine pictures, which were further divided into three subsets (three pictures per subset) for different questioning conditions (see below). For the three pictures of each subset, Larry's eye gaze was directed at upper, middle, and lower levels, respectively. Whether eye gaze was directed to the right or left side was determined by a randomization procedure to ensure that all six directions were included in the pictures when Sets A and B were combined. For each subset, the exact order in which the pictures were presented to the child was determined by another randomization procedure prior to the experiment.

Procedure. Children were randomly assigned to Set A or Set B and tested individually. They were asked if they would like to play a game with the experimenter that involved looking at pictures about a little boy named Larry and answering questions about him. For the first three pictures, the child was asked: "In this picture here, what does Larry *want?*" (the Want Question condition). This question determined whether the children could spontaneously infer Larry's desired object based on information from his eye gaze. For the subsequent three pictures, the child was asked: "In this picture here, *where* is Larry looking?" (the Where Question condition). This question tested the children's ability to determine the direction of Larry's eye gaze. For the last three pictures, the child was asked: "In this picture here, *what* is

Larry looking at?" (the What Question condition). This question examined whether the children could determine Larry's focus of attention.

No feedback was given to the children. If the child was unsure of responding, the experimenter explained that guessing was allowed. As each new picture was shown, the experimenter first stressed "In *this* picture here . . ." so that the child would not carry over the answer from the last picture. Each time a new question was asked, the experimenter tried to ensure that the child realized the question to be asked was about to change ("Now, I am going to ask you a different question"). The Want Question was always asked before the other two eye gaze questions to avoid biasing children to infer that the experimenter was expecting an answer that must involve eye gaze. The Where Question was always asked before the What Question to allow for answers about the direction of Larry's eye gaze rather than the specific objects depicted in the picture that was the focus of Larry's attention. As our main purpose was to determine children's ability to use eye gaze for determining another's desire, we did not counterbalance the order of presentation to avoid a potential learning confound for the Want condition.

Scoring. Children received one point for each correct answer given. For both the Want and What Questions, to obtain one point, children had to indicate the object in the picture at which Larry was looking. For the Where Question, however, children could receive one point if they indicated the specific direction of Larry's eye gaze (e.g., upper left, lower right). In addition, a half point was given for a more general answer that was still somewhat correct (e.g., answering that Larry is looking up rather than up *and* to the right- or left-hand corner).

Results

Preliminary analyses failed to reveal any effects of Larry's specific eye directions (upper, middle, or lower levels, and left or right). Hence, for each condition, children's correct scores for the three trials were combined to obtain an accuracy score between 0 to 3. Further analyses with Picture Set and Gender as factors also yielded no significant results. Therefore, the data were collapsed on these dimensions for all subsequent analyses.

Figure 2 illustrates the children's performance on each question type as a function of age. Clearly, performance on each of the questions improved with age, and children performed better on the Where and What Questions than the Want Question. This observation was confirmed by a 4 × 3 (Age Group × Question Type) analysis of variance (ANOVA) on the children's accuracy scores. The effect of question type was significant, $F(2, 180) = 39.08, p < .001$. A Tukey test ($\alpha = .05$) revealed significantly higher scores in the What and Where Questions than the Want Question, and no significant difference between the What and Where Questions. The main effect of age was also significant, $F(3, 90) = 16.06, p < .001$. According to Tukey post hoc testing, 3-year-olds' accuracy scores were significantly lower than any of the other age groups' scores. Four-year-olds' accuracy scores were significantly different from 5- and 6-year-olds, whereas 5- and 6-year-olds' accuracy scores were similar.

As indicated on Figure 2, the overall chance score for each question is .5 ($\frac{1}{6}$ for each picture times three trials). Planned t tests were conducted to determine the age at which children's performance on each of the questions became significantly different from chance. Three-year-olds' accuracy scores for the What and Where Questions were significantly above chance: What, $t(21) = 2.81, p < .05$; Where, $t(21) = 3.86, p < .01$. All the age groups except the 3-year-olds performed above chance on the Want Question: 3-year-olds, $t(21) = 1.10$, *ns;* 4-year-olds, $t(25) = 2.87, p < .01$; 5-year-olds, $t(24) = 4.37, p < 0.01$; 6-year-olds, $t(20) = 6.35, p < .01$.

Discussion

The results of Experiment 1 indicate that, although 3-year-olds performed considerably better on the What and Where

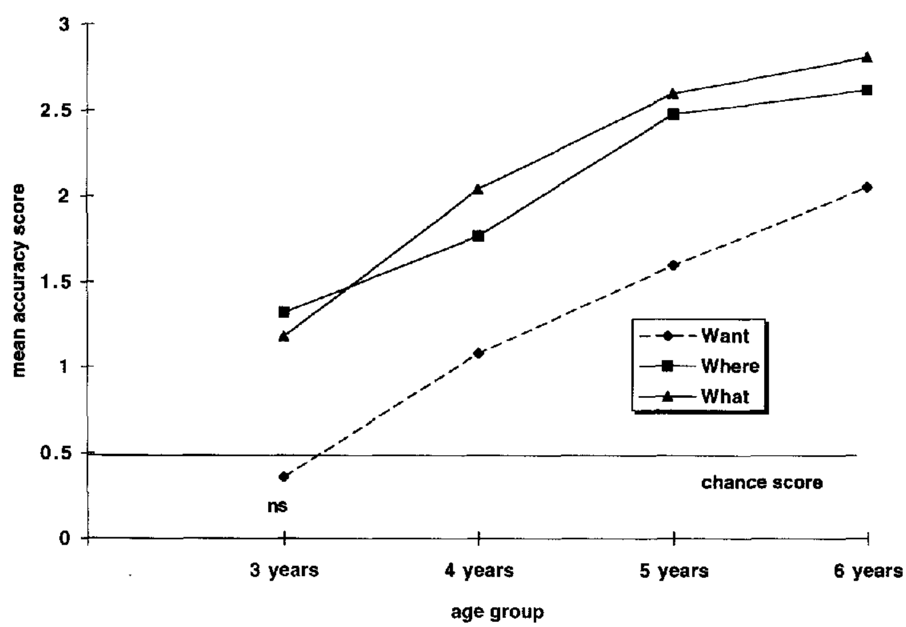

Figure 2. Three-, 4-, 5-, and 6-year-olds' mean accuracy in the Want, Where, and What Question conditions of Experiment 1.

Questions, they had difficulty with the Want Question. Most of these children failed to use Larry's eye gaze to infer his desired objects. Our 4-year-olds' performance on the Want Question replicated Baron-Cohen et al.'s (1995) findings. The 4-year-olds in both studies performed at better than chance levels in inferring another's desire based on eye direction cues.

Three-year-olds' poor performance in the Larry task, however, does not necessarily indicate that 3-year-olds cannot use another's eye direction to infer his or her mental states. Our paradigm may have been too abstract for the young children. They might not be familiar with the format of the task. More important, the relation between Larry's eye gaze and the object that Larry supposedly desired may not have been meaningfully indicated to the child. Although the experimenter pointed out to the child that Larry desired something, there was no background information that suggested why Larry desired certain things. In other words, the present paradigm failed to situate the task in a meaningful context that justified Larry's desire to the children. Thus, Larry's display of eye direction was unmotivated. The eye gaze information provided in the Larry task might appear to be irrelevant to 3-year-olds who, after all, only have an emergent understanding of others' mental lives (Perner, 1992; Wellman, 1990). This lack of contextual information might be the main reason for 3-year-olds' failure on the Want Question.

Experiment 2

To address the possibility mentioned above, a new task called the "Larry story" was used in Experiment 2. In the story, a child named Larry went to shop for birthday presents with his mother. Larry and his mother visited a pet store and a toy store. In each of the stores, there were several toys and pets. Larry announced to his mother that he knew what he wanted and signaled to her with his eye gaze. Children were asked to indicate which toy or pet Larry wanted. With these modifications to the Larry task, Larry's desires were more clearly indicated. It was expected that younger children would perform better in the new task (Larry story) than in Experiment 1 (the Larry task) if the lack of a familiar context was a key factor hindering younger children's performance in Experiment 1.

Method

Participants. One hundred and five children (57 girls) participated in the experiment. Parental consent was obtained prior to the children's participation. They were divided into the following age groups: twenty-eight 3-year-olds (M age = 3 years 7 months), thirty 4-year-olds (M age = 4 years 6 months), twenty-five 5-year-olds (M age = 5 years 6 months), and twenty-two 6-year-olds (M age = 6 years 6 months).

Materials. A story of a little boy named Larry who is shopping with his mother for his birthday present was constructed (see the Appendix). The critical pages of the story depicted Larry in either a toy or a pet store (see Figure 1b). His eyes were directed at one of the four toys or pets in the store. Two sets of stories were used. Both sets were identical in story content but differed in Larry's eye directions. In Set A, Larry looks at a toy on his lower right side and a pet on his lower left side. In Set B, Larry looks at a toy on his lower left side and a pet on his lower right side.

Procedure. Children were randomly assigned Set A or Set B, seen individually, and read the Larry story. During the story, the child was asked various questions. When Larry is in the toy store, the child was asked "Does Larry want anything?" If the child responded "yes," the child was then asked "What does Larry want?" (the Toy Store Want Question 1). If the child responded, "no," the child was read "Larry then says, 'I know what I want!' " Then, the child was asked "What does Larry want?" (the Toy Store Want Question 2). The child had to answer correctly either of the Toy Store Want Questions to obtain one point. For the pet store, the questions asked were the same except that instead of being asked "What does Larry want?", the child was asked "Which pet does Larry want?" (the Pet Store Want Questions 1 and 2).

After the story was finished, the experimenter went back to the critical pages where Larry is looking at an object, and asked, "What is Larry looking at?" (the What Questions 1 and 2). This question assessed the children's accuracy in following eye gaze. Again order of condition was deliberately not counterbalanced for the reasons mentioned in the first experiment. If children answered that they did not know, they were told that guessing was allowed.

Results

A preliminary analysis revealed no difference between children's responses to the Toy Store Want Question and those to the Pet Store Want Question. Therefore, the data for both questions were combined. Children received one point for correctly answering each of the Want Questions (maximum score = 2). One point was also given for correctly responding to each of the What Questions (maximum score = 2). Additional analyses showed no significant effect of gender and story set on children's accuracy scores. Therefore, the data were combined on these dimensions for all subsequent analyses.

Each age group's mean scores for the Want and What conditions are shown in Figure 3. For the purpose of comparison across experiments, a linear transformation was performed on the scores (new score = old score divided by 2 and multiplied by 3). The chance level for answering the two Want questions correctly was .75 (after the linear transformation). The chance score for passing the two What questions was also .75. A 4 × 2 (Age Group × Question Type) ANOVA was conducted on children's accuracy scores. Both age group and question type effects were significant, $F(3, 99) = 9.71$, $p < .001$, and $F(1, 99) = 46.76$, $p < .001$, respectively. Post hoc analyses (Tukey's) showed that children above 4 years of age were better at the task than 3-year-olds. For the main effect for question type, the two Want Questions were more difficult for children to answer than the two What Questions. Planned comparisons between the chance level and the means of each age group revealed that, as in Experiment 1, children answered the What questions significantly above chance as young as 3 years of age, $t(27) = 7.13$, $p < .01$, and the Want questions at 4 years, $t(29) = 3.44$, $p < .01$.

Discussion

Experiment 2 modified the Larry task used in Experiment 1 by adding a story line to the task. Despite this modification, most 3-year-olds still failed to answer correctly the Want Questions. These children were, however, more successful in following the direction of Larry's eye gaze but did not use this information to infer Larry's desires. It was not until 4 years of age that children's scores for the Want Question were above chance. Contrary to expectation, contextual information provided in a

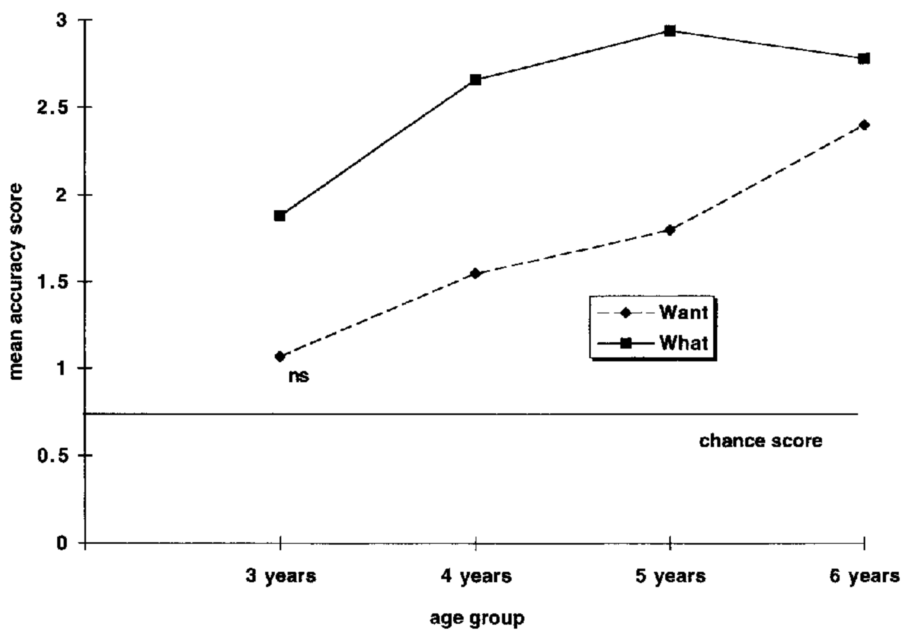

Figure 3. Three-, 4-, 5-, and 6-year-olds' mean accuracy in the Want and What Question conditions of Experiment 2.

narrative format did not aid 3-year-olds to link a story character's eye gaze to his desires.

Experiment 3

The 3-year-olds' difficulty with the Want Question in both Experiments 1 and 2 gives rise to a more general question: Is it possible that 3-year-olds have a more general "mind-reading" difficulty? They may be simply unable to link any nonverbal cues displayed by an individual to the individual's desire. If this is the case, 3-year-olds should show a similarly low level of performance when other nonverbal signals (e.g., pointing and head direction) are used to cue observers about a person's desire.

Experiment 3 was conducted to address this issue. In Experiment 3, a modified version of the Larry task (Experiment 1), a Mary task, was used. In this task, the children were required to identify the direction of a nonverbal cue (pointing, head direction, or eye-gaze) and to infer Mary's desire from this cue. The children were also tested in an additional condition in which an arrow pointed from Mary to an object.

Method

Participants. Fifty-three 3- to 5-year-olds (22 girls) from local day-care centers participated in the study. There were sixteen 3-year-olds (M age = 3 years 7 months), twenty 4-year-olds (M age = 4 years 5 months), and seventeen 5-year-olds (M age = 5 years 6 months).

Materials. The stimuli used were similar to those in Experiment 1. Participants were shown 32 different pictures with a girl named Mary. In each picture, Mary was surrounded by four objects, one in each corner of the display (see Figure 1c). Different pages had different objects. On each of the pages Mary indicated one of the objects with a directional cue. The cues were either pointing, eye direction, head direction, or an arrow originating from Mary (but not in contact with her) pointing to one of the objects.

Procedure. Participants were tested individually. A female experimenter explained to the children that she was going to play a game with them. She was going to show them some pictures of a little girl named Mary and ask them some questions about her. Children took part in the Want condition first. In the Want condition, the experimenter showed a picture to children, pointed to the little girl in the center of the page, and said, "This is Mary. She wants something. Can you tell me, in this picture here, what does Mary want?" The same question was asked for the next 15 pages. The 16 pictures of the Want condition were further divided into four sets according to cue types. Each set of four pictures depicted Mary with a single cue (either pointing, head, eye gaze, or an arrow) directed toward an object in the pictures. The directions of the cues in the pictures were predetermined according to a randomization table, and two versions of the stimuli were produced and randomly assigned to each subject. As well, within a question condition, the order of cue type was counterbalanced between participants.

When the Want condition was completed, the Where condition followed. Eight pictures were used, two for each cue type. Children were asked "Where is Mary pointing?" for pictures depicting Mary pointing, "Where is Mary looking?" for the eye gaze cue, and "Where is Mary facing?" for the head direction cue. For pictures that included the arrow, "Where is the arrow pointing?" was asked.

In the final What condition, children were shown another eight pictures, two for each cue type. Children were asked "What is Mary pointing at?" when the picture contained the pointing cue, "What is Mary looking at?" for the eye gaze cue, "What is Mary facing?" for the head direction cue, and "What is the arrow pointing to?" for the arrow cue.

Throughout the experiment, children were given no feedback as to the correct answer. If children answered that they did not know, they were told that guessing was allowed. To reiterate, the order of the question conditions was not counterbalanced to avoid a potential learning confound for the Want condition.

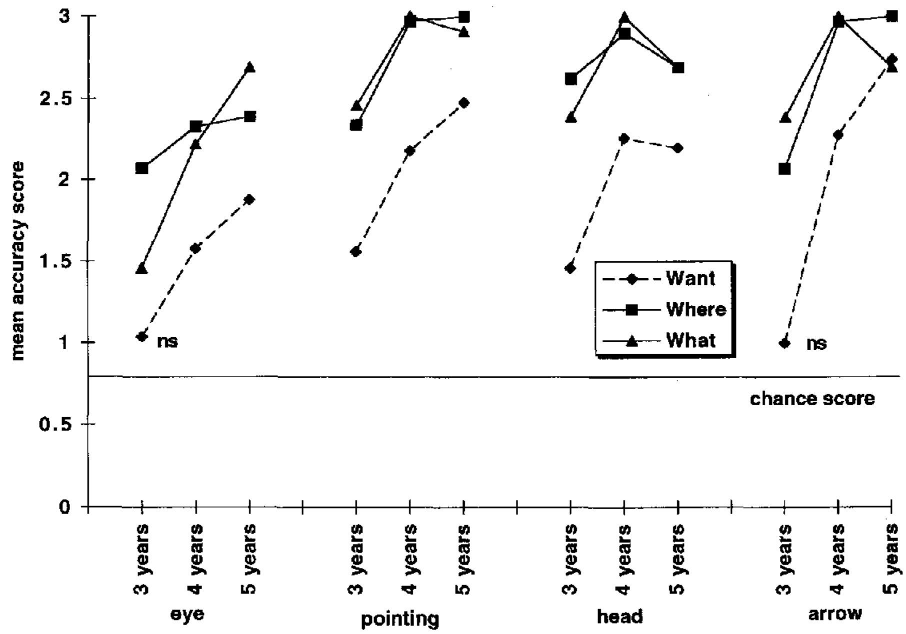

Figure 4. Three-, 4-, and 5-year-olds' mean accuracy scores for each cue type in the Want, Where, and What Question conditions of Experiment 3.

Scoring. Children received one point when they used the directional cue depicted in the picture to answer the Want Question. A separate score was obtained for each cue type with a maximum score of 4 (four trials per cue type). The total score for each cue type for the Want Question was then divided by four and multiplied by three. This procedure made the scores comparable to the other questions in the Mary Task as well as the scoring schemes in Experiments 1 and 2. For the Where and What Questions (two trials for each cue type), children received one point for using the directional cue to answer the questions. The total score for each cue type was divided by two and multiplied by three. Hence, the maximum score that could be obtained for each cue type for each question was three. The chance level for each question was .75.

Results

The mean accuracy scores for each cue type and question condition are shown in Figure 4. A 3 (age group) × 3 (question) × 4 (cue type) ANOVA on the accuracy scores revealed a main effect of age, $F(2, 50) = 11.56$, $p < .001$. Post hoc analyses (Tukey) indicated that the accuracy scores for 4- and 5-year-olds were significantly higher than that for 3-year-olds. No significant differences were found between the 4- and 5-year-olds. A significant effect of question type was also found, $F(2, 100) = 51.97$, $p < .001$; the Want Question was more difficult than the other two questions. There was a significant cue type effect, $F(3, 150) = 19.35$, $p < .001$; the Age Group × Cue Type interaction was also significant, $F(6, 150) = 2.39$, $p < .05$. For the older children, the pointing, head direction, and arrow cue conditions were easier than the eye direction cue condition. By contrast, younger children found both eye direction and arrow cues to be more difficult to use for desire inference than pointing and head direction.

Planned comparisons were conducted to determine whether children's scores for each of the questions and cue types were above chance levels. The three age groups performed better than chance on all cue types for the What and Where Questions. That is, most children correctly used one of the directional cues to determine Mary's focus of attention. Three-year-olds were also above chance in using the pointing and head direction cues to infer Mary's desires, $t(15) = 2.36$, $p < .05$, and $t(15) = 2.39$, $p < .05$, respectively, while failing to use eye gaze and arrow cues. Four-year-olds performed significantly above chance for all cues including eye direction and arrow cues on the Want Question, $t(18) = 3.58$, $p < .01$; $t(18) = 7.43$, $p < .01$.

Discussion

The results of Experiment 3 showed that 3-year-olds, like older children, were able to use nonverbal directional cues such as pointing and head direction to infer another's desires. They could also easily determine Mary's eye direction and her focus of attention. This finding refutes the notion that young children have a more general difficulty in linking nonverbal cues displayed by an individual to the individual's mental states.

Additional findings of the experiment are worth noting. Three-year-olds not only failed the Want Question for eye gaze but also for arrow cues. This was not due to the fact that they did not understand the conventional meaning of arrows. In fact, most 3-year-olds correctly identified the direction and target object indicated by the arrows (see Figure 4). Given that the same 3-year-olds were able to use head and pointing cues to infer another person's desires, their low scores in the arrow condition suggest that even 3-year-olds were sensitive to the difference between nonverbal gestural cues (e.g., pointing, head direction) and arbitrary cues defined by convention (e.g., the arrow). That is, they were more inclined to use a nonverbal gestural cue than a symbolic, abstract cue for inferring mental states. The former is intrinsically linked to a person and thus possibly his or her internal states, and the latter must be established by convention. As age increased, children seemed to become less reluctant to attach intentional meanings to an arrow, possibly due to their increased experience with the conventional usage of the arrow, or simply that they became less reluctant to use the only directional cue available in the task. In a similar experiment, Baron-Cohen et al. (1995) showed that, when an arrow cue conflicted with an eye gaze cue, most 4-year-olds chose eye gaze for desire inference. Four-year-olds are clearly aware of which observable cues are more likely the ''windows to the soul'' and can be used for desire inference.

On the basis of the evidence from both the present experiment and that of Baron-Cohen et al. (1995), two conclusions can be drawn. First, 4-year-olds and older children are capable of using eye gaze and other nonverbal directional cues for desire inference. Second, 3-year-olds have no general difficulty in using a nonverbal cue to infer another's desire. A ''mind-reading'' ability is in fact already in existence by at least 3 years of age as indicated by their successful use of other nonverbal directional cues (e.g., pointing) in the present experiment.

Nevertheless, Experiments 1, 2, and 3 consistently showed that 3-year-olds, while being able to determine eye gaze directions, failed to use eye gaze cues to infer desires. Given that desire inference itself is not an issue to 3-year-olds, a likely problem that might have so far impeded 3-year-olds' use of eye gaze for desire inference is the paradigm used in all three experiments. In natural settings, triadic eye gaze takes place during social interactions between the actor who displays nonverbal cues and the observer who is motivated to use the cues. As well, triadic eye gaze is in and of itself a dynamic process that involves not only directional information achieved by the process as its final product, but also the actor's coordinated eye movement before the direction is obtained. Most importantly, the actor not only displays eye gaze but also other verbal and nonverbal cues to express his or her desires and intentions. Hence, it is possible that the difference between 3-year-olds and older children is not due to their differing ability to infer another's desire. Rather, the difference may lie in whether children would readily use eye gaze information displayed statically and in a relatively impoverished context. It is clear from the results of Baron-Cohen et al. (1995) and our results in the first three experiments that robust and consistent desire inference can be elicited among normal 4-year-olds and Down's Syndrome children (Baron-Cohen et al., 1995) even when eye gaze information is displayed statically without rich contextual support. Also, 3-year-olds in the first three experiments demonstrated the ability to determine accurately eye direction displayed pictorially. Nevertheless, 3-year-olds may require more dynamic and more enriched contextual information than older children to infer another's desire. In other words, 3-year-olds' desire inference may be achieved optimally when eye gaze is situated in an enriched, dynamic context. Experiments 4 and 5 tested this possibility.

Experiment 4

Experiment 4 was conducted with a scaffolding procedure to approximate a more naturalistic interaction in which eye gaze is normally associated with other cues. Among the prominent features of this scaffolding procedure are the use of a dynamic display and the initial presentation of the eye gaze cue concurrently with a number of other nonverbal cues to desire that were gradually eliminated. As Experiment 3 showed that 3-year-olds were already capable of using other nonverbal cues of desire (e.g., pointing and head direction), it was hoped that using these scaffolding cues might sensitize the children to the task and aid them in their use of eye gaze alone to infer desire.

In this experiment, 2- and 3-year-olds were shown a television program in which a clown named Giggles indicated her desired object by using various nonverbal cues (pointing, head direction, and eye gaze). They were then asked to determine which object Giggles desired. A scaffolding procedure was used in which children participated in three conditions in a fixed order, and fewer cues were present as they proceeded from one condition to another: an All Cues condition (pointing, head, and eyes all directed at the same object), a Head and Eyes condition (head and eyes directed at the same object without pointing), and an Eyes Only condition (eyes fixated at an object with head facing the children and no pointing). For each condition, a nonverbal cue from its initiation to its end was clearly displayed. The scaffolding procedure was used to examine (a) whether 2- and 3-year-olds were able to determine another's desire when both eye gaze and other nonverbal directional cues were available, and (b) whether children continued to do so when these cues were removed.

After the three conditions, the children also participated in two more conditions: an Eyes versus Head condition and an Eyes versus Pointing condition in which Giggles's eye gaze was directed at one object while the other cue was directed at another. These conditions were designed to determine whether children were more inclined to use eye gaze cues or other nonverbal directional cues to infer another person's desires.

Method

Participants. Eight 2-year-olds (M age = 2 years 5 months) and ten 3-year-olds (M age = 3 years 10 months) participated (7 boys). Originally, 22 children were recruited through local birth announcements, but four 2-year-olds were dropped from the study for refusing to finish the experimental procedure. Nine of the children's mothers also volunteered to participate in the experiment as a comparison group.

Materials and procedure. Each child was seen individually. The child was seated on a small chair about 30 cm from an 81-cm (32-in.) television screen. The experimenter sat beside the child. The child's parent sat behind the child in another chair. The experimenter informed the child that she or he was going to watch a television show about a clown and play a game with the clown. The television show, produced in a local television station, was called ''Giggles the Clown.'' In the television show, a clown named Giggles first introduced herself and told the child that they were going to play a guessing game. Three objects lay in front of Giggles, one in the middle, one to her right, and one to her left. There were 18 scenes altogether. For each scene, different objects were used. The objects included various toys (e.g., figurines, balls, teacups, and cars) and storybooks. The directions indicated by Giggle's nonverbal cues varied from one trial to another according to a predetermined random order. In the first scene, Giggles turned her head, looked at, and pointed to one of the toys and said ''I want that!'' The television screen went blank for about 1 s. The scene was repeated, and at this point, the mother of the child was asked to state which object Giggles wanted. Then, Giggles reappeared and picked up the object that she indicated and said, "This is what I wanted!" The next two scenes (Scenes 2 and 3) were identical to Scene 1 except that Giggles indicated a different object. Again, the child's mother was required to respond. These three trials were used to familiarize the child with the procedure.

The testing trials then began. The first three test trials (Scenes 4, 5, and 6) consisted of an All Cues condition. They were similar to the above-mentioned three scenes except that the child was asked to respond. The next three trials (Head and Eyes condition [Scenes 7, 8, and 9]) were similar to the first six except that in these scenes Giggles only turned her head towards and looked at an object. Giggles's hands were not visible in these scenes. In the subsequent three trials (Eyes Only condition [Scenes 10, 11, and 12]), Giggles looked at an object without turning her head (her head was facing the child while her eye gaze was directed at an object) and her hands were again not visible (see Figure 1d).

In the last six trials (Scenes 13–18), Giggles displayed conflicting cues. In three trials (Pointing vs. Eyes condition), she looked at one object but pointed to another. In the other three trials (Head vs. Eyes condition) she turned her head toward one object but looked at another. The eye direction was the correct response for the two conflicting cue conditions. The order of the two conditions was counterbalanced between children who were randomly assigned to one of the two orders. Note that, for all the conditions, to maintain the natural flow of the game, children were informed of what Giggles actually desired at the end of each trial.

The participating mothers were tested together with their child. To prevent children's response from being influenced by the mothers, the mothers were instructed not to respond verbally. Instead, they were asked to write down their responses on a sheet of paper. Like the child participants, all the adults participated in the All Cues, Head and Eyes, and Eyes Only conditions in the same order. Half of them received the Pointing versus Eyes condition first and the Head versus Eyes condition second. The other half received the two conditions in a reversed order.

Scoring. The participants were allowed to respond either verbally or nonverbally (e.g., by pointing at an object on the television screen). The correct answers for the first three conditions were the objects indicated by Giggles's nonverbal cues. In the conflicting cues conditions, the object indicated by Giggles's eye gaze was the correct answer. The participants were given one point per trial for giving a correct answer.

Results

For the first three conditions, preliminary analyses showed no order effect for the three trials of each condition. Hence, children's scores for the three trials were combined to obtain a final accuracy score with a maximum correct score of three and a chance score of one ($\frac{1}{3}$ for each trial). Figure 5 shows the means of the accuracy scores of each age group in the five conditions. A 2 (age group) × 2 (condition) ANOVA was conducted on the children's correct scores in the Head and Eyes and Eyes Only conditions. Because 3-year-olds performed at ceiling in the All Cues condition, the All Cues condition was excluded from the analysis. Both age and condition effects were significant, $F(1, 16) = 7.57, p < .02$, and $F(1, 16) = 21.8, p < .001$, respectively. The Age × Condition interaction was also significant, $F(1, 16) = 6.58, p < .02$. As can be seen in Figure 5, overall, 3-year-olds performed better in all three conditions than 2-year-olds. Two-year-olds scored lower in the Eyes Only condition than in the other two conditions in which other nonverbal cues were present. Three-year-olds' scores decreased over conditions as more cues were removed.

Planned comparisons were conducted to compare the mean accuracy scores with chance (1.00). Two-year-olds scored above chance in the All Cues condition and the Head and Eyes condition, $t(7) = 7.94, p < .01$, and $t(7) = 10.69, p < .01$, respectively, but at chance in the Eyes Only condition. Three-year-olds were 100% correct in the All Cues condition, and their mean scores in the other two conditions were significantly above chance, Head and Eyes, $t(9) = 19.0, p < .05$, and Eyes Only, $t(9) = 9.0, p < .01$.

A preliminary analysis revealed no order effect for children's correct scores in the two conflicting cues conditions. Therefore,

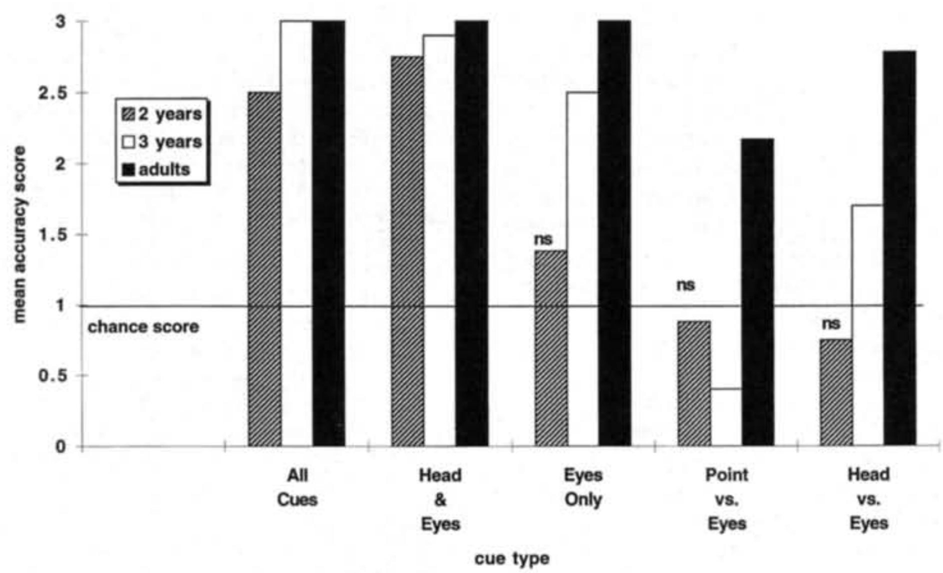

Figure 5. Two-year-olds', 3-year-olds', and adults' mean accuracy scores in the four conditions of Experiment 4.

the data for both orders were combined in a 2 (age group) × 2 (condition) ANOVA for comparing children's accuracy scores in the two conflicting cues conditions, Pointing versus Eyes and Head versus Eyes conditions. Both the condition effect and the Age × Condition interaction were significant, $F(1, 16) = 8.95$, $p < .001$, and $F(1, 16) = 15.69, p < .001$, respectively, whereas the age effect was not significant.

Planned comparisons were performed to compare the mean correct scores with chance (1.00) in the two conflicting cues conditions. Two-year-olds performed at chance in both conditions, indicating that they were somewhat confused by the conflicting cues displayed by Giggles. In the Head versus Eyes condition, 3-year-olds performed significantly above chance, $t(9) = 3.27, p < .01$. They tended to choose the object indicated by eye gaze rather than head direction. By contrast, when the eye gaze cue conflicted with pointing (the Pointing versus Eyes condition), 3-year-olds performed significantly below chance, $t(9) = 3.67$, $p < .01$; they chose the pointing cue as indicating the object desired by Giggles. Furthermore, their preference for the pointing cue over eye gaze persisted even when they were repeatedly told that the pointing cue was not the correct cue to choose.

Adults performed perfectly in the All Cues, Head and Eyes, and Eyes Only conditions. Although they reported that it was difficult to make a decision when the direction of eye gaze conflicted with pointing, they followed the eye direction cues on most trials (see Figure 5).

Discussion

Unlike the first three Experiments, 3-year-olds in the present experiment correctly used eye gaze to infer another's desire. The 3-year-olds' responses in the conflicting cue condition are worth noting. On the one hand, when presented with the pointing versus eye gaze, many of the 3-year-olds consistently chose to use the pointing cue despite feedback that eye direction was the correct cue to follow. On the other hand, 3-year-olds reliably chose eye gaze over head direction when both cues conflicted with each other. These results suggest that 3-year-olds attached different levels of importance to the three cues for inferring another's desires. Pointing appears to be more salient than eye gaze and eye gaze more salient than head direction. A direct comparison between pointing and head direction to determine their relative saliency remains to be conducted. The difference between adults' scores for the Eyes versus Head condition and those for the Eyes versus Pointing condition also indicated that adults might hold a similar view.

The present results suggest the importance of providing young children with both dynamic eye gaze information and scaffolding cues (e.g., feedback and other directional cues) to achieve desire inference. It is clear that 3-year-olds were able to use eye gaze alone to infer another person's desire when placed within an enriched, dynamic context. As the purpose of this experiment was primarily to approximate a naturalistic interaction in which eye gaze is only one of many cues to desire, we deliberately did not test the individual factors within this paradigm. It would be interesting, however, to see if specific factors, such as the dynamic nature of the eye gaze display alone, or feedback are sufficient to elicit the same performance in 2- and 3-year-olds. The effects of these two factors were tested in Experiment 5.

The performance of 2-year-olds is worth noting. Impressively, 2-year-olds demonstrated the ability to infer desire when eye gaze was displayed in conjunction either with pointing and head direction, or with head direction alone. However, they failed to determine what Giggles wanted when the only cue available was eye gaze. Two-year-olds' chance performance in the Eyes Only condition might be due to the fact that the cue reduction procedure was confusing to them. The results of the present experiment indicated that 2-year-olds could infer another's desire when multiple cues were both available and consistent (i.e., the All Cues condition and the Head and Eyes condition). They were perhaps using multiple cues for desire inference and were reinforced for doing so in the first two conditions. In the Eyes Only condition when the head or pointing cue was removed, they were confused as to how to respond. This explanation is consistent with results of the two subsequent conflicting cues conditions. Two-year-olds responded at chance rather than below chance, indicating that they might have noticed the direction of Giggles' eye gaze as well as her pointing or head direction but were confused about which cue to follow. They did not merely follow the head direction or pointing cue, and ignore eye gaze. To examine this possibility, Experiment 5 also tested 2-year-olds' use of eye gaze information for desire inference when the other directional cues were not present.

Experiment 5

Method

Participants. Twelve 2-year-olds (*M* age = 2 years 6 months) and ten 3-year-olds (*M* age = 3 years 7 months) participated (11 girls). Originally, 24 children were recruited through local birth announcements, but one 2-year-old and one 3-year-old were dropped from the study for refusing to finish the experimental procedure.

Materials and procedure. The same procedure was used as in Experiment 4 except for several major modifications to the video presentation used in Experiment 4. The All Cue, Head and Eyes, Head versus Eyes, and Pointing versus Eyes conditions were removed. The new video presentation had only six Eyes Only trials without feedback (the Eyes Only No Feedback condition) and three additional eye only trials with feedback (the Eyes Only Feedback condition). The first three trials (without feedback) served as the first block of the Eyes Only No Feedback condition, and the next three trials served as the second block. From the viewer's point of view, however, there was no physical difference between the two blocks. The reason for dividing the six trials into two blocks was twofold: (a) to make the results of each block comparable to those of Experiment 4 and (b) to allow for examination of such effects as fatigue during the testing. Two versions of the video presentation were produced. Both versions were identical except for the direction of eye gaze for each trial (left, right, middle), which was determined according to a randomization table. The same scoring procedure as the one for the Eyes Only condition in Experiment 4 was used.

Results

Preliminary analyses revealed no version or gender effects. Hence, the data for both factors were combined for the subsequent analyses.

Figure 6 shows the means for the two blocks of the Eyes Only No Feedback condition and the Eyes Only Feedback condition. A 2 (age) × 2 (blocks) repeated measure ANOVA with the last factor as the repeated measure was conducted on children's scores on the two blocks of the Eyes Only No Feedback condition, which yielded nonsignificant block and age effects, $F(1, 20) = .67$, *ns*, $F(1, 20) = 2.01$, *ns*, respectively. The Age × Condition effect was also not significant, $F(1, 20) = .67$, *ns*. These results indicate that children's scores in general did not change over trials.

A 2 (age) × 2 (condition) repeated measure ANOVA with the last factor as the repeated measure was conducted to compare children's scores on the first three trials of the Eyes Only No Feedback condition and those of the Eyes Only Feedback condition. The age, condition, and Age × Condition interaction effects were not significant, $F(1, 20) = 1.82$, *ns*, $F(1, 20) = .95$, *ns*, and $F(1, 20) = 1.82$, *ns*, respectively.

Another 2 (age) × 2 (condition) repeated measure ANOVA with the last factor as the repeated measure was conducted to compare children's scores on the second block of the Eyes Only No Feedback condition and those of the Eyes Only Feedback condition. Again, the age, condition, and Age × Condition interaction effects were not significant, $F(1, 20) = .44$, *ns*, $F(1, 20) = .48$, *ns*, and $F(1, 20) = .48$, *ns*, respectively. These results indicate that feedback did not significantly improve children's use of Giggles's eye gaze cues to infer her desires.

The children's mean scores on each block of the Eyes Only No Feedback condition and those of the Eyes Only Feedback condition were compared with the chance score (chance score for each trial = .33; total chance score = 1). Three-year-olds' means for Blocks 1 and 2 of the Eyes Only No Feedback condition and the Eyes Only Feedback condition were significantly above chance, $t(9) = 3.91, p < .05$, $t(9) = 2.81, p < .05$, $t(9) = 2.20, p < .05$, respectively. Two-year-olds' mean scores for the second block of the Eyes Only No Feedback condition and the Eyes Only Feedback condition were also significantly above chance, $t(11) = 1.92, p < .05$, and $t(11) = 2.50, p < .05$, respectively, whereas the mean score for the first block of the Eyes Only No Feedback condition was not significantly different from chance, $t(11) = .83$, *ns*. Thus, although the ANOVA showed no effect of feedback, some learning was present as demonstrated by the change in 2-year-olds' performance relative to chance from the first block to the second block.

Discussion

Several important findings were obtained in Experiment 5. Three-year-olds were able to use eye gaze cues alone to infer an individual's desire. This finding extended the results of Experiment 4 and suggested that the enriched procedure used in Experiment 4 was not necessary for 3-year-olds to succeed in making a desire inference. It should be noted, however, that the enriched procedure in Experiment 4 seemed to enhance 3-year-olds' performance, in comparison with the simplified procedure of Experiment 5. Exploratory analyses were conducted to compare 3-year-olds' performance in the Eyes Only condition of Experiment 4 and in the Eyes Only Feedback condition of Experiment 5 because the two conditions were most comparable. For example, both conditions involved trials with feedback, and both were the seventh, eighth, and ninth trials of the procedure. Although the adjusted t test showed that the means of the two conditions were not significantly different from each other, Le-

Figure 6. Two- and 3-year-olds' mean accuracy scores in the three conditions of Experiment 5.

vene's test of homogeneity of variance showed that the variance in Experiment 4 was significantly greater than that in Experiment 5, $F(9, 9) = 14.68$, $p < .01$. This effect can be seen by comparing the number of children's correct and incorrect responses in the two conditions. In Experiment 4, five 3-year-olds were correct on all three trials and another five were correct on two out of three trials, whereas none scored one or zero. By contrast, 4 out of ten 3-year-olds in the present experiment scored one or zero. Nevertheless, five 3-year-olds in the present experiment also performed perfectly. Thus, the enriched procedure of Experiment 4 did seem to encourage 3-year-olds to use eye gaze information to infer another's desires.

The enriched procedure of Experiment 4 did not appear to enhance the performance of 2-year-olds. Indeed, 2-year-olds' mean score in the Eyes Only Feedback condition was significantly above chance in Experiment 5, whereas their mean score was at chance in the Eyes Only condition of Experiment 4! This finding supported our suspicion that 2-year-olds might have been confused by the cue reduction procedure used in Experiment 4. It should be noted, however, that statistical comparison between 2-year-olds' mean score and variance in the Eyes Only condition of Experiment 4 and those of the Eyes Only Feedback condition of Experiment 5 yielded no significant result. Hence, it is still unclear whether the procedure used in Experiment 4 had a detrimental effect on 2-year-olds' eye gaze use. A final question answered by Experiment 5 is whether or not the 2-year-olds' chance performance in the Eyes Only condition of Experiment 4 was due to fatigue. The 2-year-olds in Experiment 5 also endured the same number of trials, but their performance remained above chance and statistically similar over trials, refuting the fatigue explanation.

General Discussion

To our knowledge, the present study is the first to describe a developmental function regarding children's use of eye gaze and other directional cues to infer another person's desire. It is clear that the use of nonverbal directional cues to infer another individual's desire is present in children as young as 2 years of age. Children at about 2 years of age begin to use eye gaze alone to achieve desire inference when eye gaze information is dynamically displayed, and by 4 years of age children can do so even when an eye gaze cue is presented in a relatively impoverished, pictorial context.

The present findings provide partial support for the general predictions from Wellman's (1990) and Baron-Cohen's (1994) theories that postulate an early development of desire-related "mind-reading" capacity, with an onset around 3 years of age. Our findings, however, point out limitations in Baron-Cohen's mind-reading model. In his model, eye gaze is stipulated to play a special and critical role in the Shared Attention Mechanism. The Shared Attention Mechanism allows children to infer another individual's focus of attention and desire and to achieve an understanding of beliefs, or more generally, a "theory of mind." Our findings suggest his model is incomplete. Although young children do make use of eye gaze for desire inference, they also rely on other nonverbal directional cues such as pointing and head direction, the use of which apparently emerges earlier than the use of eye gaze (see Moore & Corkum, 1994). When the information indicated by eye gaze conflicts with pointing, 3-year-olds frequently choose the latter cue as the critical indicator of another individual's desire. Contrary to Baron-Cohen's theory, eye gaze is not the only, nor the most important, cue used by children to infer desires. Both children and adults attach more importance to pointing than to eye gaze for desire inference. This result is in fact not surprising as some recent findings show that infants use eye gaze to engage another individual while pointing to an object in the environment (Desrochers, Morissette, & Ricard, 1995). Also, Gomez (1991, 1994a) suggested that when children request that their mother fetch an object for them, they tend to look at their mother and point to the desired object. In these cases, pointing, not eye gaze, reveals the desired object.

Our results emphasize the importance of contextual information in children's desire inference, which is absent in Baron-Cohen's model. Young children use eye gaze as well as pointing and head direction as directional cues to infer another's desire. These directional cues individually do not necessarily give rise to desire inference. To infer correctly an individual's desires, one must take into consideration concurrent verbal information and additional nonverbal cues (e.g., emotional expressions) displayed by the individual, as well as other contextual information (Bartsch & Wellman, 1995; Wellman & Woolley, 1990). When contextual information changes, these directional cues may lead to other mentalistic inferences (e.g., knowledge or ignorance, liking or disliking, deception). Hence, pointing, head direction, and eye gaze are merely "attentional" cues (i.e., cues indicating focus of attention; see also Baldwin, 1995) rather than "intentional cues" (i.e., cues indicating mental states). These directional cues only reveal the focus of attention, not the mental state, of the individual. Intentional information must be obtained from a combination of other sources (e.g., an individual's verbal statements, other nonverbal behaviors, knowledge of the individual's past behavior). This distinction falls into a more general distinction made by Flavell and his associates regarding young children's Level 2 distinction between perception and mental representation (Flavell, 1988).

It should also be noted that the early use of directional cues for inferring another individual's focus of attention and desire is a significant achievement in young children. Its operation marks a new developmental level of referential communication. Previous studies have shown that by about 12 months of age, children begin to use an individual's, often an adult's, directional cues (e.g., pointing) as referential pointers (Butterworth & Grover, 1990; Desrochers et al., 1995). That is, they use the cues to guide their own attention to people and objects in their immediate environment during referential communication (e.g., obtaining the name of a novel object; Akhtar, Dunham, & Dunham, 1991; O'Neill, 1996; Tomasello, 1995; Tomasello & Akhtar, 1995). The findings of the present study further suggest that by approximately 2 years of age young children not only use the directional cues displayed by an individual to seek information about the target in the focus of the individual's attention but also to gain information about the relationship between the individual and the target. More importantly, these young children begin to relate the directional cues to the mind, an entity that is intangible, and mental states (e.g., desire) that can only be inferred. Children now make connections between the directional cues and entities in the environment to infer whether the individual likes–dislikes, desires, or thinks about the entities. They also differentiate between various directional cues and attach different levels of importance to the cues (e.g., when eye direction conflicts with pointing, they opt for pointing). By contrast, when eye direction and head orientation conflict, 3-year-olds rely on eye direction to infer another's desire. This is a remarkable achievement given recent evidence by Vecera and Johnson (1995) that the perception of eye direction can be strongly biased by head direction. Three-year-olds clearly overcome this bias when making desire inferences.

On the basis of the present findings and existing literature, we speculate that desire inference is achieved from multiple sources of information, including nonverbal cues (e.g., attentional cues and emotional expressions) and verbal cues. The use of attentional cues, and eye gaze in particular, represents only one of the strategies that children use for desire understanding. Baron-Cohen's (1994) model needs to be expanded to account for the relation between eye gaze (as an attentional cue) and other directional cues, and that between eye gaze and other contextual cues in the development of mentalistic understanding.

Baron-Cohen suggested that eye gaze monitoring is accomplished by a cognitive module (Baron-Cohen, 1994; Fodor, 1992). In contrast to this notion, we suggest that the development of the use of attentional cues for mind reading is an active meaning-making process (Bruner, 1990, 1996) on the part of children, which involves two main interdependent meaning-making processes. One is an "association process" that enables children to associate attentional cues with contextual information indicating mental states, resulting in a representation of another person's mental state. The other is a "differentiation process." This latter process not only operates at the perceptual level (Gibson & Gibson, 1955, 1991; Postman, 1955) but also at the representational level. The differentiation process allows children to discriminate others' referential cues (i.e., those that merely refer to an object or a position in space) from attentional cues (i.e., those that indicate the focus of a person's attention), and one attentional cue from another.

With regard to the association process, we suggest that, at an early stage of development, children use another individual's directional cue as a pointer to direct their own attention to objects in the environment. Later, they realize that these cues are not only "about" the objects, but also "about" relations between the person and the objects. For instance, they begin to understand that directional cues reflect the person's focus of attention. As their understanding of mental activities (e.g., perception, emotion, desire, and knowledge) and related language knowledge develop (e.g., mentalistic words; Bartsch & Wellman, 1995), children begin to associate these attentional cues with overt displays of the person's mental states. Once a link between the two is established, children may understand the value of observable attentional cues for revealing the person's unobservable, covert mental activities, and begin to use them for mind reading purposes.

As the association process establishes links between directional cues and mental states, the differentiation process operates to "fine-tune" the links. Initially, all attentional cues (pointing, head direction, and eye gaze) are grouped together for such a purpose. Gradually, with experience these cues become differentiated and the most reliable and salient cue is generally used alone first (e.g., pointing). Next, young children will use an attentional cue such as eye gaze that is less salient and tends to have multiple meanings. The differentiation process enables children to distinguish different mentalistic meanings of the eye gaze cue in various contexts. For example, a person gazing upward with no objects in the line of sight suggests thinking (Baron-Cohen et al., 1995; Flavell, Green, & Flavell, 1995a, 1995b). Looking down while talking to others may be taken as an indication of guilt or lack of self-confidence (Argyle & Cook, 1976; Kleinke, 1986; Rutter, 1984).

Concerning the relationship between the development of the mentalistic use of attentional cues and theory of mind, there are at least two possibilities. One possible relation is that the use of attentional cues leads to the understanding of belief and false belief, which is consistent with Baron-Cohen's (1994) theory. Another possibility proposed by Wellman (1990) is that the understanding of belief and false belief is built on the understanding of intention, desire, and knowledge. Attentional cues may be used for inferring a certain mental state only by children who understand the mental state in the first instance. In other words, the use of attentional cues is not the prerequisite for the development of theory of mind, but rather one of its outcomes. Whether the former or the latter is true awaits empirical verification.

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Appendix

The Larry Story Narrative

The following is the narrative for the story, "What does Larry Want for His Birthday?" The order in which the toy store and pet store scenario are presented is counterbalanced between children.

Page 1. Title page: What does Larry Want for his Birthday?

Page 2. Larry is playing outside. He is very excited. It is two more days till his birthday! He can't wait!

Page 3. Larry's mother comes outside too. She asks Larry, "What do you want as a birthday present?"

Larry answers, "I don't know yet."

Larry's mom tells Larry, "Larry, I'm going shopping. You can come with me and show me what you would like for your birthday."

Larry agrees and they go shopping.

Page 4. See, here's Larry and his mom going shopping.

Page 5. Toy Store Scenario

Here is Larry in a toy store.

Questions: Does Larry know what he wants for his birthday now?

> (If child answers (yes)), Question: What does Larry want?
> (If child answers (no)) Larry says, "I know what I want now!"
> Question: What does Larry want?

Larry looks around and decides he wants a sailboat or ball, so his mother buys it.

Page 6. Pet Store Scenario

Then Larry and his mother go into a pet store.

Here is Larry in the pet store.

Questions: Which pet does Larry want?

Then Larry's mother asks, "Larry do you want anything in this store?" and Larry answers, "Yes, I want that."

Question: Which pet does Larry want?

So Larry's mom buys Larry the goldfish or turtle.

Page 7. On their way home from shopping Larry says to his mother, "Thanks Mom! These are great presents. I'm going to have a great birthday."

After reading the entire story then go back and ask the child, "What is Larry looking at?" in each of the stores.

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