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PAPER

To see or not to see: infants prefer to follow the gaze of a reliable looker

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Abstract

In two experiments, we examined whether 14-month-olds understand the subjective nature of gaze. In the first experiment, infants first observed an experimenter express happiness as she looked inside a container that either contained a toy (reliable looker condition) or was empty (unreliable looker condition). Then, infants had to follow the same experimenter's gaze to a target object located either behind or in front of a barrier. Infants in the reliable looker condition followed the experimenter's gaze behind the barrier more often than infants in the unreliable looker condition, whereas both groups followed the experimenter's gaze to the target object located in front of the barrier equally often. In the second experiment, infants did not generalize their knowledge about the unreliability of a looker to a second 'naïve' looker. These findings suggest that 14-month-old infants adapt their gaze following as a function of their past experience with the looker.

Introduction

Gaze following occurs when one person focuses his/her visual attention to where another person is looking. The ability to follow the gaze direction of others is considered a critical component in social interactions (Argyle & Cook, 1976; Kleinke, 1986; Langton, Watt & Bruce, 2000) and is posited to be a developmental precursor to children's later theory of mind abilities (e.g. Corkum & Moore, 1998). The capacity to follow another person's line of sight is relevant for a number of abilities including understanding the meaning of an emotional display (Moses, Baldwin, Rosicky & Tidball, 2001; Repacholi, 1998), language acquisition (Baldwin, 1995; Bloom, 2002; Tomasello, 1995), and inferring a range of mental states that include intentions, beliefs, and desires (Baldwin & Moses, 1994; Lee, Eskritt, Symons & Muir, 1998; Meltzoff & Brooks, 2001; Onishi & Baillargeon, 2005). The importance of gaze following as a developmental milestone can be inferred from the case of children with autism. Specifically, autistic children often lack the ability to use gaze direction as a cue to understand a speaker's referential intent (Baron-Cohen, Baldwin & Crowson, 1997).

Research on infants' ability to follow the gaze direction of others has revealed that from 3 months of age, infants can follow gaze to a highly visible object that is within their immediate visual field (Caron, Caron, Roberts & Brooks, 1997; D'Entremont, 2000; D'Entremont, Hains & Muir, 1997) and later, at 12 months of age, to targets outside their visual field (Carpenter, Nagell & Tomasello, 1998; Moll & Tomasello, 2004; Morissette, Ricard & Gouin-Décarie, 1995). However, there is an ongoing debate in the literature concerning the meaning of infants' gaze following and whether it should necessarily be construed as being mentalistic. Specifically, there is uncertainty as to whether infants understand adults' looking as directing their attention towards an object in the environment (Bretherton, 1991; Baron-Cohen, 1995; Carpenter *et al.*, 1998; Caron, Kiel, Dayton & Butler, 2002) or whether infants' attention is drawn to a location as a result of a built-in orienting response (Langton *et al.*, 2000; Moore & Corkum, 1994; Moore, 1999; Povinelli, 2001).

Experimental studies that have provided support for a 'richer' or mentalistic interpretation have typically used one of two basic experimental paradigms to demonstrate that infants understand the link between visual perception and objects in the environment. First, the Eye Status paradigm has been used wherein a person systematically moves just his/her eyes, head, or both toward an object in order to identify the cues that elicit gaze following in infants. Using this approach, evidence suggests that it is not until 18 to 19 months that infants are able to follow gaze on the basis of eye movement (head remains frontal; Corkum & Moore, 1995; Moore & Corkum, 1998). However, a recent ERP study has reported the encoding of gaze–object relations on the basis of gaze alone in 9-month-old infants (Senju, Johnson & Csibra, 2006). Before this age, when head and eye movements are discordant (head and eyes turn in different directions), infants seem more inclined to follow the head direction than the eye direction (Corkum & Moore, 1998; Caron,

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Butler & Brooks, 2002). For example, 15- to 16-month-olds are equally likely to follow a head turn alone (with eyes frontal) as they are to follow both a head and eye turn (Corkum & Moore, 1998). To eliminate the presence of conflicting head and eye cues, infants' gaze following was explored when a person's head turn was accompanied by eyes that were either opened or closed (Brooks & Meltzoff, 2002, 2005; Caron *et al.*, 2002; Dunphy-Lelii & Wellman, 2004). Results revealed that infants as young as 10 months were more likely to follow gaze in the opened eye condition. However, when blindfolded eyes were substituted for the closed eye condition in a follow-up study, Brooks and Meltzoff (2002) found that 14- and 18-month-olds, but not 12-month-olds, followed gaze more in the opened eyes condition, whereas D'Entremont and Morgan (2006) indeed found the same pattern of results for 12- to 13-month-olds. On the basis of these findings, authors have concluded that infants as young as 10 months of age are sensitive to the status of the adult's eyes and their reference to external targets (Meltzoff & Brooks, 2007).

The Barrier paradigm is the second experimental paradigm that has been used to examine gaze following when an obstacle blocks the person's line of sight to a target. For example, a study by Butler, Caron and Brooks (2000) found that 14- and 18-month-olds were more likely to follow an experimenter's gaze to a target when her line of sight was clear than when it was blocked by an opaque screen. However, once the presence of the screen was controlled for, and an additional condition of a screen with a window was used, 18-month-olds (but not 14-month-olds) followed gaze direction in the window condition as much as in the condition without the screen, thus indicating that the understanding of the requirement of a clear line of sight develops somewhere between 14 and 18 months of age. In a follow-up study with 12- and 15-month-olds, only the 15-month-old infants showed understanding of line-of-sight requirements when combining pointing and head turning (Caron *et al.*, 2002). In contrast, the 12-month-olds construed neither pointing nor looking as referential behaviors in the presence of barriers. To reduce the limitation of having a barrier so close to the looker, which may create an unusual situation, Moll and Tomasello (2004) recently used a variation of this paradigm to create a more natural situation in which the infant's line of sight to the target was blocked as opposed to the experimenter's. Using large barriers, the authors examined 12- and 18-month-olds' gaze following in a condition where the experimenter looked toward a target located behind a barrier (experimental condition) and at a visible target located in front of the barrier (control condition), thus drawing attention equally to the barrier in both conditions. The results suggest that infants as young as 12 months will crawl or walk a short distance to look at what the adult is looking at behind a barrier; thus, understanding that there is a connection between a person's eye gaze and the object of her visual attention. Taken together, these findings indicate that infants in their second year of life recognize that a person will see an object if his/her eyes are directed toward the object and if his/her line of sight is not blocked by an obstacle (Flavell, 1992).

Additional evidence for infants' understanding of the referential nature of gaze has also been provided by recent studies using visual habituation methods (Woodward, 2003). Using these experimental methods, research has found that by 8 months of age, infants expect to find an object behind an occluder toward which a person's attentional behaviors (e.g. gaze, head shift) are directed (Csibra & Volein, 2008). By 9 months, infants seem able to encode the relation between an actor and the target of her head and eye turns if the turns involve multiple fixations (Johnson, Ok & Luo, 2007).

In contrast to the 'richer' interpretation of infants' gaze following, some researchers have offered a 'leaner' interpretation (Langton *et al.*, 2000; Moore & Corkum 1994; Moore, 1999; Povinelli, 2001). Specifically, these researchers argue that a person's head turn could draw an infant's attention to a particular location without invoking any understanding of the gazer's attention. For example, an equally likely explanation for Moll and Tomasello's above-mentioned findings (2004) is that the experimenter's looking behavior may have simply attracted the child's attention to a section of space where the target object is located behind the barrier and not because they want to see what the adult is seeing.

One way to demonstrate that infants understand the referential significance of gaze is to examine whether the credibility of a person's looking behavior influences whether or not the child chooses to follow the looker's gaze. Recent research with preschoolers shows that they can appraise the reliability of their informants. For example, when presented with two informants, one who provides consistently accurate names for familiar objects and one who provides consistently inaccurate names, 4-year-olds prefer the names offered by the reliable informant to label new objects (Clément, Koenig & Harris, 2004; Koenig, Clément & Harris, 2004). Other research has shown that 3-year-olds learn new words from confident rather than uncertain speakers (Sabbagh & Baldwin, 2001). To test this idea, infants in the current study were first trained using a variation of Repacholi's search task (1998) in which they either found a toy (Reliable Looker condition) or did not find a toy (Unreliable Looker condition) when they followed the experimenter's visual and facial cues as she looked inside a container. This task was originally used to demonstrate that 14- and 18-month-old infants can identify the referent of an adult's emotional display. Then, using a variation of Moll and Tomasello's paradigm (2004), we compared, across these two conditions, infants' gaze following to targets in front of and behind a barrier. If infants' gaze following is simply a learned response to a person's global head movement, then infants should follow the experimenter's gaze equally to both target objects in both conditions. However, if infants understand that the

experimenter is directing her attention at a target object, then infants in the reliable looker condition may be more likely to follow the adult's gaze behind the barrier than infants in the unreliable looker condition. In contrast, infants in both conditions should follow the adult's gaze equally to target objects in front of the barrier.

Experiment 1

In this study, we investigated whether 14-month-olds follow the gaze direction of an adult behind various barriers when their gaze and excitement was previously associated with either empty containers or interesting toys within the containers.

Method

Participants

Thirty-eight infants participated in the study; with 20 infants in the reliable looker condition (nine males, 11 females) and 18 in the unreliable looker condition (12 females, six males). Children's mean age was 14.33 months (SD = .56, range = 13.16 to 15.46 months). Fourteen additional infants were excluded from the study due to fussiness (n = 3), parental interference (n = 4), and lack of compliance with the task (n = 7). On the basis of parental report, all infants had a minimum of a 35-week gestation period and had no vision or hearing impairments. All infants were recruited from birth records provided by a government health services agency.

Materials

Search task: Three opaque cylindrical plastic containers with loose-fitting lids were used to administer the training task. These containers differed in color (one yellow, one blue, one orange) but were identical in their dimensions (10 cm diameter, 11 cm height). The number of times each colored container was used was counterbalanced across the four training trials. Two blocks (one blue, one pink) were used in the warm-up trials and four small toys (teddy bear, fish, ladybug, cat) that produced a sound effect when manipulated were used in the training trials in the reliable looker condition.

Gaze following task: Each infant was exposed to four barriers, which consisted of the following: (1) Blue barrier: solid barrier made of wood (140 cm length, 165 cm height, 45 cm width), (2) Yellow box: a box covered with yellow paper (96 cm length, 64 cm height, 26 cm width), (3) White trolley: wooden movable trolley covered in white Bristol board (95 cm length, 73 cm height, 60 cm width), and (4) Red bucket: plastic bucket (30 cm diameter, 27 cm height).

Four figurines familiar to infants (Tigger, Winnie the Pooh, Baby Bop, and Tinky Winky) were used in the experimental condition, one for each barrier. Four brightly colored stickers (approximately 3 cm length × 4.5 cm height) were used in the control condition. A sticker was placed on the front of each barrier, approximately 20 cm from the bottom.

Design and procedure

Infants were first brought to a reception room where they were familiarized with the experimenter. Following this warm-up period, the infant and parent were brought into the testing room where two tasks were administered: a search task and a barrier task. Infants were randomly assigned to two conditions: a reliable looker condition and an unreliable looker condition. All the observations were videotaped.

Search task: A modified version of Repacholi's procedure (1998) was used. This task was designed to train infants to either expect to find a toy after the experimenter looked inside a container with positive affect (Reliable Looker condition) or to expect to find the container empty (Unreliable Looker condition). Infants in each group completed two warm-up trials and four training trials. Responses for each of the trials were recorded to indicate whether children (a) opened the lid of the container and (b) examined the contents of the container by either looking inside or by inserting their hand into the container.

Each infant was seated in a child seat attached to a table facing the experimenter, and the parent was seated directly behind the child. In the warm-up phase, infants in both the Reliable and Unreliable conditions observed the experimenter looking inside the yellow container while exclaiming, 'What's in here?' Then, the experimenter shook the container, removed the lid, and tilted the container in order for the child to see the toy block inside. After closing the lid, the experimenter encouraged the child to open the container by saying, 'Now, it's your turn.' This was followed by an exploration period of 30 s during which the child could play with the container and examine its content. The same procedure was repeated with the training trials except that orange and blue containers were used. Also, an exclamation ('Wow!') accompanied the experimenter's look inside the container along with a matching happy facial expression (i.e. raised eyebrows, open mouth in the shape of a smile). In the reliable looker condition, the experimenter looked into a container that had a toy inside. In the unreliable looker condition, the experimenter looked into an empty container. Each demonstration lasted approximately 10 s.

Gaze following task: This procedure closely followed the one designed by Moll and Tomasello (2004) and was used to examine whether infants' gaze following would be influenced by their prior knowledge of the experimenter's credibility in the search task. Consequently, it

was always administered after the training task. Three large barriers and a bucket were positioned around a small stool on which the parent was seated with the child. The distance between the stool and the front of each barrier was about 60 cm. For each of the barriers, infants completed a control and an experimental condition before moving onto the next barrier, for a total of eight trials (four control, four experimental). Overall, order of conditions and order of barriers were counterbalanced across children. For a given child, order of conditions (experimental first or control first) was identical across all four barriers, whereas the side of the barrier on which the experimenter was seated (left side or right side) was counterbalanced across barriers. For each condition, infants' response was coded in terms of whether they followed the experimenter's gaze to the target. Unlike other gaze following experiments with barriers, infants saw no object but a barrier when they turned to look in the direction in which the adult was looking. Consequently, the criterion for gaze following in the experimental condition consisted of the child moving a short distance until he or she had visual access to the back of the barrier. In the case of the bucket, the child had to lean forward and look inside the bucket. Criteria for gaze following in the control condition consisted of the child moving a short distance to look or point at the sticker in front of the barrier or the bucket.

Parents were asked to sit on the stool and to hold their child in front of them until they were given a signal to let their child go. The experimental procedure began with the experimenter kneeling while facing the side of the barrier and attracting the infant's attention by saying, 'Hi.' When the infant looked toward the experimenter, she began the demonstration. In the experimental condition, the experimenter leaned sideways to look at the figurine behind the barrier, while exclaiming with interest, 'Oooooh.' Thereafter, the experimenter held her gaze for a duration of 3 s and then moved a step back to allow the infant room to move around the barrier. The distance between the experimenter and the target was approximately 60 cm. If the child did not follow the experimenter's gaze after a 4 s delay, the experimenter repeated the demonstration one more time for a maximum of two trials per condition. The best response was used for data analysis. The same procedure was followed in the control condition, except that the experimenter leaned sideways to look at the sticker in front of the barrier. On trials during which the child did not approach the target, the experimenter did not show them the figurine or sticker so as not to alter their learning experience from the search task. Also, access to the back of the barrier was blocked by the experimenter during the control condition if the child attempted to look or go behind the barrier (in both reliable and unreliable looker conditions). In this way, the infants could not inadvertently discover the toy located behind the barrier, rendering the experimental condition invalid.

Reliability

An independent observer coded a random selection of 25% (n = 10) of the videotaped sessions to assess inter-observer reliability, with an equal number of participants selected from each group. Using Pearson product-moment correlations, the mean inter-observer reliability was r = .98 (range = .94 to 1.00) for both the Search and Barrier Tasks.

Results and discussion

To assess whether the infants from each group paid attention to what the experimenter saw inside the containers during the training task, we compared the number of times infants examined the contents of the container during the training trials (out of four trials) in the reliable and unreliable looker conditions. Results indicated that infants in both groups looked equally often inside the containers (reliable looker: M = 3.85, SD = .49; unreliable looker: M = 3.83, SD = .51), $t(36)$ = .10, p = .92. Also of interest was whether infants developed an expectation about the content of the containers over time. Figure 1 shows infants' latency to examine the content of containers between the first and last trial of the training phase using an analysis of variance (ANOVA) with Looker Type (Reliable, Unreliable) as the between-subjects factor. As expected, results revealed an interaction between trial and type of looker. Infants in the unreliable looker condition took longer to examine the contents of the container in the last trial (M = 11.14 s, SD = 8.92) as compared to the first training trial (M = 5.84 s, SD = 4.60, $p < .05$), whereas infants in the reliable looker condition took equally long to examine contents in both trials (M = 6.47 s, SD = 7.72, and M = 9.04 s, SD = 10.35 s, respectively, p = .32). This suggests that infants in the unreliable looker condition understood that there was nothing to look at inside the containers and became disinterested in its contents.

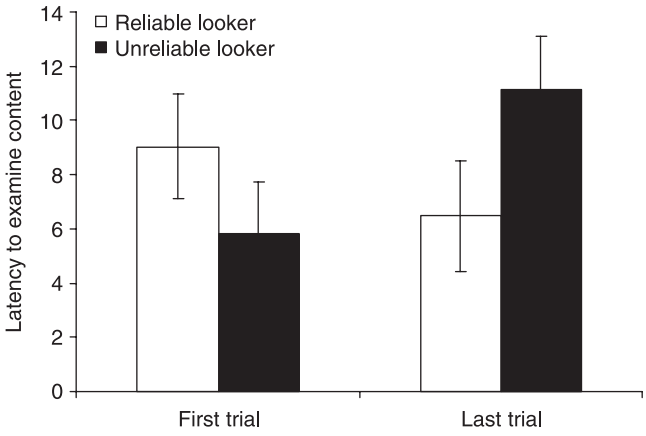

Figure 1 *Mean latency (max = 30 seconds) to examine contents of container in first and last training trials for reliable and unreliable looker conditions in Experiment 1.*

A series of three-way ANOVAs were conducted to examine whether infants' prior experience with the experimenter's reliability during the training task influenced their subsequent gaze following behavior during the gaze following task. First, we conducted a three-way ANOVA with gender and type of looker as between-subjects factors and gaze following condition (control, experimental) as a repeated measure. Since no significant effects were found for gender, a subsequent two-way ANOVA using only type of looker and gaze following condition was conducted. As predicted, a significant interaction between type of looker and gaze following condition was found, $F(1, 36) = 11.65$, $p < .01$. Pairwise comparisons with Bonferonni corrections revealed that infants from the reliable looker condition followed the experimenter's gaze behind the barriers in the experimental trials ($M = 2.20$, $SD = 1.32$) more often than infants in the unreliable looker condition ($M = .83$, $SD = .71$, $p < .001$). However, infants in both groups followed the experimenter's gaze equally often in front of the barriers during the control trials (reliable looker: $M = 1.50$, $SD = 1.15$; unreliable looker: $M = 1.78$, $SD = .73$, $p = .32$). Pairwise comparisons also reveal a crossover effect, whereby infants in the reliable looker group followed the experimenter's gaze more often behind ($M = 2.20$ s, $SD = 1.32$) than in front of the barriers ($M = 1.50$ s, $SD = 1.15$), whereas the opposite pattern was observed with infants in the unreliable looker group (experimental: $M = .83$ s, $SD = .71$; control: $M = 1.78$ s, $SD = .73$, respectively), $p < .05$.

To determine whether infants in the reliable looker condition did not simply learn the demands of the gaze following task better than those in the other group, we examined the proportion of infants who successfully followed the experimenter's gaze to the target behind the barrier in the first trial. Among the infants in the reliable looker group, 70% of them ($n = 20$) followed the experimenter's gaze to the target behind the barrier, compared to 11% in the unreliable looker group ($n = 18$), $\chi^2(1, 38) = 13.49$, $p < .001$. Thus, gaze following experience with additional barriers cannot account for the differences in results between the two groups.

In this experiment, 14-month-old infants were less likely to follow an adult's gaze to a target location behind a barrier if the looker was unreliable, that is, when she showed happiness while looking inside an empty container in a prior task. Although this finding suggests that infants' behaviors are modulated, as preschoolers, by the reliability of the informant, there is another interpretation for the findings. It could be argued that infants made no attribution of reliability to the experimenter but became bored of following her gaze without finding interesting objects to look at inside the container. In other words, maybe what the training task achieved was simply extinguishing a conditioned response to eye turns. In order to disambiguate these findings, we conducted a second experiment in which a second experimenter administered the gaze following task after the training task with an unreliable looker. We expected that infants would follow gaze behind the screen equally often as the infants who witnessed the reliable looker in Experiment 1 if they are sensitive to an individual's pattern of reliability.

With regard to the crossover pattern observed in the type of looker by gaze following interaction, this pattern of finding seems to support the view that infants are selective in terms of whose gaze they choose to follow. It appears as though when infants see a target that is clearly visible, they can confirm with their own visual experience what the experimenter is looking at and therefore are more likely to follow the person's gaze. In contrast, when the target is not visible and infants cannot validate what the other person is seeing, they appear to rely more on their own prior experience with the looker's reliability. Nonetheless, it is important to note that although infants in the reliable looker condition followed gaze more often behind rather than to the front of barriers, it is possible that infants already detected the visible sticker in front of the barrier and therefore did not feel the need to point or move closer to look at it.

Experiment 2

The aim of this study was to determine whether the pattern of results observed in the gaze following task in Experiment 1 was due to an extinction of response acquired during the search task or whether infants can track the reliability of the person's gaze. To further this understanding, the unreliable looker condition of Experiment 1 was replicated, using a different experimenter in the gaze following task to contrast the subjective nature of gaze between an unreliable and naïve looker.

Method

Participants

A group of 24 infants participated in the study (11 females, 13 males). Infants' mean age was 14.80 months ($SD = .57$, range = 14.10 to 15.75 months) and they were recruited using the same means as in Experiment 1. Fifteen additional infants were excluded from the study on the basis of experimenter error ($n = 3$), shyness ($n = 3$), fussiness ($n = 4$), parental interference ($n = 2$), not meeting the inclusion criteria ($n = 1$), and for not examining the contents of the container across the training trials greater than chance ($n = 2$).

Materials, design and procedure

The same materials used in the search and gaze following tasks in Experiment 1 were used in this study. The design of the current experiment replicated that of the unreliable looker condition in the first experiment, whereby infants saw the looker examine the empty

containers and express happiness in the search task. However, a different experimenter (naïve looker) was used in the gaze following task to determine whether infants understand the subjectivity of a person's gaze. Therefore, infants did not receive prior training regarding the 'reliability' of the Naïve Looker's gaze. Infants' responses in the search and gaze following tasks were scored in the same way as in Experiment 1.

Reliability

An independent observer coded a random selection of 25% (n = 6) of the videotaped sessions to assess inter-observer reliability. Using Pearson product-moment correlations, the mean inter-observer reliability was r = .97 (range = .82 to 1.00) for both the Search and Barrier Tasks.

Results and discussion

To ensure that infants paid attention to what the experimenter saw in the containers during the search task, we compared the number of times infants examined the contents of the container during the training trials (out of four trials) in this study to infants in the Reliable and Unreliable looker conditions in Experiment 1. Pairwise comparisons with Bonferroni corrections indicated that infants looked equally often inside the containers (M = 3.69, SD = .60) as compared to infants in the reliable (M = 3.85 s, SD = .49) and unreliable looker conditions in Experiment 1 (M = 3.83, SD = .51), $F(2, 53) = .48$, $p = .62$. To determine whether infants developed an expectation about the content of the containers over time, we compared the latency to examine the content of the containers between the first and last trial of the training phase. As expected, results revealed that infants took longer to examine the contents of the container in the first trial (M = 6.90 s, SD = 8.31) as compared to the last training trial (M = 13.95 s, SD = 11.66), $t(23) = 2.83$, $p < .01$. This suggests that infants understood that there was nothing to look at inside the containers by the fourth trial and had become disinterested in its contents by the end of the task.

To examine whether infants could track the reliability of the experimenter's visual perception, we conducted a 2 × 2 × 3 ANOVA with gender and type of looker (reliable, unreliable, naïve) as between-subjects factors and gaze following condition (experimental, control) as a repeated measure. Since no significant effects for gender were found, a subsequent two-way ANOVA using only type of looker and gaze following condition was conducted. Figure 2 presents the mean scores (out of 4) for looking in front of and behind barriers in the three looker conditions across the two experiments. As predicted, a significant interaction between type of looker and gaze following condition, $F(2, 59) = 8.31$, $p < .001$, revealed that infants in the 'naïve' looker condition followed the experimenter's gaze behind the barriers in the experimental trials (M = 2.20, SD = 1.32) more often than infants in the unreliable looker condition (M = .83, SD = .71), $p < .01$, though infants in both groups followed the experimenter's gaze equally often in front of the barriers during the control trials (naïve looker: M = 1.25, SD = .99; unreliable looker: M = 1.78, SD = .73), $p = .27$. Also, as expected, pairwise comparisons revealed that infants in the naïve looker condition followed the experimenter's gaze behind the barrier equally often as infants who experienced the reliable looker (naïve looker: M = 1.88, SD = .95; reliable looker: M = 2.20, SD = 1.32), $p = .91$. This pattern of findings suggests that infants treated the naïve looker in the same way as the reliable looker and that their gaze following in the barrier task was not modulated by the reliability of the unreliable looker conducting the search task. Likewise, no significant differences were observed between the number of times infants followed the experimenter's gaze in the control condition in the naïve and reliable looker conditions (naïve looker: M = 1.25, SD = .99; reliable looker: M = 1.50, SD = 1.15), $p = .27$.

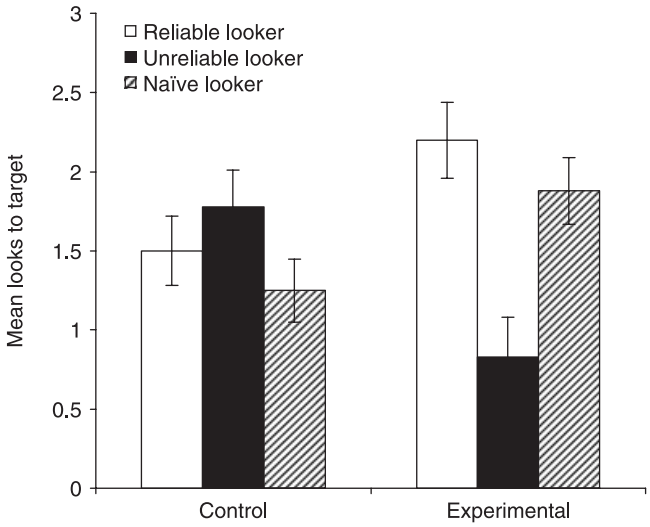

Figure 2 *Mean scores (out of 4) for looking at targets in the control and experimental conditions in the Reliable, Unreliable, and Naïve Looker conditions. Error bars show standard errors of the means.*

To determine whether infants in the naïve looker condition understood the demands of the gaze following task and did not simply follow the experimenter's gaze as a result of experience with subsequent barriers, we compared the proportion of infants who successfully followed the experimenter's gaze to the target behind the barrier in the first trial with infants in the reliable looker condition in Experiment 1. Among the infants in the naïve looker group, 42% of infants (n = 10) followed the experimenter's gaze to the target behind the barrier. This proportion of infants is significantly higher than that of the unreliable looker group (11%, n = 18) in Experiment 1, $\chi^2 = 4.71$, $p < .05$, whereas there were no such differences with the reliable looker group (70%, n = 20), $\chi^2 = 1.46$,

$p > .05$. This suggests that learning experience cannot account for infants' gaze following behavior in the experimental condition.

General discussion

In this paper, we considered infants' abilities to attribute unique visual experiences to individuals. Infants observed an adult look at a target in front of and behind a barrier. In Experiment 1, 14-month-old infants who had previously observed an adult react positively to a hidden toy inside a container were more likely to follow her gaze to a target hidden behind a barrier compared to infants who had previously seen the adult act similarly toward an empty container. Overall, infants in both groups had no difficulty following the experimenter's gaze to the target in front of the barrier, suggesting that the differential gaze following behavior was not a general avoidance of the unreliable looker's gaze. These findings replicate the results reported by Moll and Tomasello (2004) by demonstrating that infants are able to follow an adult's gaze to a space outside their field of vision (behind a barrier). Our study extends these findings by showing that infants' gaze following is influenced by their previous experience with the looker. In Experiment 2, infants had experience with an unreliable looker in the search task but were requested to follow the gaze of a second, naïve looker behind and in front of barriers in a second task. In contrast to the situation where the unreliable looker administered both tasks, infants followed the gaze of the naïve looker behind barriers equally often as the infants who had experienced a reliable looker, suggesting that infants treat an unfamiliar adult as reliable by default, unless their expectation has been violated. In other words, there may be no reason for infants to question the reliability of a looker as their experience with other adults suggests that their looking and emotional behavior is contingent upon a visual experience. Findings from the second experiment ruled out an interpretation of the data of Experiment 1 as being due to a simple decline of interest in following the gaze of the unreliable looker in the absence of an interesting object to look at. This is the first study to date to show that infants are sensitive to a person's record of reliability. Thus far, the influence of prior experience with individuals on children's behavior has only been demonstrated in preschoolers (Jaswal & Neely, 2006; Koenig *et al.*, 2004; Koenig & Harris, 2005).

In our view, prior exposure to what an adult sees provides a unique way of examining the depth of infants' understanding of gaze. If infants simply follow an adult's head turn as a result of an automatic gaze mechanism (e.g. Langton *et al.*, 2000) or a learned contingency (Moore, 1996), then infants from the reliable looker group should have followed the adult's head turn to the target behind the barrier more often than infants in the naïve looker group, who had experienced no reinforcement for their gaze following. We believe that our findings demonstrate, albeit indirectly, an understanding of another person's gaze as both referential and experiential by 14 months of age. A full-fledged understanding of vision requires that one understands vision as intentionally directed at an object, and thus referring to the object (the referential component). However, it also involves an understanding that the visual connection between the looker and the object leads to a visual experience that is distinctive. An experiential understanding of vision has been demonstrated in studies on Level-1 visual perspective taking with 2- to 4-year-old children (Flavell, Shipstead & Croft, 1978; Masangkay, 1974; Wellman, Phillips & Rodriguez, 2000). Recent studies employing looking-time methods have revealed that infants as young as 12.5 months might understand that another person does not have visual access to an object that they themselves are able to see (Luo & Baillargeon, 2007; Sodian, Thoermer & Metz, 2007). The present findings, particularly those based on the switch-actor procedure, provide additional support for the hypothesis that infants have nascent understanding of the experience of seeing.

The current studies add to the growing number of studies that show that early in the second year, infants reach important milestones in their understanding of vision. Previous research with occluders has shown that infants know that another person cannot see something they can see. At the same time, when an object is hidden behind a barrier, research has shown that infants know that another person can see something they cannot see. Our demonstration that infants' gaze following differs as a function of individual agents provides the first evidence to date that infants take into account the agent's *past* looking behavior. Of course, infants' understanding of the epistemic aspects of seeing becomes more elaborate in the following months and years, as other aspects of folk psychology develop (Doherty, 2006). For example, it is not until the age of 15 to 18 months that infants can encode not only what another person sees and does not see, but also can infer the person's subsequent correct or incorrect action from her visual access to information (Onishi & Baillargeon, 2005; Poulin-Dubois, Demke & Olineck, 2007; Poulin-Dubois, Sodian, Metz, Tilden & Schoeppner, 2007). Between 18 and 24 months of age, children develop a robust reliance on gaze cues in word learning situations (Baldwin, 1991, 1993; Baldwin, Markman, Bill, Desjardins, Irwin & Tidball, 1996; Hollich, Hirsh-Pasek & Golinkoff, 2000; Moore, Angelopoulos & Bennett, 1999; Akhtar, 2005; Sabbagh & Baldwin, 2005; Graham, Nilsen & Nayer, 2007). There is also evidence that explicit judgment of eye direction is a skill that improves between 3 and 4 years of age (Baron-Cohen & Cross, 1992; Doherty & Anderson, 1999; Doherty, 2006). Another level of eye gaze comprehension involves the realization that direction of eye gaze can indicate mental states (Povinelli & Eddy, 1996). By preschool age, children can use eye gaze to infer the object of desire (Baron-Cohen *et al.*, 1997; Lee *et al.*, 1998), knowledge (Pillow, 1989; Wimmer, Hogrefe & Perner, 1988), and

thinking (Flavell, Green & Flavell, 1995). Finally, the most sophisticated forms of understanding of eye gaze information are reached at 6 or 7 years of age (see Eskritt & Lee, 2007, for a review).

The current findings raise a number of questions for future investigations. These include the youngest age at which children could understand the subjective nature of gaze, as tested with the present paradigm. Since previous research has shown that Level-1 perspective taking can be observed in infants as young as 12 months, further research is needed to determine whether infants younger than those tested in the present set of studies understand what different individuals can and cannot see. Another important issue concerns the extent to which infants generalize their knowledge about the reliability of a person's gaze to contexts that are more remote from the one tested in the current tasks. Experiments are under way in our laboratory to examine the possibility that 16-month-old infants exposed to an unreliable looker in a search task will fail a belief task involving the same actor (Onishi & Baillargeon, 2005). These questions aside, our findings have revealed that early in the second year, infants attribute a subjective sense of vision to others.

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