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Brief report

Experience with visual barriers and its effects on subsequent gaze-following in 12- to 13-month-olds

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Thirty 12- to 13-month-olds were tested to determine whether they could use the self as an analogy for understanding others' looking. Using a procedure similar to Brooks and Meltzoff (2002), we examined gaze-following when the adult's view of a target was occluded by a blindfold (blindfold without training). Some infants received experience with the blindfold's sight-blocking qualities (blindfold with training). The control was a headband condition. Gaze-following was highest in the headband condition. Gaze-following in the headband and blindfold without training conditions, but not the blindfold with training conditions, were significantly greater than zero. These results demonstrate that 12- to 13-month-olds have some understanding of the looking behaviour of others. Only weak support was found for simulation theories of the development of social cognition.

Towards the end of the first year, infants develop a new level of social understanding where they are able to share attention to objects with others. This skill is often referred to as *joint attention*. Before this time, infants are either able to pay attention to people or objects separately, but not both jointly. One of the outward manifestations of joint attention is the ability to follow the gaze of others (*gaze-following*; Carpenter, Nagell, & Tomasello, 1998). Gaze-following is one of the first means through which infants attempt to share experiences with other people (Tomasello, 1995, 1999). Gaze-following allows infants to share attention with others towards objects and it also allows them to acquire thoughts and opinions about how other people interpret the world. When they look at people, observe their emotions and then follow their gaze to objects, infants can learn about the others' emotional relation to objects (i.e. social referencing; Baldwin & Moses, 1996). Gaze-following is also important for the development of language. Gaze-following at 6 months of age has been found to be correlated with later language development (Morales *et al.*, 2000; Morales, Mundy, & Rojas, 1998); infants are able to use gaze direction to map words to objects (Baldwin, 1991, 1993, 1995) and to understand the speaker's referential intent when labelling an object (Moore, Angelopoulos, & Bennett, 1999).

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Infants have been found to gaze-follow as early as 3–6 months of age (D'Entremont, Hains, & Muir, 1997; Scaife & Bruner, 1975). How infants accomplish this has been subject to debate in the literature (see, for example, chapters in Moore & Dunham, 1995; Rochat, 1999). Simulation accounts of social-cognitive development state that infants recognize similarities between their own intentional looking behaviour and that of others and this understanding of others as 'like me' allows them to understand the adults' behaviour as intentional looking towards an object. Thus, when an infant gaze-follows, one assumption is that the infant understands that the adult has intentionally turned to look at something and consequently turns to look at the object that the adult is looking at (Baron-Cohen, 1994; Bretherton, 1991; Tomasello, 1995). There are two major variants on the simulation viewpoints found in the literature. One variation holds that the ability to recognize others as 'like me' is present from birth (Meltzoff, 2002; Meltzoff & Gopnik, 1993). The other variation holds that infants must first recognize themselves as intentional before they can recognize others as intentional. According to this view, it is this understanding of self and other as intentional, which develops around 9–12 months of age, which subsequently allows the infant to use self as an analogy for the understanding of others (Tomasello, 1995, 1999). Although the views differ as to the age at which they view simulation to be present, both agree that the infant uses his/her own behaviour as a means of understanding the behaviour of others.

One way to support simulation theories has been to establish that the infant knows something of what the other can see. Hence, many researchers have attempted to determine what the infant understands about the role of eyes for seeing. If infants are able to follow where the eyes, specifically, are looking, rather than their attention simply being captured by the movement of the adult's head, this would support claims that the infant knows something of the referential nature of the adult's sight (i.e. that the adult is looking at something). Initial research did not support this interpretation. Systematic observations of infant gaze-following suggested that it was not until 18 months of age that infants were able to follow eye direction; before that age, they appeared to simply follow the direction of the head (Corkum & More, 1995, 1998; Moore & Corkum, 1998). However, as noted by Brooks and Meltzoff (2002), in this research the eyes and head were presented such that they moved in independent directions creating an unnatural conflict between head and eyes. Another way to test what infants know about eyes is to test them under conditions where the adult's vision is occluded. If infants understand the referential nature of looking, they should not follow the gaze direction of an adult if the adult's view is obstructed. Research with visual barriers indicates that this understanding may be present as early as 12–14 months of age. Several studies have shown that 12- and 14- month-olds followed the adult's gaze less when the adult's view of a target was impeded by external visual barriers (screens, blindfolds) or when the adult's eyes were closed (e.g. Brooks & Meltzoff, 2002; Butler, Caron, & Brooks, 2002; Caron, Kiel, Dayton, & Butler, 2002b). However, not all infants were successful in all conditions, suggesting that 12–14 months of age is a transition period for infants' understanding the role of eyes in seeing.

Pinpointing a specific age at which infants follow eye (as opposed to head) direction is important for charting developmental progress, but does not, in itself, effectively support simulation theories. Infants could come to selectively follow the gaze of eyes through mechanisms that do not require any understanding of the adult's mental experience of seeing (Corkum & Moore, 1995, 1998). For example, it could be that discriminative learning takes place over time, whereby infants learn to use the discriminative cue of eye direction (Deák, Flom, & Pick, 2000). One way to strengthen the simulation view would be to test infants who do not yet show understanding of visual barriers. One could give these infants first-hand experience with the sight-blocking qualities of the visual barrier and then test their performance in a gaze-following task where the spectator's view is impeded by the barrier. If, for example, infants are simply responding to the adult head turn as a cue to gaze-follow, their own first-hand experience with the barrier should not affect their level of gaze-following when the adult's view is subsequently impeded by the visual barrier, since the head-turn cue remains the same. Alternatively, if simulation plays an important role, the infants should decrease their level of gaze-following when an adult's view is impeded by a barrier that the infant just experienced. This would provide a more direct test of the simulation theory which, to our knowledge, has not been done before. Consequently, we examined infants' gaze-following when the adult's view of a target was occluded by a headband-blindfold using a procedure similar to Brooks and Meltzoff (2002); however, we gave one group of infants experience with the sight-blocking qualities of the blindfold. We tested 12- to 13-month-olds since this appears to be the age at which infants' understanding of others as intentional beings who have object-related goals emerges (i.e. Tomasello, 1999), and since 12-month-olds failed the blindfold test in Brooks and Meltzoff. Following Brooks and Meltzoff, we expected 12- to 13-month-olds to gaze-follow as much in our blindfold condition as in our headband condition when they had not experienced the sight-blocking qualities of the blindfold. Following simulation theories, we expected less gaze-following after infants experienced the sight-blocking qualities of the blindfold.

Method

Participants

The participants for this study were 30 infants (14 boys, 16 girls) between 12 and 13 months old ($M = 12$ months, 15 days; range = 11 months, 19 days to 13 months, 17 days) recruited from birth announcements in the local newspaper, poster advertisements, and public service announcements. One additional infant was excluded from the study due to fussiness. All infants were from Caucasian families and the majority came from middle- to upper-class homes with parents who had at least some college education. Infants were randomly assigned to one of three groups (headband: $M = 12$ months 24 days; range = 12 months, 8 days to 13 months, 17 days; blindfold with training: $M = 12$ months 6 days; range = 11 months, 19 days to 13 months, 1 day; blindfold without training: $M = 12$ months 15 days; range = 11 months, 21 days to 13 months, 17 days).

Procedure

Infant and experimenter sat facing each other at a table with two identical stuffed toys mounted on posts flanking them at approximately 135 cm from the table. The stuffed toys, which served as targets, were placed approximately 75 degrees from the infant's midline. Separate cameras videotaped the experimenter and infant with the resulting images being combined by a special effects generator to create one image with a time-line superimposed. The infants were divided into three groups (headband, blindfold without training and blindfold with training). A dark-coloured cloth elasticized headband served as both the headband and the blindfold. The experimenter began the study by announcing, 'Sometimes I like to play with the headband'. Depending on the experimental condition, the experimenter proceeded to perform activities to allow the infant to become familiar with the headband. In the headband and blindfold without training conditions, the experimenter familiarized the child to the headband without demonstrating its sight-blocking qualities. This was achieved by wrapping the headband around her wrists, the wrists of a stuffed toy located on the table, and finally the wrists of the infant. In the blindfold with training condition, she demonstrated the sight-blocking qualities of the headband. This was done by holding the headband up to the experimenters eyes and playing peek-a-boo with the infant, by holding the headband up to the eyes of the stuffed toy and playing peek-a-boo and, finally, by holding the headband up to the infant's eyes and playing peek-a-boo. Following familiarization, the experimenter announced, 'Sometimes I like to wear the headband', and proceeded to put the headband on her head. She then conducted four gaze-following trials following either a left-right-right-left or a right-left-left-right pattern, counterbalanced across infants. For each trial, she interacted with the infant to gain his/her attention. She then stopped interacting and either pulled the headband down to her forehead, (headband condition) or down covering her eyes (both blindfold conditions), and turned her head to look in the direction of one of the targets for 7 seconds.

The videotaped image was used to score the infants' gaze-following behaviour. Gaze-following was scored when the infants' eyes or head aligned in the direction of either target during a trial. While coding, the image of the experimenter was covered so that coders were blind to the condition and the direction of the adult's turn. Infant looking was then compared with adult looking to determine whether the infant looked in the same (match), or the opposite (mismatch) direction as the experimenter or made no response. A random sample of 25% of the sessions was coded by a second coder. Percentage agreement between the coders was 88%. Cohen's kappa coefficient was $\kappa = 0.84$. The main coder's data was used for analyses.

Results

Gaze-following behaviour can be seen in Table 1. In general, infants rarely looked in the opposite direction as the experimenter, regardless of condition. The largest number of no-response trials occurred in the two blindfold conditions. Looking scores were created by subtracting the number of mismatch looks from the number of match looks; thus, looking scores had a possible range of -4 to $+4$. Two sets of analyses were initially carried out on the looking scores. First, looking scores in each condition were submitted to independent *t* tests to determine whether they were significantly different from zero. An average-looking score above zero would indicate that infants looked to the same target as the adult more often than they looked to the opposite target. A looking score

Table 1. Means and standard deviations of infant looking behaviour in the three conditions

	Condition		
	Headband	Blindfold with training	Blindfold without training
Match looks	2.50 (1.18)	0.90 (0.99)	1.30 (1.25)
Mismatch looks	0.30 (0.48)	0.30 (0.48)	0.30 (0.48)
No response	1.20 (1.03)	2.80 (0.92)	2.40 (1.58)
Looking score (match-mismatch)	2.20 (1.48)	0.60 (1.26)	1.00 (1.05)

below zero would indicate more looking in the opposite direction as the adult while a looking score of zero would indicate either no gaze-following or random responding. Looking scores in the headband and blindfold without training conditions were significantly greater than zero, $t(9) = 4.71$, $p < .001$ and $t(9) = 3.00$, $p < .05$, respectively. Looking scores in the blindfold with training did not differ from zero. Next, a one-way ANOVA with three levels (condition: headband, blindfold without training, blindfold with training) was conducted to compare the groups' looking scores to each other. This analysis revealed a main effect of condition, $F(2, 27) = 4.26$, $p < .05$. *Post hoc* testing revealed that looking scores were significantly higher in the headband condition than either blindfold condition ($p < .05$ and $p < .01$ for blindfold without training and blindfold with training, respectively) and the two blindfold conditions did not differ from each other.

Similar analyses were conducted on the number of no-response trials since this is arguably a better test of the infants' understanding of the blindfold.[1] All three groups had no-response scores which were greater than zero ($t = 3.67$; $p < .01$; $t = 9.64$; $p < .001$; $t = 4.81$; $p = .001$ for the headband, blindfold with training and blindfold without training conditions, respectively). A one-way ANOVA with three levels (condition: headband, blindfold with training and blindfold without training) revealed a group effect, $F(2, 27) = 4.73$; $p < .05$. *Post hoc* testing revealed that the no-response scores were lower in the headband condition than either the blindfold with training ($p < .01$) or blindfold without training ($p < .05$) condition.

We expected the two blindfold conditions to be different from each other. Specifically, we expected that infants would follow the gaze of the experimenter in the blindfold without training condition since previous research indicated that 12-month-olds do not understand the sight-blocking qualities of blindfolds (Brooks & Meltzoff, 2002). In contrast, based on simulation theories, we expected that experiencing the sight-blocking qualities of the blindfold themselves would allow the infants, through analogy, to understand its sight-blocking effects on the experimenter. Consequently, we expected that infants would not follow the gaze of the experimenter in the blindfold with training condition. The *t* tests on looking scores described above support this pattern; however, the ANOVAs indicate that the two blindfold conditions did not differ significantly from each other either in looking scores or in terms of number of no-response trials. To help us understand this discrepancy between the *t* tests and the ANOVA, we looked at the patterns of individual responding.

If we make no assumptions about whether infants gaze-follow, we would expect random responding, that is, we would expect infants to gaze-follow on half the trials and not to gaze-follow on the other half. To assess whether responding was at chance level in each of the three groups, we used a matched-pairs Sign test to compare the number of trials on which the infants followed the gaze of the experimenter with the number of trials on which the infants did not follow the experimenter's gaze. For this analysis, a match response was considered 'following' whereas a mismatch or no response was considered 'not-following'. Infants were considered 'followers' if their following score was higher than their not-following score and 'not-followers' if their not-following score was higher than their following score. In neither the headband nor the blindfold without training did the number of infants who were followers versus not-followers reach significance. In the headband condition, five out of six infants were followers.

[1] *Thanks to an anonymous reviewer for pointing this out to us.*

Four infants had ties. This number is not greater than chance (Sign test exact $p = .22$). In the blindfold without training condition, only two out of seven infants were followers. Three infants had ties. This number is also not greater than chance (Sign test exact $p = .45$). In contrast, in the blindfold with training condition, eight out of nine infants were not-followers. One infant had a tie. This number is greater than chance (Sign test exact $p = .04$).

We also looked at the infants' most frequent response. These data are presented in Table 2. No infants had mismatch as their most frequent response, so these are eliminated from this analysis. The most frequent behaviour in the headband condition was for infants to match their gaze with that of the experimenter (six infants). The most frequent behaviour in the blindfold with training condition was for infants to make no response (eight infants). Infants in the blindfold without training condition were about equally divided between matching their gaze with the experimenter's and making no response (four infants made matching responses, five made no response, and one tied matching and no response). This different distribution of response type by condition was significant ($\chi^2 = 10.34$; $p < .05$).

Table 2. Most frequent response type, by group

	Condition		
	Headband	Blindfold with training	Blindfold without training
Most frequent response			
Match	6	1	4
No response	1	8	5
Match, no response tie	3	1	1

As noted, previous findings by Brooks and Meltzoff (2002) showed that 12-month-old infants did not score differently in the headband condition than the blindfold condition. In contrast, 12- to 13-month-old infants in the current study showed significant differences between headband and blindfold without training conditions. Since our infants were, on average, slightly older than the 12-month-olds tested in the Brooks and Meltzoff study and our group had a larger age range, we examined the correlation between the age and looking score; the result was non-significant ($r = .23$, $p > .05$).

In summary, looking scores were significantly higher, and no-response scores significantly lower, in the headband than in either blindfold condition, and the blindfold conditions were not significantly different from each other. However, this does not tell the entire story. In the headband condition, infants tended to align their gaze with the direction of the gaze of the experimenter. In contrast, in the blindfold with training condition infants tended to make no response, while in the blindfold without training condition about half the infants tended to align their gaze with the direction of the experimenter and about half tended to make no response.

Discussion

At the outset of this study we expected 12-month-olds to have no knowledge of the role of eyes for seeing and consequently to gaze-follow equally in the headband and blindfold without training conditions. In keeping with the simulation theories, we expected less gaze-following in the blindfold with training condition after infants experienced the sight-blocking qualities of the blindfold. Our results did not quite fit this pattern. Contrary to predictions, infants showed less gaze-following in both blindfold conditions compared with the headband condition. Specifically, the looking scores were higher, and the no response scores lower, in the headband condition than the two blindfold conditions. The two blindfold conditions did not differ from each other in terms of looking scores or number of no-response trials. This would suggest that our 12-month-old sample knew something of the role of the eyes for seeing, in that they gaze-followed when the adult's view was unobstructed and did not gaze-follow when her eyes were covered with the blindfold.

We expected that experience with the sight-blocking qualities of the blindfold would reduce the infants' gaze-following by allowing them to use the self as an analogue for understanding the behaviour of others. Brooks and Meltzoff (2002) made similar arguments regarding 12-month-olds' responses to conditions where the adult turned her head with closed eyes. They suggested that the infants' own experience with closed eyes allowed them to reason about the closed eyes of the experimenter. The peek-a-boo game allowed infants in the current study the experience of seeing and not seeing the experimenter as a result of the cloth headband obstructing their view. According to simulation theories (Meltzoff, 2002; Tomasello, 1999), if infants recognized others as like the self, they should have been able to reason that the headband also blocked the experimenter's view when it was worn as a blindfold in front of her eyes. The patterns of individual responding and *t* tests provide some evidence consistent with this theory. Of the two blindfold conditions, infants' gaze-following was significantly greater than zero in the blindfold without training condition but not in the blindfold with training condition. In the headband condition, almost all infants were followers and the most frequent response of the majority of infants was the match response. In the blindfold without training condition, five infants were followers and infants' responses tended to be evenly divided between match and no response. In contrast, in the blindfold with training condition, almost all infants were not-followers and the most frequent response for the majority of infants was no response. However, this weak support for simulation theories must be tempered by the fact that the two blindfold conditions did not differ from each other in terms of overall looking scores or no-response rates. These results do not replicate Brooks and Meltzoff (2002) who found no difference between headband and blindfold conditions at 12 months of age. Since the infants tested by Brooks and Meltzoff were slightly younger with a narrower age range than those tested in the current study, we examined the possibility of a relationship between age and gaze-following. Analyses revealed no correlations between age and looking scores. We also examined the ages of those who followed gaze versus those who did not follow gaze in the blindfold (not reported in the results). We defined *followed gaze* as having looking scores greater than zero or as having 'match' (vs. 'no response') as the most frequent response. No differences emerged on either analysis. Thus, general developmental maturity probably does not account for the better performance of infants in the blindfold condition in the current study. Neither does conditioning account for the difference between the headband and blindfold conditions, since the head-turn cue and the reinforcement contingencies were identical in all three conditions. That is, in all three conditions, infants saw a head turn and were reinforced by the interesting sight of the toy when they followed the adult's head turn direction.

Previous research has produced mixed findings regarding the ability of 12-month-olds to understand eyes. For example, 12 month-olds followed the gaze of an adult less when the adult's view was blocked by a screen than when no screen was present, but they followed the least when a window was situated between the adult and the target (Butler *et al.*, 2000). Brooks and Meltzoff (2002) found that 12-month-olds gaze-followed more when the adult turned his/her head with eyes open than closed, but Caron, Butler, and Brooks (2002a) found no such difference. In a recent study, 12-month-olds were found to reposition themselves to a new location in order to follow an experimenter's gaze to location behind a barrier which blocked the child's (but not the experimenter's) line of sight (Moll & Tomasello, 2004). It is possible that some of these conflicting results are due to testing different aspects of Level 1 perspective taking (Masangkay, 1974; Moll & Tomasello, 2004). There are two aspects to Level 1 perspective taking: (1) understanding that another person cannot see something that the child can see; and (2) knowing that another person can see something that the child cannot see (Flavell, Everett, & Croft, 1981). Conditions where an adult's view is blocked by barriers are essentially a test of the former and may be more difficult (Moll & Tomasello, 2004).

Another, not unrelated, alternative is that infants' understanding of others' intentions may have to reach a certain level to be able to engage in Level 1 perspective taking. Tomasello (1995, 1999) has suggested that infants develop the ability to engage in gaze-following and other joint attention behaviours when they come to understand others as intentional beings with intentions towards outside things. With regards to gaze-following, the infant recognizes that the adult's behaviour is intentional looking towards an object. However, to recognize that the adult cannot see something that the infant can see may take more than a simple recognition of others' intentions to third objects. It may be that to understand the effects of the blindfolds on others, infants have to recognize that others may have intentions that do not match one's own or that do not match reality (as in the case of unfulfilled intentions or accidents). There is evidence to support these two aspects of understanding of intentions. For example, Carpenter, Call, and Tomasello (2005) found that 12-month-olds would imitate actions in terms of goals when they saw a model fully complete her intended act. In contrast, Bellagamba and Tomasello (1999) reported that 12-month-olds had difficulty imitating a model's intended acts when the model never successfully completed her intended act. Perhaps the discrepancies across studies regarding 12-month-olds' understanding of eyes is a result of sampling differing numbers of those who have this understanding versus those who do have not this understanding. It would be interesting in future research to see if there is a difference between those who understand blindfolds and those who do not in terms of their perspective-taking abilities and/or ability to reason about others' unfulfilled intentions.

In summary, our research adds to a growing body of literature demonstrating that 12-month-olds have some understanding of what others can see and to what they are attending. In contrast, the evidence that 12-month-olds can use self as an analogue for understanding what others can perceive was weak. Clearly, more work needs to be done to effectively support simulation theories. Future research could benefit from testing younger children. Perhaps if we had tested younger children, we may have been able to tap into a sample who did not already know something about blindfolds. In so doing, we may have been able to demonstrate a clear benefit of training. If it is the case that infants can reason about others' intentional, object-directed looking once they themselves become intentional, then 9- to 11-month-olds should be able to benefit from first-hand experience with the blindfold. On the other hand, while 6-month-olds will follow gaze under certain conditions (D'Entremont *et al.*, 1997), it has been argued that they do not attribute any object-related mentalizing to the looker (D'Entremont, 2000; Moore & D'Entremont, 2001). Thus, 6-month-olds should not be able to use their own experience with a visual barrier to understand its effects on others. However, even though 6- to 9-month-olds infants do not yet reason about an agent's intentional relation towards objects, they do know much about agents before their first birthday. They can detect causal agents (Cohen & Oakes, 1993), they selectively attend to aspects of an actor's behaviour that are relevant to the actor's underlying intentions (Woodward, 1998, 1999), they begin to see hands as agents of change and this is facilitated by head and eye direction (Amano, Kezuka, & Yamamoto, 2004), and they expect people to behave differently towards objects than towards other people (Legerstee, Barna, & DiAdamo, 2000). Whether these abilities serve as stepping stones for the older infant's ability to reason about agents' mental states could be a subject of further investigation.

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