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Effects of Gesture and Target on 12- and 18-Month-Olds' Joint Visual Attention to Objects in Front of or Behind Them

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Factors affecting joint visual attention in 12- and 18-month-olds were investigated. In Experiment 1 infants responded to 1 of 3 parental gestures: looking, looking and pointing, or looking, pointing, and verbalizing. Target objects were either identical to or distinctive from distractor objects. Targets were in front of or behind the infant to test G. E. Butterworth's (1991b) hypothesis that 12-month-olds do not follow gaze to objects behind them. Pointing elicited more episodes of joint visual attention than looking alone. Distinctive targets elicited more episodes of joint visual attention than identical targets. Although infants most reliably followed gestures to targets in front of them, even 12-month-olds followed gestures to targets behind them. In Experiment 2 parents were rotated so that the magnitude of their head turns to fixate front and back targets was equivalent. Infants looked more at front than at back targets, but there was also an effect of magnitude of head turn. Infants' relative neglect of back targets is partly due to the "size" of adult's gesture.

By the end of their first year, infants are sensitive to information specifying where others are looking. Scaife and Bruner (1975) first documented infants' tendency to turn to follow an adult's gaze. Gaze-following is a critical component of *joint visual attention,* defined as looking toward the object of another person's attention because it is the object of their attention. Joint visual attention is a particularly important social event because it is thought to be the earliest manifestation of intersubjectivity, that is, the ability to infer others' mental states (Baron-Cohen, 1995; Tomasello, 1995; Trevarthen & Hubley, 1978). It also seems to facilitate language development. Toddlers' vocabulary is predicted by the frequency of mothers' and infants' joint visual attention (Tomasello & Todd, 1983). It is also predicted by infants' responsiveness to pointing (Harris, Barlow-Brown, & Chasin, 1995; Smith, Adamson, & Bakeman, 1988). In addition, failure to respond to others' gaze predicts childhood autism, which is typified by severe language deficits (Loveland & Landry, 1986; Mundy, Sigman, & Kasari, 1990). Finally, infants use a speaker's gaze to infer which of several objects is the referent of a novel word (see Baldwin, 1995).

Because joint visual attention has implications for early social and language development, it is important to understand how adults' actions elicit joint attention with infants. Infants are sensitive to changes in the orientation of an adult's head and eyes and to movement of the head, particularly motion contingent on the child's actions (Corkum & Moore, 1995; Hains & Muir, 1996; Johnson, Slaughter, & Carey, 1998). Between 9 and 15 months of age, infants follow at least two attention-specifying gestures: (a) turning the head to gaze at an object and (b) pointing (with outstretched arm) at an object (Butterworth & Cochran, 1980; Butterworth & Grover, 1988; Butterworth & Jarrett, 1991; Collis, 1977; Morissette, Ricard, & Gouin Décarie, 1995; Murphy & Messer, 1977). Butterworth and Cochran (1980), for example, found that 12-month-olds often followed their mother's gaze to the correct quadrant of the room. Similarly, Morissette et al. (1995) found that 12-month-olds accurately followed an adult's gaze and pointing to one of four locations.

Despite this evidence, 12-month-olds' ability to follow another's gaze appears limited. Butterworth and colleagues (1991b; Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991) found that infants younger than 12 months turn in the direction of an adult's gesture, but they fixate on the first object along the scan path even if it is not the target object. The researchers also found that infants establish joint visual attention to objects within their visual field before they do so for objects outside their visual field (i.e., behind them). The ability to ignore objects in front of them and to follow an adult's gaze to targets behind them emerges between 12 and 18 months of age.

Butterworth (1991b) attributed these changes to infants developing joint visual attention mechanisms. The earliest, *ecological* mechanism is largely driven by interesting or attractive objects in

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the environment. An adult looking toward an object compels infants to turn in the appropriate direction until they see an interesting object (whether or not it is the object of the adult's attention). There is no attempt, however, to coordinate attention with the adult. At around 12 months of age, a new *geometric* mechanism emerges. Now infants can extrapolate an imagined line from the adult's direction of gaze (or point) to an object. Infants will follow a gesture to the target even if another object is closer to their midline—but only if the target is within their visual field. They will not follow a gesture to look at targets behind them, presumably because they can form only non-Euclidean or egocentric spatial representations. That is, they cannot represent their environment as a plane, some region of which is visible from their vantage, and other regions of which might be visible to another person. This Euclidean representation must await the emergence of a *representational* mechanism at around 18 months of age. Thereafter infants can infer that things occupy space currently out of view and that other people can see objects that the infant cannot see. Other researchers also believe that by 18 to 24 months, infants can make inferences about other people's unobservable mental states, including attention (Baron-Cohen, 1995; Dunham & Dunham, 1995; Repacholi & Gopnik, 1997; Tomasello, 1995; Wellman, 1993).

Butterworth and colleagues (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991) have reported evidence consistent with this theory, but there are other possible accounts of the development of joint visual attention. These deserve serious consideration because Butterworth's theory, in which two qualitatively different mechanisms are acquired during infancy, is not optimally parsimonious. One alternative, explicated by Moore and Corkum (1994), is that joint visual attention is learned. It follows months of reciprocal social interactions between infants and caregivers in which changes in facial expression and gestures play an important role. Joint attention might emerge from learning to turn in the direction of the caregiver's gaze, because doing so is more likely to result in an interesting sight. Thus, social learning drives joint attention, though learning is constrained by certain causal and social sensitivities (Corkum & Moore, 1998; Moore & Corkum, 1994). Such a learning mechanism could also explain progressive improvement in accuracy of joint attention. For example, early in conditioning, following gaze to the correct side (i.e., the infant's left or right) might be reinforced because fixating on any interesting object is sufficiently interesting. But over time, infants could learn to follow gaze to the precise object of the caregiver's attention, even if it is initially out of sight, because finding the true object of attention prolongs enjoyable social interaction with the caregiver. Although the studies reported here do not directly test a conditioning account of joint visual attention, such an account is more parsimonious than Butterworth's theory. If behavioral evidence is inconsistent with Butterworth's account, a conditioning account will remain credible.

We hypothesized that the critical findings for Butterworth's account—specifically, failure of 9–12-month-olds to follow gaze to targets behind them—might instead be explained by perceptual factors. Younger infants sometimes might fail to detect changes, especially small changes, in adults' gaze direction. More elaborate or expansive gestures, such as pointing at an object or talking about it while looking at it, might elicit joint attention more reliably from 12-month-olds. We investigated this hypothesis in Experiment 1.

If younger infants are unlikely to detect small changes in gaze direction, the standard laboratory procedure for testing joint visual attention might prevent infants from following another's gaze to objects outside their visual field. When infant and adult face each other straight on (i.e., the typical procedure), the adult makes only a small head turn to look at an object behind the baby but makes a large head turn to look at an object in front of the baby. This confound is depicted in Figure 1. Infants, especially younger infants, might be more likely to notice and follow larger head turns. We tested this hypothesis in Experiment 2 by rotating the mother so that the magnitude of her head turn was independent of the location of objects relative to the infant. That is, the mother turned her head the same radial distance whether the target was in front of or behind the infant.

We also hypothesized that the nature of the target objects affects whether young infants engage in joint visual attention with an adult. In many studies (e.g., Butterworth & Jarrett, 1991; Morissette et al., 1995), potential target objects are identical and often quite simple (e.g., yellow squares). Infants might expect adults to direct their attention to items that are distinctive and moderately complex. If objects are distinctive and complex (i.e., interesting), infants might look at the specific object an adult is attending to, even if it is outside of their visual field. In contrast, if objects are identical and simple, infants might quickly stop responding to adults' gestures.

In this study we investigated the effects of three factors on joint visual attention in 12- and 18-month-olds. These factors were the type of attention-directing gesture, the magnitude of the gesture (i.e., large vs. small head turns), and the distinctiveness of the target objects.

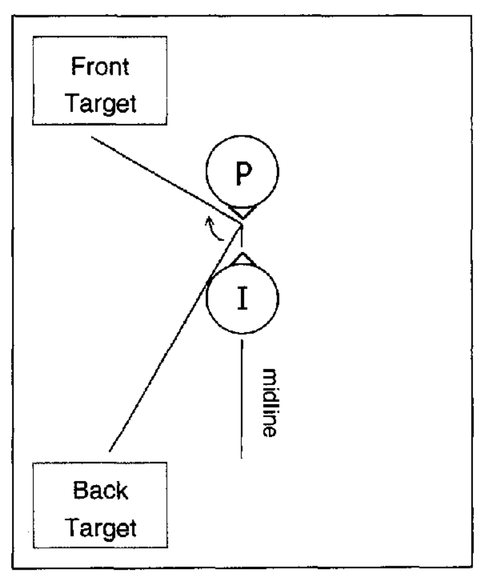

Figure 1. Schematic diagram of typical joint attention paradigm with infant (I) and parent (P). Note that parent produces a small head turn to gaze at target behind infant (back target) but a large head turn to gaze at target in front of infant.

Experiment 1

In the first experiment, we explored the relative effectiveness of different gestures and different kinds of objects in promoting joint visual attention. Parents were instructed to produce one of three gestures toward a specified object. The objects were either identical or distinctive. The designated target object was located in different regions of the infant's visual field (i.e., front, periphery, or back). Twelve- and 18-month-olds were recruited in order to test the hypothesis that the ability to follow an adult's gesture to targets outside the visual field emerges between 12 and 18 months of age.

Gesture Type

Head–eye orientation indicates the locus of a person's attention, as does the direction of a point. Gaze and pointing are not, however, equivalent. When Butterworth and Grover (1988) and Morissette et al. (1995) compared infants' responses to adults' gaze orientation alone versus to adults' gazing and pointing, infants older than 9 months more often followed adults' gazing and pointing. Even when pointing accompanies gaze, however, infants' responsiveness depends on target location (i.e., front, periphery, or back). Morissette et al. (1995) found that 12-month-olds reliably followed gazing and pointing to front targets (i.e., 20° from midline) but not to peripheral targets (i.e., 70° from midline). Fifteen-month-olds reliably followed gazing and pointing to peripheral targets, and 18-month-olds reliably followed gazing (either alone or with pointing) to peripheral targets. Butterworth and Grover (1988) reported that 12-month-olds reliably looked at targets in front of them but not at targets behind them, even if the adult pointed. In sum, gaze accompanied by pointing elicits joint attention more effectively than gaze alone from infants 9 months or older. Even with pointing added, however, infants do not follow gaze to targets outside their visual field until after their first birthday.

We compared 12- and 18-month-olds' responsiveness to three different attention-directing gestures. One group of parents turned their head to gaze at a target object. We called this the *look* condition. A second group of parents gazed and simultaneously pointed toward a target object. This was called the *look-and-point* condition. A third group of parents gazed and pointed toward a target while verbally encouraging their infants to look at it. This was called the *look, point, and verbalize* condition. We presumed that in everyday interactions, parents seldom remain silent while trying to direct their infant's attention. Instead, they are likely to verbally exhort their infant to look at an interesting object or event. This combination of actions is therefore believed to be representative of everyday parental bids for infant attention. The effect of parents' verbalizations on joint visual attention has not previously been explored.

A secondary question was whether children respond more readily to some attention-directing gestures than to others. That is, gestures that more reliably elicit joint attention might also elicit it more rapidly. We tested whether more elaborate attention-directing gestures elicit a higher percentage of hits (i.e., looks at target) within a few seconds of the onset of the parent's gesture.

Target Type

Half of the infants in every group saw identical blue squares at each target location on every trial. The other half saw multicolored, irregularly shaped objects with gaudy decorations attached. Because each object in the latter set was unique, the targets necessarily differed across location and trial. We speculated that in previous investigations, 9–12-month-olds followed adults' gaze in the correct direction but fixated at the first object along the scan path because all objects were identical. If all objects are identical, there is little motivation to search for and identify a particular item. The parent's gesture loses its validity, in a sense. Even in older infants, the added effort required to turn around to follow another's gaze might have exceeded their motivation to look at simple, identical targets. In general, the presence of distinctive objects may help sustain infants' interest in the joint attention task. For these reasons, half of the infants saw distinctive objects, and half saw identical objects. We expected the former to follow parents' gestures more reliably. We also predicted that the frequency of gaze-following would decrease across trials more for infants who saw identical targets than for infants who saw distinctive targets.

Method

Participants. One hundred and twenty infants and parents participated. Sixty 12-month-olds (30 girls, 30 boys; mean age = 12 months 7 days, range = 11 months 18 days to 13 months 4 days) and sixty 18-month-olds (30 girls, 30 boys; mean age = 18 months 7 days, range = 17 months 15 days to 19 months) were included in the analyses. Twelve additional infants were excluded due either to experimenter error ($n = 4$) or fussiness ($n = 8$). Infants were recruited from a database maintained at the University of Minnesota and were primarily Caucasian and middle class. Parents were initially contacted by telephone.

Apparatus and objects. To eliminate any interesting visual stimuli other than the target objects, we conducted the experiment in a room in which white sheets were hung from ceiling to floor around the perimeter. The space within the sheets measured 4.4 × 3.2 m. The infant was seated in a booster chair in the center of the room. The parent's chair faced the infant seat. The seats were situated so that the infants' and parents' eyes were at the same height.

One set of objects included 4 identical squares (15 cm × 15 cm) covered with blue construction paper. The other set included 14 irregular polygons, similar in size to the squares, covered with multicolored construction paper and decorated with various colorful, shiny items. Each object in the latter set had a unique shape, color scheme, and decorations. Objects were mounted on four movable, white stanchions placed in front of the sheets and were turned so that each target faced the infant. A video camera mounted on the ceiling directly above the infant's head recorded a bird's-eye view of the infant. The objects were not visible on videotape. A digital stopwatch was electronically printed on the videotape for coding purposes. A hand-held stopwatch was used during the session to monitor trial length.

Design. Twelve- and 18-month-olds were quasi-randomly assigned to 12 groups, with the constraint that each group included approximately equal numbers of girls and boys. Each of 6 groups within each age received one of three parental gestures (look; look and point; or look, point, and verbalize) and one of two types of objects (identical or distinctive).

Object location was varied within-subjects. Ten locations were paired, one on each side of the room, in five "latitudes" ranging from the front to the back of the infant. The configuration is represented in Figure 2. Note that Locations 1 and 2 were in front of the infant, that is, close to the infant's midline and within his or her midline visual field. Location 3 was in the infants' periphery (75° from midline), and Locations 4 and 5 were behind the infant, outside her or his visual field.

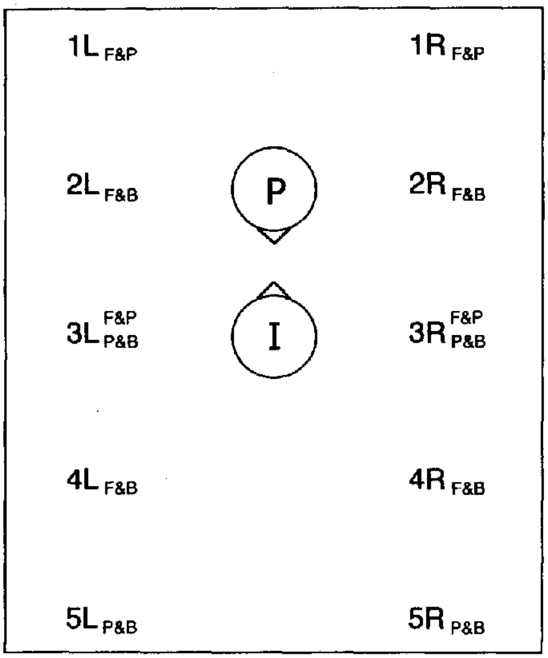

Figure 2. Schematic diagram of room showing location of infant, parent, and targets in Experiment 1. P = parent; I = infant; F&P = front and periphery configuration; F&B = front and back configuration; P&B = periphery and back configuration. Distance from infant's midline, and side of the room, are specified by location codes (e.g., 2L).

An object was placed at 4 of the 10 target locations in every trial. Three trial configurations were used (similar to those used by Butterworth & Jarrett, 1991). In *front-and-periphery* (F&P) trials, objects were at Locations 1 and 3. In *front-and-back* (F&B) trials, objects were at Locations 2 and 4. In *periphery-and-back* (P&B) trials, objects were at Locations 3 and 5. In each configuration, the four objects were in two parallel right–left target pairs. One object (either front or peripheral) was therefore seen first if the infant turned from midline to scan in either direction.

Peripheral objects were present in two configurations: F&P and P&B. In the former they were the second object seen when scanning from midline; in the latter they were the first object seen. Varying the location of objects accompanying the peripheral target allowed us to test Butterworth's (1991b) finding that 12–18-month-olds fixate on the first object along the path they are scanning when the target is far from the infant's midline.

In all configurations, the first and second objects on one side were separated by 60°.

All infants completed 12 trials: 4 F&P trials, 4 F&B trials, and 4 P&B trials. On each trial one object was the designated target toward which the parent gestured, and the other three were distractors. Across 4 trials within a given configuration, the designated target was at each location once. Across all 12 trials, then, the designated target was at each location once, except twice it was at Locations 3 left and right (i.e., for F&P and P&B trials). Every infant within a condition (n = 10) received a different random order of configurations and locations, with the constraints that each parent gestured toward a different target location on the first trial, and no more than 2 successive trials were in the same configuration.

Procedure. The purpose of the experiment and the procedure were explained to the parent upon arrival at the laboratory.[1] The parent was instructed to use a particular gesture to direct her infant's attention.[2] Parents in the *look* condition were instructed to turn their heads and look directly at the target object, without gesturing or speaking. Parents in the *look-and-point* condition were instructed to turn their heads to look at the target object and to point to it without speaking. Parents in the *look, point, and verbalize* condition were instructed to turn their heads to look at the target, point to it, and verbally encourage their child to look at it. Parents in this group were asked to say whatever they would normally say to redirect their child's attention. Parents were instructed to play with and distract their child between trials but not to touch the child once a trial began (in pilot testing, parents sometimes touched their children to encourage them to look at the target). Parents who did not follow the instructions (e.g., who talked to their infant during trials, unless in the look, point, and verbalize condition) were replaced. Before each trial, the experimenter told the parent which location contained the upcoming target. The parent then called the infant until she or he looked at the parent. The experimenter then signaled the parent to begin the trial, whereupon the parent gestured toward the designated target. The experimenter did not give the signal until he or she saw that the infant was looking at the parent. Each trial lasted 15 s from when the parent first turned toward the target.

Coding. A coder recorded the direction of every visual fixation by every infant. A fixation was defined as absence of head movement (i.e., scanning or turning) for at least 0.5 s.[3] The radial orientation (i.e., direction) of the infant's head during a fixation was measured by an acrylic disc, marked with 35 radial lines separated by 10°, mounted on the video monitor. The center of the disc was placed over the center of the infant's head and adjusted so that child's midline was at 0°. Head orientation was then measured for every fixation within 15 s of the onset of the parent's gesture. Any fixation within 25° of the designated target was coded a "hit." These fixations were an average of 13° (SD = 7°) from the actual target location. We do not know how much of this deviation reflects measurement error, but because there were no objects visible to the infant other than the target and the three distractors, and the closest distractor was 60° from the target, the 25° criterion seems reasonable. For an unbiased test of infants' propensity to follow gestures to the designated target, any fixation within 25° of any of the three distractor objects was coded a "miss." Coders were blind to target type (i.e., identical or distinctive) and to the exact locations of the objects.

A second coder, naive to the hypotheses of the study, independently recoded 36 randomly selected infants (twenty 12-month-olds and sixteen 18-month-olds; 30% of the sample). Interrater agreement for hits and misses was assessed by kappas (Cohen, 1960), which adjust for base rates and thus are more conservative than simple agreement. The mean kappas were .80 for 12-month-olds and .76 for 18-month-olds; this exceeds the criterion for good agreement using kappas.

[1] During initial telephone contact we asked any primary caregiver to accompany the infant. All but 2 infants were brought by their mother.

[2] Although using parents to deliver gestures probably introduced some error variance due to individual differences in parents' manner of gesturing, this procedure was chosen for several reasons. First, it minimized negative affective responses from infants caused by interactions with strange adults. Second, because dyads were randomly assigned to conditions, it is likely that any individual differences were reasonably well distributed. Third, greater error variance would tend to increase Type II error; however, the critical hypotheses examined here all stipulate rejection of the null hypothesis; thus, it is increases in Type I error that would have been of concern.

[3] Given that adults' fixations are as short as 200 ms and that young infants' visual scanning and processing are somewhat slower than adults', 500 ms seemed a reasonable, if slightly conservative, criterion for fixations in 12–18-month-olds.

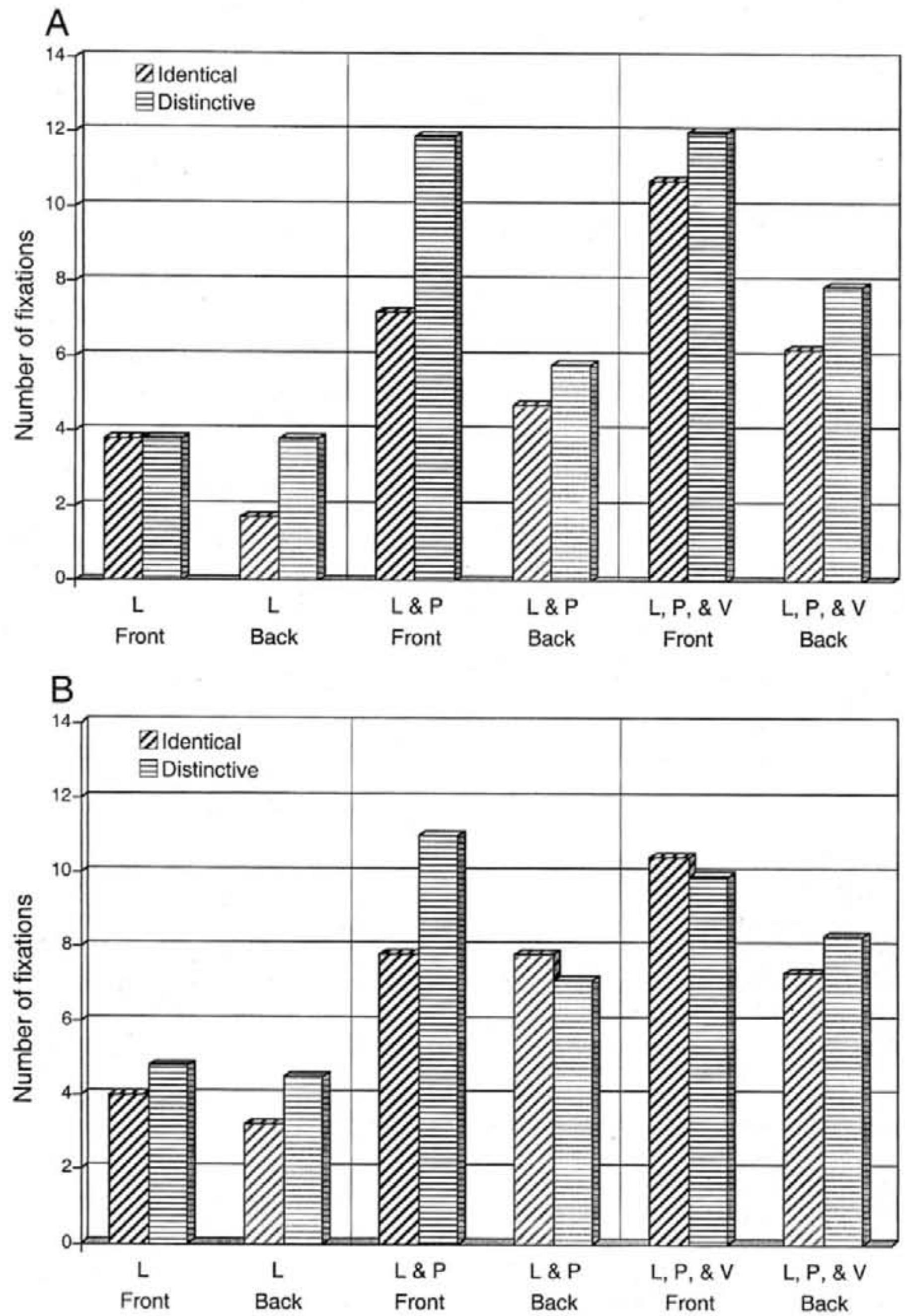

Figure 3. Mean number of fixations on front and back targets, by gesture combination and target type in Experiment 1. A: 12-month-olds. B: 18-month-olds. L = look condition; L & P = look-and-point condition; L, P, & V = look, point, and verbalize condition.

Results

The main dependent variable was the frequency of visual fixations of designated targets during test trials.[4] The total number of hits across all 12 trials is shown in Figure 3A (12-month-olds) and 3B (18-month-olds). Because the literature suggests that 9–18-month-olds follow adults' gestures more often to targets within their visual field than to targets outside their visual field, total hits were divided into "front" and "back" hits. Front hits were the number of correct hits in all trials in which the designated target was at Locations 1 or 2, or 3 F&P. Back hits were the number of hits when the target was at Locations 4 or 5, or 3 P&B. Location 3 was considered a front target if the ipsilateral distractor was behind the infant (P&B trials) and a back target if the distractor was in

[4] This measure is highly correlated with total looking time (r = .77; Flom, Burmeister, & Pick, 1998).

front of the infant (F&P trials). This is consistent with findings that infants are less likely to follow gaze to a peripheral target if the distractor is in front of the target than if the distractor is behind the target (Butterworth & Jarrett, 1991). In other words, peripheral targets are treated by infants more like back targets in an F&P configuration and more like front targets in a P&B configuration. This justifies the designation of Location 3 as either front or back, but note that the results below are similar if Location 3 trials are excluded from the analyses.

Total front and back hits for each infant were entered into a multivariate analysis of variance (MANOVA), with age (12- vs. 18-month-olds), gesture (look vs. look-and-point vs. look, point, and verbalize), target (identical vs. distinctive), and gender as between-subjects variables.

Although 18-month-olds fixated somewhat more than 12-month-olds on correct target objects (*M*s = 14.3 vs. 13.3, *SD*s = 7.3 and 7.5), the multivariate age effect was not significant, $F(2, 95) = 1.9$ (Hotelling's T^2 is reported for all multivariate tests). Univariate tests showed that the age effect was not reliable for either front or back hits. The data therefore do not confirm that 12-month-olds are less able than 18-month-olds to follow gestures outside their visual field.

Infants' hit frequency differed significantly across gesture conditions, $F(4, 188) = 24.4$, $p < .001$. Infants whose parents only looked at targets produced a mean of 7.4 hits ($SD = 4.3$); infants whose parents looked and pointed produced a mean of 15.9 hits ($SD = 7.1$); and infants whose parents looked, pointed, and verbalized produced a mean of 18.2 hits ($SD = 5.5$).

Post hoc comparisons revealed that infants produced more hits in the look-and-point condition than in the look condition ($p < .05$ by two-tailed Scheffé tests). The difference between the look, point, and verbalize condition and the look-and-point condition, however, was not significant. Thus, pointing significantly added to the efficacy of the looking gesture, but parental verbalizations did not reliably increase joint attention above and beyond looking and pointing. It is important to note that the effect of parental gesture was significant for back and front hits, $F(2, 96) = 10.6$ and 48.4, respectively, $ps < .001$. This suggests that infants follow gestures to targets behind them more frequently if the gestures are more elaborate and therefore, perhaps, more noticeable.

Target type also influenced infants' hit frequency, $F(2, 95) = 5.2$, $p < .01$. Infants followed gestures a mean of 12.5 times ($SD = 7.7$) to identical targets and 15.2 times ($SD = 6.8$) to distinctive targets. Univariate tests showed that this effect was significant for front targets, $F(1, 96) = 9.3$, $p < .005$, as well as for back targets, $F(1, 96) = 3.9$, $p = .05$. This suggests that infants more often follow gestures to distinctive, complex targets than to repetitive, simple targets. Perhaps infants habituate to gestures that terminate in boring targets. We tested this hypothesis separately (see below).

Although girls followed parents' gestures more often ($M = 15.1$, $SD = 8.1$) than boys ($M = 12.6$, $SD = 6.4$), the gender effect did not achieve statistical significance, $F(2, 95) = 2.2$. Sex differences in joint attention are not predicted by any previous findings.

The MANOVA revealed only one significant interaction: Gesture × Target Type, $F(4, 188) = 2.9$, $p < .03$. The interaction was reliable for front targets only, $F(2, 96) = 4.7$, $p < .02$. The advantage of distinctive over identical targets was greater in the look-and-point condition than in the other gesture conditions.

To test the hypothesis that infants more rapidly habituate to nondistinctive targets than to repetitive, identical targets, we examined the difference between total number of hits in the first six trials and in the last six trials. If rate of habituation differs for identical and distinctive targets, the difference between the first six and last six trials should be larger for identical targets. Difference scores were entered into an analysis of variance (ANOVA), with age (12- vs. 18-months), gesture (look vs. look and point vs. look, point, and verbalize), and target type (identical vs. distinctive) as between-subjects variables. Total number of hits was covaried to control for individual differences in overall responsiveness. The analysis showed no significant effects except a main effect of target type, $F(1, 107) = 5.2$, $p < .03$. Infants' gesture-following declined more across trials when targets were identical than when they were distinctive.

To test how rapidly 12- and 18-month-olds responded to different gestures, we compared, by gesture condition and infant age, the percentage of hits that occurred within 5 s of the onset of the parent's gesture. This provides some indication of how rapidly infants responded to different gestures. Overall, 49% of infants' hits occurred within 5 s of gesture onset (the remainder occurred within the subsequent 10 s). An ANOVA revealed that the percentage differed marginally by age, $F(1, 114) = 3.6$, $p < .06$, and significantly by gesture, $F(1, 114) = 4.2$, $p < .02$. Older infants more than younger infants tended to look at the target during the first 5 s. Infants also followed looking and pointing during the first 5 s more than looking alone. Mean percentages (and standard deviations) are shown in Table 1.

To assess individual infants' consistency in establishing joint attention, we counted the number of trials (out of 12) in which an infant looked at the target at least once. Trials in which the infant looked at the three distractor objects more often than the target were not counted. The overall mean was 7.0 trials ($SD = 2.7$). Six infants (all of them 12-month-olds) looked at the target more than at the distractors on only 0–2 trials, and 24 infants (16 of them 18-month-olds) did so on 10–12 trials. Sixty-one percent of the sample (thirty-four 12-month-olds and thirty-nine 18-month-olds) looked at the target more than at the distractors on most trials (at least 7 out of 12). Most infants, then, responded to adults' gestures on most trials.

The data allowed a test of Butterworth's (1991b) claim that 12-month-olds' visual attention is captured by the first object seen as they scan in the direction of an adult's gaze. The number of hits when the target was at Location 3 during P&B trials (i.e., periph-

Table 1
Mean Percentages (and Standard Deviations) of Hits Produced Within 5 Seconds of the Parent's Gesture, by Age and Gesture Condition: Experiment 1

Age of infant (in months)	Look *M*	Look *SD*	Look and point *M*	Look and point *SD*	Look, point, and verbalize *M*	Look, point, and verbalize *SD*
12	33.1	29.1	57.1	20.5	46.5	11.3
18	54.4	31.6	59.9	18.1	50.6	13.2

eral target was the first object in the scan path) was compared with the number during F&P trials (i.e., peripheral target was second). If infants tend to fixate the first object on the scan path, they should produce fewer hits to peripheral targets when the distractor is in front than when it is in back. The difference for each child between Location 3 hits in F&P trials and in P&B trials was entered into an ANOVA, with age and target type as between-subjects variables. There were no significant effects, and the mean difference across all children was not significantly different from zero (M = 0.06, SD = 2.1), $t(119) < 1$. There is no evidence, then, that 12- and 18-month-olds looked less often at peripheral targets when the distractor was close to midline.

The findings thus far generally do not confirm Butterworth's (1991b, 1995) theory that 12-month-olds cannot follow gaze to targets outside their visual field. These results might, however, reflect a statistical artifact. Some conditions might elicit overall higher base rates of scanning the room and looking at different objects. This would elevate the number of hits to the designated target as well as to distractor objects. The apparent increase in joint visual attention would in fact be an artifact of increased looking activity. To rule out this possibility, we conducted analyses taking into account base rates of looking at all objects. Difference scores were calculated by subtracting the average number of fixations of the three distractor objects in every trial from the number of looks to the target object. A difference score of zero would mean that infants looked on average at any given distractor as often as they looked at the target object. This would suggest that parents' gestures did not guide infants' looking. Positive scores would suggest that infants looked more often at the designated target than at any given distractor. This is a more controlled assessment of the incidence of joint visual attention.

Difference scores for the six trials in which the target was in front of the infant were significantly greater than zero (M = 7.2, SD = 4.3), $t(119) = 18.0$, $p < .001$. Difference scores for the six trials in which the target was behind the infant were also greater than zero (M = 4.0, SD = 4.2), $t(119) = 10.4$, $p < .001$. This suggests that infants followed gestures to targets outside of their visual field. Perhaps only 18-month-olds contributed to this effect. This was not the case, however: 12-month-olds' difference scores for back targets exceeded zero (M = 3.1, SD = 3.4), $t(59) = 7.0$, $p < .001$. Their difference scores for front targets also significantly exceeded zero (M = 7.7, SD = 4.7), $t(59) = 11.9$, $p < .001$. Even among 12-month-olds whose parents only looked at the target, back target difference scores exceeded zero (M = 1.6, SD = 2.7), $t(19) = 2.7$, $p < .02$. This is the first demonstration that 12-month-olds reliably follow an adult's gaze to targets outside their visual field, even when there are distractor objects in front of the infant.[5]

Discussion

These findings have several implications for previous findings and current hypotheses about infant joint attention. Similar to earlier findings (e.g., Butterworth & Grover, 1988) demonstrating that some gesture combinations are more effective than others at guiding infants' attention, the results of Experiment 1 reveal that pointing and looking at a target are more compelling than looking alone. Why is pointing so effective? Perhaps infants have learned that pointing is an intentional request to recruit and direct another person's attention, whereas gaze is not necessarily intended to direct attention, and therefore does not always mandate a shift of attention. Another possibility is that pointing is a better geometric cue than head orientation. That is, although infants can extrapolate a vector from the orientation of a person's head, an outstretched arm provides a longer, more precise segment of the vector. Finally, pointing might be more effective because raising and outstretching one's arm is more noticeable than simply rotating one's head, particularly if the radial magnitude of the head turn is small. We tested this last possibility in Experiment 2.

The gesture effect raises ancillary questions. For example, the effects of looking and pointing might be cumulative. Perhaps looking and pointing toward a target provide a critical mass of redundant information about the location of the object of attention. Future studies that independently vary looking and pointing could address this possibility. A related question is whether looking and pointing together imposed a ceiling effect. Verbally exhorting infants to look at the target did not significantly increase the frequency of joint visual attention above looking and pointing. It is unlikely, however, that parental utterances have no effect on joint attention. More likely, pointing was so effective that it masked the effects of verbalizations. Further research on the effects of parental verbalizations on infant attention will be needed to resolve this issue.

Infants more often followed an adult's gesture to distinctive and relatively complex target objects than to identical and simple objects. Infants might have been less motivated to follow adults' gestures if, after a few trials, they came to expect gestures to indicate repetitive, boring objects. This is supported by the finding that target type alone contributed significant variance to the difference between hits in the first and second half of the session (when total hits were covaried). More generally, the target type effect exemplifies the triadic nature of joint attention: Another person's gesture mediates the infant's allocation of attention to an array of objects and events within a perceptually shared (or shareable) environment. Not all objects and events are equally worthy of joint attention. There is evidence, for example, that infants follow gestures to moving objects more than to static objects (Butterworth, 1991a). Some objects are more interesting to look at than others, and it might be possible to specify the stimulus variables that mediate these differences. Yet not everything that interests adults (e.g., stock reports, rare coins) interests babies. Part of the "economics" of joint attention involves knowledge of what kinds of things are likely to interest another person. If an adult often calls attention to uninteresting things, a baby should learn to ignore that person's gestures as invalid. The target-type effects imply that infants rapidly adapt to the validity of an adult's attention-specifying gestures and habituate to gestures that do not "pay off" in interesting sights.

To maximize the possibility of finding a target-type effect, we conflated complexity and distinctiveness. That is, distinctive tar-

[5] Because mean difference scores in some conditions were positively skewed, we conducted another analysis of the log of each infant's difference score plus 10. This provides a more normally distributed sample in which scores greater than 1.0 indicate more fixations on the target than on any given distractor. This more conservative test yields similar results. For example, 12-month-olds in the look condition produced difference logs greater than 1, $t(19) = 2.6$, $p < .02$.

gets were also more complex, and therefore we do not know how each variable contributed to the effect. Future studies are needed to determine how these variables affect infants' persistence in following adults' gestures. Moreover, only two levels of distinctiveness and complexity were tested, yet both variables are multidimensional and difficult to define. Future research should establish how different aspects or degrees of distinctiveness and complexity influence joint visual attention. An informative starting point would be provided by naturalistic studies of the kinds of objects and events that infants and adults spontaneously call to one another's attention.

There is an alternative explanation of the target-type effect. Perhaps parents gesture more emphatically or effectively toward some targets than others. Parents might gesture more emphatically toward interesting targets because such targets are worth pointing out or toward boring targets to overcome the target's shortcomings. By this account, the target-type effect might be conflated with an unintended gesture effect. This suggests a more general question: Did the manner in which parents executed a gesture influence the probability that the child would follow it? If so, an adult observer should be able to predict whether the target object was interesting on the basis of the gesture's efficacy. In addition, an observer's estimate of the efficacy of the gesture should predict the incidence of joint attention. To test these hypotheses, a coder with extensive experience observing and testing infants coded videotapes of parents in the look-and-point condition. The coder rated, on a 5-point Likert scale, the effectiveness and enthusiasm of the parent's gesture in every trial. The coder was blind to the target type and to the infant's response. After coding all 12 trials for an infant, the coder inferred whether the targets had been "interesting" or "boring." The gesture efficacy across 12 trials was averaged for each parent. The difference of the means for parents who gestured at identical targets (M = 2.4) versus distinctive targets (M = 2.6) did not reach conventional levels of significance, $t(34) = 1.7, p < .11$. We cannot conclude that parents systematically gestured more effectively or emphatically toward distinctive targets. Moreover, parents' mean gesture efficacy was unrelated to how often infants looked at target objects (r = .09). Finally, the coder was correct only 55% of the time about the target type, which does not differ from chance. These findings, although limited, reveal no evidence that parents' production of a given gesture differed as a function of target type.

In the current findings, as in Butterworth and Jarrett's (1991) study, 12-month-olds followed gestures more often to targets in front of them than to targets behind them. The current results nonetheless fail to confirm Butterworth's (1991b) developmental theory. Butterworth's theory suggests that between 12 and 18 months of age, infants develop the ability to represent the environment as a Euclidean space in which different people can look at different locations, not all of which are visible to all viewers. Twelve-month-old infants will not follow another person's gaze to unseen locations even if there are no distractors in view. By 18 months, infants follow another's gaze to unseen locations unless there is competition from visible distractors. During and after this period there is a decoupling of joint visual attention from the visibility of different locations. In contrast to this picture, 12-month-olds followed gestures to targets behind them, even when there were competing objects in the visual field. Also, the differences between 12- and 18-month-olds were small and not significant. Perhaps these differences, as reported in previous studies (e.g., Butterworth & Jarrett, 1991), are apparent only when adult gestures and visual targets are subtle and not compelling. Providing more informative gestures and more distinctive targets increased both 12- and 18-month-olds' tendency to follow gestures to targets out of view. This suggests that deficits in spatial representation (i.e., a non-Euclidean schema) do not explain why infants more reliably follow gestures to front targets. Rather, we must consider how and why specific combinations of gestures compel infants to look at a particular location inside or outside their current visual field. This apparently depends partly on how compelling the gesture is and whether it is likely to terminate in a distinctive, interesting target.

Experiment 2

The purpose of Experiment 2 was to explore why young infants more readily follow adults' gestures to locations within their current visual field than to locations outside their visual field. In regard to objects behind them, infants more often followed looking and pointing than looking alone. To understand this finding, consider again the spatial arrangement in Figure 1. When the infant and parent face each other (as in Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991, and Experiment 1 of the present study), the distance that the parent's head rotates from the infant to the target depends on the target location. Targets behind the infant are close to the parent's midline, whereas those in front of the infant are in the parent's periphery or behind the parent. To look at an object behind the infant (e.g., Location 5), the parent produces a small head turn. To look at an object in front of the infant (e.g., Location 1), the parent produces a large head turn. Infants might detect a larger movement more readily than a smaller movement.

To investigate this possibility, we changed the spatial arrangement of the infant and parent in relation to the objects. The new configuration is depicted in Figure 4. Infants were situated as in Experiment 1, but parents were rotated 90° (to the infant's left or right). In this configuration, in order to look at one front and one back target (Locations F/S and B/S in Figure 4), the parent must produce relatively small but equal-sized head turns. To look at the other front and back target (Locations F/L and B/L in Figure 4), the parent must produce relatively larger but nonetheless equal-sized head turns.

If 12-month-olds follow gestures to front targets more than to back targets because their spatial representations are egocentric, gesture magnitude should not mediate joint visual attention. If the front target advantage is an effect of gesture magnitude, however, infants should follow large gestures (i.e., toward /L locations) more than small gestures (i.e., toward /S locations) whether the target is within or outside their visual field.

Two gesture conditions were included: look and look and point. The latter was included because the effect of head-turn magnitude might be reduced when pointing is added. Pointing is a relatively noticeable body motion, and it provides redundant spatial information. Both 12-month-olds and 18-month-olds participated.

Method

Participants. Forty-eight infants and their parents participated in Experiment 2. Twenty-four 12-month-olds (12 girls, 12 boys; mean age = 12

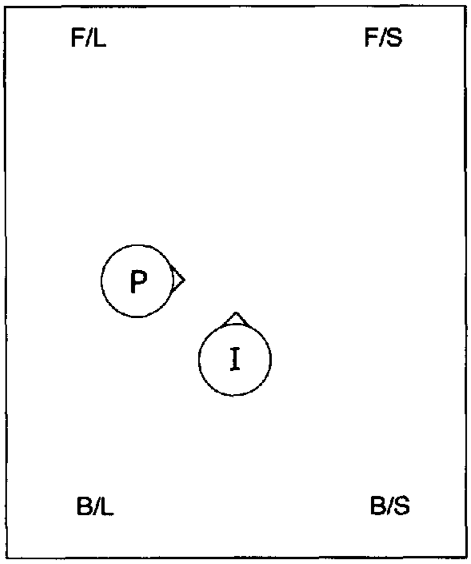

Figure 4. Schematic diagram of room, showing location of infant, parent, and targets in Experiment 2. P = parent; I = infant; F = front target; B = back target; S = target brought into view by a small gaze shift; L = target brought into view by a large gaze shift (e.g., F/S is the target in front of the infant that the parent looks at by producing a small head turn).

months 1 day, range = 11 months 3 days to 12 months 2 days) and twenty-four 18-month-olds (12 girls, 12 boys; mean age = 18 months 3 days, range = 17 months 18 days to 18 months 13 days) were included in the final analyses. Infants were recruited as in Experiment 1.

Materials. The apparatus and distinctive objects of Experiment 1 were used.

Design. Infants (12- and 18-month-olds) were quasi-randomly assigned to one of two gesture conditions (look or look and point), with the constraint of equal numbers of boys and girls in each group.

Target object locations were symmetrically paired. Two objects were on the infant's left, and two were on the right. Object pairs were separated by 60°. One pair was in front of the infant, and the other was behind. This configuration was used on every trial. Every infant completed 3 trials with each of four target locations, for a total of 12 trials. Trials were in blocks of four, with target location counterbalanced. Target location order was randomized within blocks. Parents were seated to one side of the infant, rotated 90° so that their midline gaze direction was perpendicular to the infant's gaze direction. The side the parent faced (left or right) was counterbalanced. From either side, parents made a small head turn to look at one target in front of the infant (F/S) and one target behind the infant (B/S). Likewise, parents made a large head turn to look at another front target (F/L) and another back target (B/L). Parents began each gesture facing midline rather than looking at the infant. A different distinctive object was the target in each trial.

Procedure. The protocol for Experiment 2 was similar to that of Experiment 1 except that (a) locations remained the same across trials, (b) only distinctive objects were used, (c) parents never verbalized, and (d) parents were seated perpendicular to infants. As in Experiment 1, parents verbally elicited their infant's attention before executing each gesture. Consequently, infants were looking at their parent, slightly to one side of midline, when the trial began.

Coding. The coding procedure and criteria for Experiment 2 were identical to those of Experiment 1. A second coder recoded videotapes of 15 infants (eight 12-month-olds and seven 18-month-olds; 31% of the sample). The overall kappa was .91, which is excellent agreement.

Results

Infants' total number of fixations on target objects were first analyzed for the effects of infant's gender and parents' seating side (right vs. left). Boys made slightly more hits than girls (Ms = 11.9 and 9.7, respectively), but the difference was not significant, $t(46) = 1.4$, $p > .15$. The effect of the parent's seating side was also nonsignificant, $t(46) = 0$. These variables therefore were excluded from subsequent analyses.

Infants' total number of fixations on target objects, in all 12 trials, were entered into a 2 × 2 ANOVA, with age (12- vs. 18-month-olds) and gesture (look vs. look and point) as between-subjects variables. The main effect of age was significant, $F(1, 44) = 6.6$, $p < .02$. Twelve- and 18-month-olds produced a mean of 9.1 (SD = 5.0) and 12.5 (SD = 5.3) total looks, respectively. The gesture effect also was significant, $F(1, 44) = 14.8$, $p < .001$. Infants in the look condition produced a mean of 8.2 (SD = 3.7) total hits versus a mean of 13.3 (SD = 5.6) in the look-and-point condition. The interaction was not significant, $F(1, 44) < 1$.

The critical questions involve effects of target object location (front vs. back) and parent's gesture magnitude. Regarding target location, mean total hits to front targets (locations F/S & F/L) and back targets (B/S and B/L), by age and gesture, are shown in Figure 5. Difference scores were calculated for every trial by subtracting the average number of hits to the three distractor objects from the number of hits to the target object. As in Experiment 1, this controls for possible between-group differences in base rates of scanning the room.[6]

Differences were summed for front and back target trials and were compared by MANOVA. The effect of age was significant, $F(2, 43) = 5.8$, $p < .01$. One-way analyses revealed that 12-month-olds followed gestures to back targets less frequently than 18-month-olds, $F(1, 44) = 11.7$, $p < .001$. This is consistent with results reported by Butterworth and Cochran (1980) and Butterworth and Jarrett (1991). The age difference was not significant for front targets, $F(1, 44) = 2.0$. As in Experiment 1, a separate analysis showed that 12-month-olds looked more often at back targets than at the distractor objects (M = 1.4, SD = 2.5), $t(23) = 2.6$, $p < .02$, even though two distractors were within the infant's visual field.

The effect of gesture was significant, $F(2, 43) = 12.3$, $p < .001$. The advantage of pointing was significant for front targets, $F(1, 44) = 24.9$, $p < .001$, and marginally significant for back targets, $F(1, 44) = 3.9$, $p < .06$. This replicated the results of Experiment 1 and was consistent with the argument that infants in previous studies did not look behind them because gaze alone is less noticeable than gaze combined with pointing. The interaction of age and gesture was not significant.

The second question was whether infants respond to large head turns more often than to small head turns. The total number of target hits on trials in which parents made small head turns (M = 4.5, SD = 2.9) was compared with the total number on trials in which parents made large head turns (M = 6.3, SD = 3.3). These were entered into a repeated-measures ANOVA, with age and gesture type as between-subjects variables. There was a sig-

[6] Note that the same pattern of findings is obtained if simple number of hits, rather than difference scores, is analyzed.

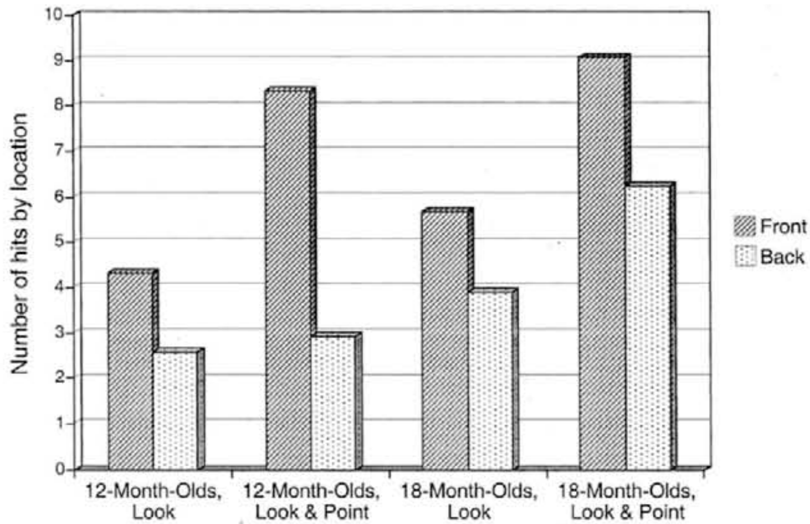

Figure 5. Mean number of correct looks toward front and back targets, by age and gesture combination: Experiment 2.

nificant within-subjects effect of gesture magnitude, $F(1, 44) = 14.5$, $p < .001$. There was no interaction either with age or gesture type. Thus, regardless of infants' age and whether or not parents pointed, the magnitude of the parent's head turn from midline to target influenced whether, and how often, infants followed the gesture.

This effect may be better understood by examining Figure 6, which shows 12- and 18-month-olds' mean hits toward each target location (F/S, F/L, B/S, and B/L). Clearly, infants responded least often to small gestures toward targets behind them. Follow-up ANOVAs on total hits at each location, with age as a between-subjects variable, showed that the age difference was reliable at the F/S target location, $F(1, 46) = 4.4$, $p < .05$, and the B/L location, $F(1, 46) = 7.6$, $p < .01$.

Discussion

The results of Experiment 2 inform our interpretation of Experiment 1. Unlike in Experiment 1, 18-month-olds established joint attention significantly more often than 12-month-olds. Because half of adults' gaze shifts were small in Experiment 2, compared with only one fifth in Experiment 1, the discrepancy suggests that 12-month-olds are less likely than 18-month-olds to respond to small shifts in adults' gaze, perhaps because small shifts are hard to detect. Also consistent with this possibility is the finding that 18-month-olds more often followed gaze to back targets, but there was no age difference in following gaze to front targets. This and previous findings (Butterworth & Jarrett, 1991) support the hypothesis that 12- and 18-month-olds differ in responsiveness to small deviations in gaze direction.

The hypothesis is most strongly supported by a significant effect of gesture magnitude, independent of target location. When parents rotated their head further to look at a target object, infants more often followed gaze. Previous studies did not reveal this effect because the radial distance, or magnitude, of parents' head turns was conflated with target location. Rotating the parent 90° from the infant's midline separates these variables and reveals that

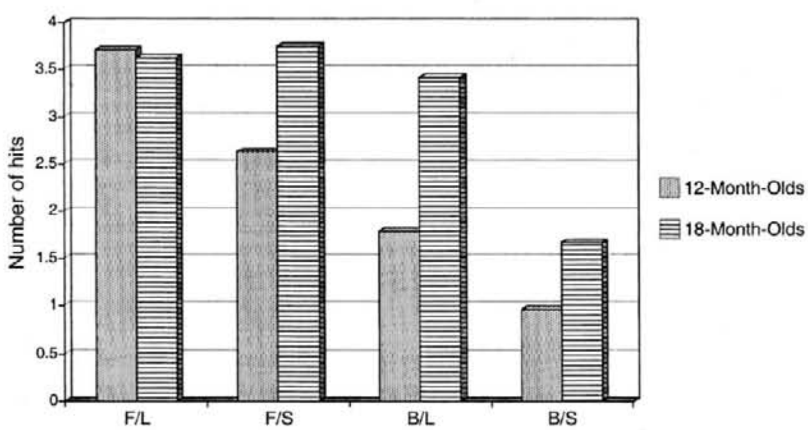

Figure 6. Mean number of looks to front and back targets requiring either a small or large head turn by the parent (F = front, B = back, S = small, L = large), by age: Experiment 2.

infants are more responsive to large head turns, presumably because these turns are more readily detected.

Separate analyses of each target location showed a subtle manifestation of this effect. A reliable age difference was found for the B/S target location. Figure 4 suggests a speculative account of this effect. In these trials, the infant's head is very close to the line of gaze between the parent and the B/S target, so it is difficult to discern whether the parent is looking at the target or the infant. Infants might have believed that their parent was looking at them. In this case, turning around would interrupt what the infant perceives as a face-to-face interaction initiated by parental gaze. Such interactions are compelling or rewarding to infants, so there is actually a disincentive to turn to look at the B/S target. Thus, the B/S disadvantage might stem from 12-month-olds' inability to discriminate whether a parent is looking at them or at an object a few degrees off center. Presumably, 18-month-olds are better able to differentiate small deviations in gaze direction and therefore show a smaller B/S disadvantage. This implies that the target location effect (i.e., following gaze less often to back targets) rests on the infant's ability to discriminate small changes in adults' gaze direction. Although this tentative explanation goes beyond the current data, it is consistent with other reports (Butterworth & Jarrett, 1991; Morissette et al., 1995).

Experiment 2 also provides strong evidence for a target location effect. The analysis of difference scores for back targets in Experiment 2 controls for both gesture magnitude and base rates of scanning for objects. It is therefore the first unconfounded demonstration that 12-month-olds, compared with 18-month-olds, follow adults' gestures less often to back targets.

In spite of the observed effects of target location and gesture magnitude, when parents gestured toward back targets, 12-month-olds looked significantly more at those objects than at distractor objects. This replicates the critical finding in Experiment 1 that 12-month-olds follow parents' gestures to targets outside their visual field.

Finally, the advantage of looking and pointing over gaze alone in recruiting infants' attention was replicated. This advantage for targets behind the infant was also replicated. This is consistent with the argument that pointing is effective because it is more readily noticed or detected than a simple head turn.

General Discussion

What is the significance of the finding that 12-month-olds can follow an adult's gaze to targets outside their visual field? Broadly, the findings refute theories that 12-month-olds are categorically limited to egocentric and non-Euclidean spatial representations. More specifically, they refute the hypothesis that 12-month-olds neglect targets outside their current visual field. This fits earlier evidence that 8- and 9-month-olds sometimes form nonegocentric spatial representations. For example, Presson and Ihrig (1982) found that most 9-month-olds, after learning to turn toward a specific location, continue to turn toward that location after being rotated 180° if a landmark (their mother) remains in the same place. Thus, infants sometimes represent an "absolute" location even if they are moved, suggesting that they can form nonegocentric spatial representations. The current evidence broadens this conclusion. Twelve-month-olds sometimes locate objects that are out of sight by responding to a social–spatial cue—namely, the direction of an adult's gaze.

How do these results inform theories of joint attention? Butterworth (1991b) proposed that a geometric mechanism, which allows infants to extrapolate imaginary lines of gaze and thereby follow gaze to peripheral targets, emerges by 12 months. A representational mechanism, which allows infants to ignore frontal distractors and follow gaze to targets outside of view, emerges by 18 months. One interpretation of the current data is that this timetable is accelerated, with a representational mechanism coming on-line by 12 months.

An alternative, parsimonious explanation is that infants acquire the tendency to respond to adults' attention-specifying gestures (e.g., direction of gaze) through gradual learning processes. There is ample evidence that infants learn contingent responses in face-to-face interactions (e.g., Dunham & Dunham, 1995; Hains & Muir, 1996). Infants younger than 12 months can, for example, be conditioned to follow an adult's gaze (Corkum & Moore, 1998). Infants ostensibly are rewarded in everyday situations for following an adult's gaze or point, because doing so brings interesting events or objects into view. Nine- to 12-month-olds might initially look in the general direction of an adult's head turn or point. Over the next 6–9 months, infants learn more precisely to discern the location of the target object or event. Later still, this faculty will be integrated with the emerging ability to make inferences about other people's attentive states. Between 9 and 18 months, the growing ability to detect small changes and discrepancies in adult gaze direction can account for a 12-month-old's relative insensitivity to parental gaze toward objects behind the child—or, more precisely, to objects that lie close to the line of gaze from parent to child. Note that although infants are minimally sensitive to whether an adult is making eye contact or looking a few degrees away (Symons, Hains, & Muir, 1998), discrimination is unreliable. Inconsistent response to small gaze shifts might account for the infrequency with which 12-month-olds, compared with 18-month-olds, followed gestures to Location B/S in Experiment 2. This implies perceptual learning about gaze information during the second year.

If infants learn through conditioning to respond to changes in a caregiver's gaze direction, cluttered visual environments (i.e., rooms with many interesting objects) might provide reinforcement for turning only part of the way toward the correct target, because interesting distractor objects will cross their visual field before the precise target of adult attention does. This can account for the phenomenon reported by Butterworth and Jarrett (1991). Nevertheless, our evidence suggests that by their first birthday, infants have learned to ignore objects within their visual field and to follow adults' gaze, with or without pointing, to target objects outside their visual field. This account makes no commitment as to how other aspects of joint attention (e.g., attentiveness to adults' faces, conceptual inferences about others' mental states) are acquired. The point is that available data on developmental improvement in the precision and reliability of gaze-following are not inconsistent with an account based on conditioning and perceptual learning.

Why did our results show that 12-month-olds can search for objects behind them, when other investigations (e.g., Butterworth & Jarrett, 1991) have not? One reason is that half of the infants in Experiment 1 and all of the infants in Experiment 2 saw interesting and unique objects. Distinctive, complex targets might compel more consistent and frequent joint visual attention than identical, simple targets. In many studies of joint visual attention, infants have followed adults' gestures to repetitive, uninteresting objects. Infants might quickly tire of following an adult's gaze to identical pegs (Morissette et al., 1995) or yellow squares (Butterworth & Jarrett, 1991). This is implied by the greater split-half decline in joint attention to identical targets than to distinctive targets (Experiment 1). In the former condition, apparently, infants learned that the parent's attention-specifying gestures were not valid and habituated to the gestures. In normal circumstances, parents' attentive gestures terminate in objects or events that are interesting to babies. Previous laboratory studies of infant joint attention might have underestimated the frequency or persistence of infants' gaze-following by asking infants to follow invalid gestures to boring targets.

The second reason, as previously discussed, is that during face-to-face interactions, infants might not notice small shifts in an adult's gaze. There is a complication here: If the infant turns around to search for the target of a parent's gesture, both the gesture and parent are taken out of view. The social signal is rendered unavailable. Now the infant cannot directly extrapolate a vector to the target because the information that specifies the vector—the parent's head and/or hand direction—is out of view. The infant must rely on a representation of the position of the adult's head and/or hand (this is similar to Butterworth & Grover's, 1988, geometrical mechanism). This memory requirement apparently makes it more difficult to locate the correct target.

There is yet another possible reason why infants less frequently follow gaze to back targets. In comparison to scanning the front visual field, turning around to search behind oneself requires a relatively extensive, deliberate sequence of actions. Infants (not to mention adults) might need to be more motivated to turn around to search for a target. This level of motivation might require both a compelling gesture and the expectation of an interesting target. If these conditions are necessary, previous studies of joint visual attention might not have motivated infants to turn around. Infants' motivational requirements, as well as their ability to detect adults' gestures, might explain the relative infrequency of joint visual attention to back targets. Future studies that manipulate reinforcement contingencies for joint visual attention should address this hypothesis.

The current findings expand our knowledge of the complexity of infants' joint visual attention between 12 and 18 months of age. To predict whether an infant will follow an adult's gesture, we must take into account the nature and complexity of the visual targets, infants' expectations about adult gestures, and the relative spatial arrangement of the infant, adult, and target. From an early age, infants are sensitive to ecological and geometric information, capable of representing space outside of view, prone to form social expectations, and inbued with the affective and motivational propensity to engage in face-to-face communication with adults. Together, these skills permit the development of a complex system for responding to social information about a shared environment.

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