

## REPORT

# Object-centered attention in 8-month-old infants

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### Abstract

*We examined the extent to which visual orienting in 8-month-old infants shows evidence of being guided by object-based representations. Infants' preferences to look at conspicuous targets presented on one of two stationary objects were measured following an event (cue) which directed their covert attention to one of the objects. The results indicate that by 8 months of age a cue presented on one part of an object directs attention to the whole object (object-centered attention). This then affects responses to targets that appear elsewhere on the cued object.*

Visual attention and action planning appear to involve representations defined in multiple frames of reference, some centered on parts of the body—the eye, head, or hand—others on objects or landmarks in the environment. A number of authors have presented evidence for object-centered attention and action in adults (Egly, Driver & Rafal, 1994; Tipper, Driver & Weaver, 1991), and some forms of acquired brain damage in adults may result in changes in these processes (Tipper & Behrmann, 1996). For example, Egly & colleagues (1994) examined whether adults who were asked to detect a target stimulus (change in luminance) on one of two identical, bar-shaped objects, would be faster to do so when a brief cue flashed prior to the target in a different spatial location as the target stimulus on the same object. Participants were faster to detect targets that appeared on the same object as the previous cue.

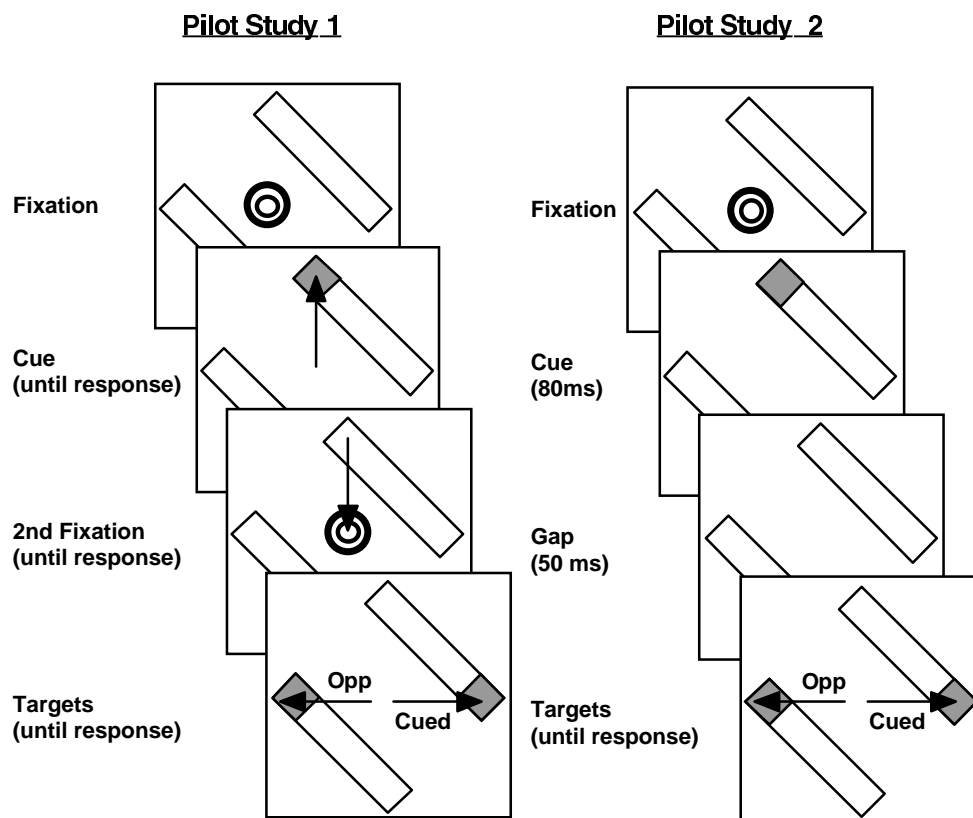
While a number of laboratories have conducted studies on visual attention and saccade planning in infants (for review, see Johnson, 1995), to our knowledge little is known about the development of object-centered representations in infants. We have previously argued that more primitive representations may underlie visually-guided action early in infancy due to the gradual development, and relative functional immaturity, of regions of the cerebral cortex crucial for sophisticated spatial processing (Gilmore and Johnson, 1997a, 1997b; Johnson *et al.*, 1998). The present research, based on behavioral procedures used by Egly

& colleagues (1994), was conducted to ascertain whether 8-month-old infants possess object-centered representations.

### Preliminary Experiments

Two preliminary experiments were conducted in order to establish the procedures most likely to elicit object-centered representations for action in infants. In both of these experiments, healthy 8-month old infants viewed a computer-presented display composed of a central fixation stimulus (designed to capture the infant's gaze) and two obliquely positioned solid colored bars (see Figure 1). Each trial began with the fixation stimulus presented in the middle of the display, followed by the appearance of a cue that flashed at the end of one of the two bars (above or below the fixation point) until the infant looked toward it (Pilot study 1) or for 80 ms (Pilot study 2). Following an eye movement back to the center (Pilot study 1), or continued fixation of the central stimulus (Pilot study 2), the ends of both bar stimuli located to the left and right of fixation began to flash simultaneously (targets). Targets flashed until the infant made a saccade toward one of the targets or looked away from the display. There were two bar orientations and two cue locations presented, and balanced blocks of trials were presented in a pseudorandom order. The reaction time and direction of infants'

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**Figure 1** This figure depicts the typical display sequence for Pilot Studies 1 and 2 with time running from top to bottom. Two targets were presented in all trials in both experiments. Looks to the cued or opposite bar were recorded as indicated in the figure.

saccades were coded from videotape. Data reported are for trials in which infants made a valid sequence, consisting of a look to the cue, back to the fixation, and finally, toward one of the targets (Pilot study 1), or made their first look away from the fixation stimulus to the target (Pilot study 2). In both of the preliminary experiments, infants showed evidence of cueing effects. However, changes in their patterns of looking occurred during the course of the experiment. While in the first block of trials they looked more frequently to the cued bar (Pilot Study 1,  $M = 0.62$ ,  $t(12) = 2.14$ ,  $p < 0.05$ ; Pilot study 2,  $M = 0.63$ ,  $t(15) = 2.24$ ,  $p = 0.04$ ), in later trials they showed no significant preference (2nd block: Pilot Study 1,  $M = 0.44$ , n.s.; Pilot study 2,  $M = 0.44$ , n.s.).

The results from these preliminary experiments provided tentative evidence that 8-month-old infants' visual orienting mechanisms engage object-based representations. The instability of the preferences during the course of the study could have emerged because the display of targets on both the cued and other objects made the cue non predictive, or neutral. Thus, in the main experiment described next, we presented a single

target on the cued object alone on two-thirds of trials. Only on test trials did targets appear on both objects. Another issue concerned the possibility that infants were making eye movements based on combined processing of the cue and targets, not based on their location on the same object. In previous studies (Gilmore, 1997; Johnson, Gilmore, Tucker & Minister, 1996) we showed that the simultaneous or sequential presentation of brief visual cues in a blank field can result in vector average saccades to an intermediate location between the two stimuli. In the current experiments, the presentation of cues in upward or downward locations followed by targets in the left and right locations might have elicited oblique saccades to the corners which coders rated as leftward or rightward looks. In a blank visual field, these vector average saccades would have been distributed uniformly, but the presence of the bar in one, but not the other corner of the display may have led to the observed difference in overall preferences. To avoid this potential line of interpretation of the results, in the main experiment we devised more complex object shapes which were distributed across the screen in a more uniform manner.

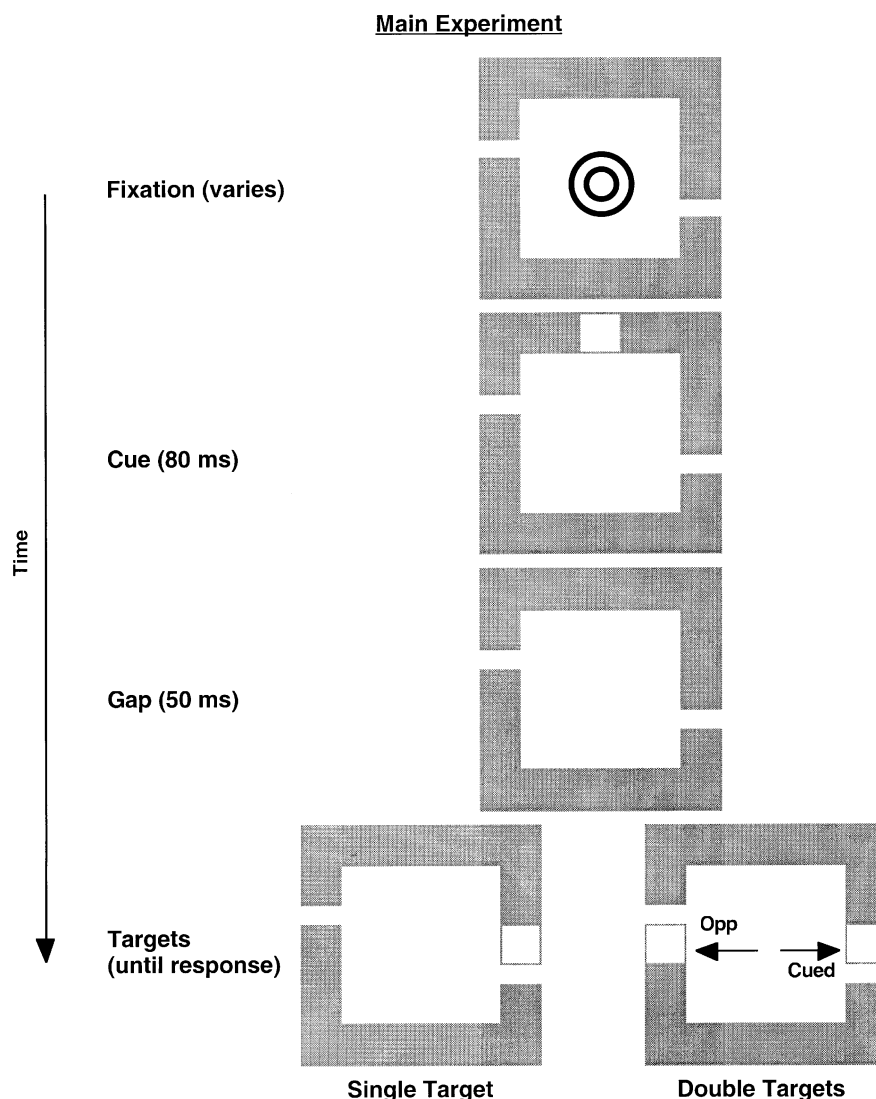
## Main Experiment

The goal of this experiment was to examine the extent of visual preferences for a visually cued object in circumstances in which the cue is frequently valid (in the sense of predicting the object on which the target will subsequently appear) and where the spatial configuration of the object is complex. Infants viewed sequences of cues and targets in which a single visual cue and a single visual target appeared on the same object on two out of three trials. In the remaining third of the trials, which consisted of a single cue and targets appearing on both the cued and opposite object, we ascertained whether infants show a preference. We note

that since object-centered attention effects have been manifest both as facilitatory and inhibitory consequences of cues, a consistent preference for either the cued or the other object would suffice to indicate that a representation of the cued object influenced infants' orienting.

## Method

Thirteen healthy 8-month-old (238–256 days,  $M = 249$ ; 6 female, 7 male) infants participated. One additional infant was excluded due to failures to respond on more than 50% of trials, and five infants were excluded



**Figure 2** This figure depicts the typical display sequence for the main experiment with time running from top to bottom. Single target trials were presented twice as often as the double target trials. Looks to the cued or opposite bar were recorded as indicated in the figure.

because more than 85% of their saccades to the double-target displays were toward a single side.

Infants sat in an adapted car seat 45 cm from a 20 in color computer monitor. Figure 2 shows the display sequence. The objects were hook-like shapes presented in solid, randomly varied colors on a dark gray background. Both objects were the same color for any given trial. The fixation stimulus consisted of a dynamic colorful sequence of geometric shapes that subtended 5 deg. of visual angle and which was presented in the middle of the screen. The shapes were varied from trial to trial in order to maintain interest in the task. The cue was a small 5 deg. square of contrasting color to the objects flashed for 80 ms 14 degrees from the center of fixation. There was a gap of 50 ms prior to the onset of either a single target on the cued object (training trials) or targets on both the cued and opposite objects (test trials). Targets were 5 degree white squares located at a position of 14 degrees from the center of fixation, and presented until the subject made a saccade to one of them or looked away from the display. There were 32 training trials – two object orientations (Left or Right) X two cue locations (Up or Down) X 8 replications – and 16 test trials – two object orientations X two cue locations X 4 replications – run in a single laboratory testing session lasting approximately 5 min. The orientation of the objects, location of the cue, and target condition (training or test) were chosen in a balanced pseudorandom order that was fixed across subjects in order to ensure that there was no predictable spatial relation between cue and target presentation.

Infants' eye movements were recorded by means of a video camera positioned above the monitor, and subsequently coded off-line on a frame-by-frame basis (20 ms per half-frame). Coders determined the direction (cued or uncued object) and start time (in half-frames) for each saccade made. Trials were included for analysis only if infants remained looking at the fixation stimulus until the target onset, and then made a saccade directly to a target. The final sample included an average of 11 double target test trials from each infant.

## Results

Across the 16 double target trials of the experiment, infants showed a significant tendency to make saccades to the object which had *not* been cued on that trial ( $M = 0.43$ ,  $t(12) = 2.50$ ,  $p < 0.03$ ). In addition, an analysis of variance on the reaction time data indicated that the mean reaction time to initiate the saccade was slower when infants looked toward the cued

( $M = 717$  ms) than the opposite object ( $M = 602$  ms),  $F(1, 118) = 6.69$ ,  $p < 0.01$ .

## Discussion

These experiments provide the first direct evidence that object-centered representations might underlie visual attention in human infants. Infants' saccades to objects were influenced by the preceding briefly flashed cue, even though the cue itself did not elicit a saccade and appeared on a different part of the object relative to the target. We conclude that cueing one part of an object extends to the whole object, and, therefore, that infants of eight months show object-centered attention.

In the main experiment, infants looked significantly more frequently and rapidly to the target that appeared on the object that had *not* been cued on that particular trial. Inhibition of a cued object ('inhibition of return') has been used as evidence for object-centered representations in experiment with adults (e.g. Tipper *et al.* 1991), and is interpreted as inhibition of objects recently attended to. Inhibition of return to cued spatial locations has been commonly observed with infants (Clohessy, Posner, Rothbart & Vecera, 1991; Hood, 1993; Valenza, Simion & Umiltà, 1994), and for reasons that are not well understood may be more robust than facilitatory effects at this age. Nevertheless, it is surprising that inhibition of return was observed in the main experiment, while facilitation of the cued object was a feature of the pilot experiments. We note, however, that after an initial phase of facilitation in the preliminary studies, there was a subsequent non-significant tendency for inhibition of return at an average percentage level nearly identical to the significant effect observed in the main study. One possible account of this pattern of data in the preliminary experiments is that attention shifts occurred faster following experience of the trial types in the main experiment.

The current studies also extend previous research on the nature of representations for visually-guided action early in life which have demonstrated a gradual transition from the use of retinocentric to head or body-centered representations of saccade target locations in the period from two to seven months of age (Gilmore & Johnson, 1997a, 1997b; Johnson *et al.*, 1998). However, the precise nature of the object representations which generate the effects we observed in the present studies remains unclear. We hypothesize that shifting of attention toward the cued object marks the whole object for a period of time as having recently been the focus of attention. Since the target appears in a different location on the object, we conclude that the

attentional cueing extends across the spatial extent of the object. Consequently, when a target appears on a different part of the cued and uncued objects, the subsequent orienting is influenced by the fact that one of the objects has been previously attended to. Future research which examines object-based representations in younger infants may help us to understand when these processes emerge and how space and object-centered representations interact.

More broadly, the finding that 8-month olds are capable of object-centered shifts of attention is consistent with evidence that infants of this age and younger are surprised when certain object properties are violated (Spelke, 1990), appear able to parse objects from their background (Kellman, 1993), and can make rudimentary numerosity judgments (Starkey, Spelke & Gelman, 1990; Wynn, 1992). How the developing visual system integrates these components so that infants eventually come to perceive the extent, number, orientation, and movement of complex objects remains unclear. In concert with continuing work on the neural basis of object representations for action (Olson & Gettner, 1995, 1996), we believe the present experiments open up the possibility of a new approach to understanding the emergence of mechanisms for object representation early in life.

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