

Time Course of Visual Attention in Infant Categorization of Cats Versus Dogs: Evidence for a Head Bias as Revealed Through Eye Tracking

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Previous looking time studies have shown that infants use the heads of cat and dog images to form category representations for these animal classes. The present research used an eye-tracking procedure to determine the time course of attention to the head and whether it reflects a preexisting bias or online learning. Six- to 7-month-olds were familiarized with cats or dogs in upright or inverted orientations and then tested with a novel cat and novel dog in the same orientation. In the upright orientation, infants fixated head over body throughout familiarization; with inversion, no head preference was observed. These findings suggest that infant reliance on the head to categorize cats versus dogs results from a bias that pushes attention to the head.

Looking time studies measuring the emergence of categorization during early development have demonstrated that young infants between the ages of 3 and 7 months will categorize nonhuman animals such as cats, dogs, and horses (Eimas & Quinn, 1994; Oakes & Ribar, 2005; Quinn, Eimas, & Rosenkrantz, 1993; Quinn, Westerlund, & Nelson, 2006; Younger & Fearing, 2000; Younger & Furrer, 2005). The infants are presented with multiple instances from a common category during familiarization (e.g., cats) and then with a preference test pairing a novel instance from the familiar category (e.g., a new cat) with a novel instance from a novel category (e.g., a new dog). Categorization is inferred if infants generalize their familiarization to the novel instance from the familiar category and display a preference for the novel instance from the novel category.

Although the evidence indicates that young infants can learn category representations on the basis of perceptual experience, an important question to consider is: What attributes are infants using to form the category representations? The answer to this question is not obvious, given that the exemplars of each category possess a number of common attributes such as a head, torso, four legs, and a tail. Quinn and Eimas (1996a) examined 3- to 4-month-olds' abilities to categorize cats versus dogs when provided with the whole stimuli, just the heads (with the bodies occluded), or just the bodies (with the heads occluded) during both the familiarization and the

preference test portions of the experiment. The results were that the infants categorized when presented with either the whole stimuli or just the heads but not when presented with just the bodies. These findings indicate that the head provided a sufficient basis for the infants to categorize cats versus dogs.

The conclusion of Quinn and Eimas (1996a) was supported by an additional study in which infants were familiarized with whole cat or dog images and then preference tested with hybrid stimuli (i.e., cat head on dog body vs. dog head on cat body; Spencer, Quinn, Johnson, & Karmiloff-Smith, 1997). Infant preference during test followed the direction of the novel category head. Interestingly, adults also seem to emphasize the head when representing animal species (Reed, McGoldrick, Shackelford, & Fidopiastis, 2004).

Use of the head could arise from a preexisting biasing mechanism that directs infant attention to the head information that is present in a visual scene (Johnson & Morton, 1991). Such a biasing mechanism would ensure that infants attend to and eventually recognize faces. It is also possible that the infants simply learn during the course of experience with the exemplars that the head is the most diagnostic part of the stimulus. In other words, the head feature may be flexibly created as the basis for the category representation in an online fashion (Quinn, Schyns, & Goldstone, 2006). This possibility seems reasonable given that the head may have fewer degrees of freedom relative to the body in terms of the various stances presented to the infants (Reed, Stone, & McGoldrick, 2005). As such, it might be more easily extracted as an invariant feature.

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The approach taken in the current article was to use an eye-tracking methodology to measure the eye fixations of infants as they scan the visual images presented in the categorization task. Although anticipatory eye movements have been used as a measure of categorization in infants (McMurray & Aslin, 2004), to our knowledge, this marks the first case in which eye tracking has been used as a measure of categorization in studies conducted with the familiarization/novelty-preference procedure. Incorporating eye tracking into a familiarization/novelty-preference task allows one to conduct a microanalysis of infant visual performance in this task that is not possible with the standard behavioral looking time measure. Consider, for example, the schematic shown in Figure 1, which depicts the visual display used in the current study and is also illustrative of the standard visual display used in familiarization/novelty-preference tasks more generally. The left and right stimulus regions in which the cat and dog images are presented are depicted against the broader backdrop of the display. What the standard behavioral measure of performance in the familiarization/novelty-preference procedure provides is overall looking time duration for the left and right stimulus regions. This would include, on Figure 1, the summed looking time accumulated from fixations shown as Data Point 1 (the head of the image), Data Point 2 (the body of the image), Data Point 3 (not on the image but in the stimulus region containing the image), and would exclude Data Point 4 (outside of the stimulus region containing the image). In contrast, the eye-tracking methodology allows one to determine how much of this overall looking time measure is composed of

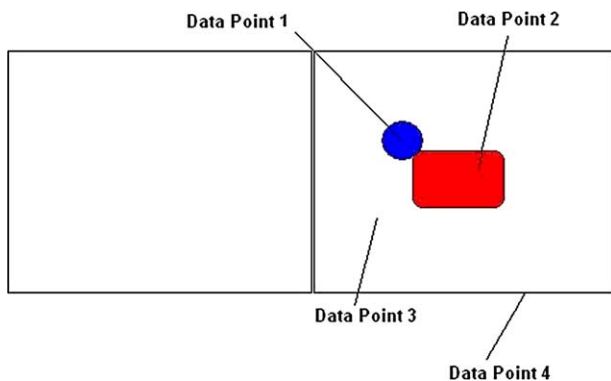


Figure 1. A schematic depiction of the visual display used in the current study with an animal image depicted in the right-side stimulus region.

Note. Data Point 1 represents a fixation on the head of the image, and Data Point 2 represents a fixation on the body of the image. Data Point 3 represents a fixation in the stimulus region containing the image, although not on the image itself, whereas Data Point 4 represents a fixation outside of the stimulus region containing the image.

fixations that were actually on the image, Data Point 1 + Data Point 2. Furthermore, one can determine how the pattern of fixations is distributed across different stimulus regions. In this case, we can measure the amount of time spent fixating the head (Data Point 1) versus the body (Data Point 2).

The eye-tracking measure will allow us to explore the time course of infants' use of the head. By determining the time course of head usage, we can better understand its nature. Specifically, on the assumption that stimulus regions used for categorization will be preferentially fixated over those not used, it can be reasoned that if the head preference results from a preexisting biasing mechanism, then infants should fixate more on the heads than the bodies of the exemplars throughout the course of the familiarization portion of the categorization task. Alternatively, if the infants are learning that the head is the most diagnostic region of the stimuli, then the head preference should emerge during the course of the familiarization trials.

Experiment 1

In Experiment 1, a group of 6- to 7-month-old infants was presented with 12 photographic images of either all cats or all dogs during six 15-s familiarization trials, followed by a novel cat paired with a novel dog for two 10-s preference test trials. This procedure replicated the methodology used in prior behavioral studies of categorization measuring infant looking time (e.g., Eimas & Quinn, 1994). All the stimuli were presented in an upright orientation (see Figure 2 top panel). The major question of interest was whether the relative percentage of head versus body fixation reflected an advantage of the head throughout familiarization in accord with a preexisting biasing mechanism or whether it built up during the course of familiarization in agreement with an online learning account. It was also of interest to learn whether the novel category preference was more readily in evidence when calculated from fixations on the head as compared with when calculated from fixations on the body. Based on past behavioral results (Quinn & Eimas, 1996a; Spencer et al., 1997) and by either the preexisting biasing mechanism or the online learning account, one would expect the novel category preference to be more clearly manifest in fixations on the head relative to those on the body.

Method

Participants. The participants were 14 healthy, full-term 6- to 7-month-olds (six females) with a mean age

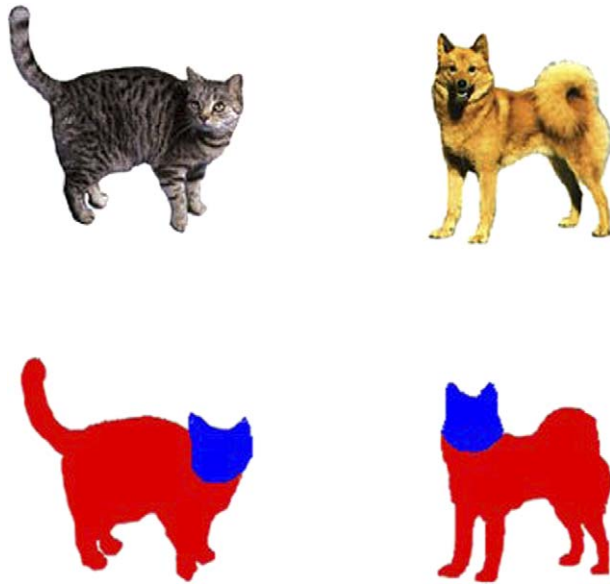


Figure 2. Examples of the cat and dog images and their corresponding areas of interest (AOI) that divide each stimulus into head and body areas. Unique AOIs were determined for each stimulus image.

of 196.64 days ($SD = 17.10$ days). Seven additional infants were tested but three failed to complete the procedure due to fussiness and four were lost due to unsuccessful calibration. None of the infants were reared in a household in which there was a cat or dog pet. Participants in both experiments were predominantly Caucasian and from middle-class backgrounds.

Stimuli. The stimuli consisted of 18 colored pictures of cats and 18 colored pictures of dogs used previously by Quinn and Eimas (1996a). All stimuli were generated on a Dell 3.6-GHz personal computer running custom software prepared by Psychology Software Tools (Pittsburgh, PA) with the E-Prime programming language. Area of the images was measured with a LASICO (Los Angeles, CA) 1281 Area/Line Meter, averaged 64.36 cm^2 ($SD = 16.44$), and did not differ on average between the two animal categories, $t(34) = 0.78, p > .20$.

Apparatus. Images were presented on an UltraScan P990 CRT monitor ($1,024 \times 768$ pixel resolution; 75-Hz frame rate) that was 27.3 cm high and 36.8 cm wide. The monitor rested on a square horizontal platform that was 40 cm in both length and width. The platform in turn rested on a table that was 74 cm wide and 148 cm long. The platform was attached to an adjustable arm that allowed the monitor to be moved vertically. At its lowest point, the platform was 11 cm off the tabletop surface. Each infant was placed in a Bumby Baby Seat (Wartburg Enterprises, Conroe, TX) that was situated on the table. The infant was positioned at

a viewing distance of 65 cm from the monitor, and the eye height of each infant was aligned with the horizontal midline of the monitor by raising or lowering the monitor with the aid of the adjustable arm. The images appeared inside white $14.5 \text{ cm} \times 17.8 \text{ cm}$ rectangles on the monitor in a left–right arrangement. They were located with their midpoints at the 25% and 75% points along the horizontal axis of the monitor and centered along the vertical axis of the monitor. The rectangles appeared against a white background in an otherwise dark room.

Eye fixations were monitored using a Tobii $\times 50$ 50-Hz eye-tracking system (Tobii Technology, Stockholm, Sweden). The system was positioned directly below and in front of the display monitor where it sat on a second platform that was situated 4 cm below the platform holding the display monitor and that extended 18 cm out in front of the display monitor. The tracker was situated at a distance of 50 cm from the infant, illuminated both eyes with an infrared light, and captured the video image of both pupils with a hidden camera. Image processing algorithms were applied to these videos to compute the location where the participant was looking at a given time. The method used to determine whether an infant was fixating on the head or body at a particular moment in time during a trial was to compare a set of gaze coordinates on the screen to an offscreen duplicate image. The duplicate was an area of interest (AOI) copy of the original in which the cat or dog stimulus was divided into differently colored head and body regions (see Figure 2, bottom panel). The AOI images were created with the magnetic-lasso and magic-wand tools in Adobe Photoshop. The location of gaze on the head or body of a stimulus was determined online by the E-Prime program based on the color of the pixel in the AOI image located at the gaze coordinates. There was no person or persons involved in the coding of the data. The infants' gaze fixations were recorded online during the experiment by the eye tracker, and these data were then compared automatically with the AOI files.

In order to determine the amount of time spent fixating the different AOIs, fixations were defined as a minimum of two gaze data points located anywhere on the same AOI consecutively in time. The minimum duration for a fixation was 20 ms because the eye data were digitized at 50 Hz. Fixation duration was then computed as the difference in time between the first and the last gaze data point in a given fixation. Thus, the amount of time spent fixating a given AOI was simply the sum of the fixation durations for all fixations on a given AOI. It should be noted that the total fixation duration is most likely a composite of multiple eye movement events within the same AOI.

This approach is appropriate, however, because the measure of interest is the total amount of time spent looking at either the head or the body AOI.

Procedure. After each infant was seated in the Bumbo chair, the eye tracker was calibrated using the standard Tobii calibration program in which an attention-grabbing blue circular target moved on a white background to five distinctive screen locations.

The infants were randomly assigned to each experimental group: those familiarized with cats or dogs. Eight infants were presented with cats and six with dogs. During familiarization, each infant was presented with 12 stimuli from the same category, at the rate of two exemplars per trial for six 15-s trials. The test trials consisted of two 10-s trials, which paired a novel cat with a novel dog. The familiarization and test stimuli were randomly selected for each infant. The intertrial interval was 1 s in duration and consisted of a 500-ms blank screen followed by 500 ms in which a blue rectangle appeared at the center of the display.

Results and Discussion

Results from the familiarization and test trials will be presented in two parts. Part 1 focuses on the standard analysis of overall looking time (from Figure 1, this is based on the summed looking time from Data Points 1 + 2 + 3), and Part 2 focuses on the microanalysis of fixations that were on the image into those on the head (Data Point 1) versus those on the body (Data Point 2).

Part 1: Familiarization trials (overall looking time). Individual looking times were summed over the left and right stimuli presented on each familiarization trial and then averaged across the first three trials and last three trials. Mean looking time on Trials 1–3 was 8.75 s ($SD = 3.34$) and on Trials 4–6 was 8.55 s ($SD = 3.72$). A Trial Block (1–3 vs. 4–6) \times Familiarization Category (cat vs. dog) mixed-model analysis of variance (ANOVA) conducted on the individual looking times failed to reveal any significant effects, $F(1, 12) < 1$, $p > .20$, in each instance. That the infants did not show a reliable decrement in looking time from the first to the second half of the trials is consistent with earlier reports that infants in this age group do not consistently habituate when many different, presumably interesting exemplars are shown during familiarization (Eimas & Quinn, 1994; Quinn, 2004a). However, as was the case in the earlier studies, the absence of habituation should not be taken as evidence for a lack of processing, as the test trial data will indicate.

Part 1: Preference test trials (novel category preference as calculated from overall looking time). Each infant's looking time to the novel category stimulus was divided by the looking time to both test stimuli and then multiplied by 100 to yield a percentage score. The mean novel category preference score was 63.62% ($SD = 17.03$), a value that was found to be reliably above the chance preference of 50%, $t(13) = 2.99$, $p < .02$, and not dependent on whether the infants were familiarized with cats or dogs, $t(12) = 0.80$, $p > .20$. The above-chance preference indicates that the infants could categorize cats and dogs as distinct from each other.

Part 2: Familiarization trials (head vs. body fixations). For each infant, looking times to the head versus body AOIs were recorded for each stimulus on each of the six trials. The times were summed over both stimuli on each trial and then summed across the first three trials and the last three trials. Table 1 shows the fixation times for the head versus the body for the first and last half of familiarization. A comparison of the mean looking times to the head + body for Trials 1–3 versus Trials 4–6 with the overall looking times to the stimuli for Trials 1–3 versus Trials 4–6 reported in the Part 1 analysis of the familiarization trials indicates that roughly half of the fixations associated with looking time to the stimulus region depicting the image are actually on the image itself. We will return to this finding in both the Results and Discussion section of Experiment 2 and the General Discussion.

A Trial Block (1–3 vs. 4–6) \times Familiarization Category (cat vs. dog) \times AOI (head vs. body) mixed-model ANOVA performed on the individual looking times revealed no significant effects, $F(1, 12) < 1$, $p > .20$, in each case. Because the lack of a significant Trial Block \times AOI interaction indicated that the relative distribution of fixations to the head and the body remained unchanged from Trials 1–3 versus Trials 4–6, one can calculate a percentage preference for the head for the 6 familiarization trials. When one divides the mean fixation time to the head by the mean fixation time to the head + body averaged across all trials ($1.96/4.31$, values taken from Table 1), and multiplies by 100 to yield a percentage score, the resulting value is 45.48%. This value provides an estimate of the head bias during familiarization.

The importance of this head preference estimate becomes apparent when it is standardized to account for relative size differences between the head and the body. Specifically, the average area of the head was 11.48 cm^2 ($SD = 5.43$) and the average area of the body was 52.88 cm^2 ($SD = 13.52$). This means that, on average, the head accounted for only 17.67% ($SD = 5.46$) of the area of the entire image (head + body),

Table 1
 Mean Fixation Times (in Seconds) to the Head and Body During the Familiarization Trials and Mean Novel Category Preferences for the Head and Body for Experiment 1

Region	Trials 1–3 M (SD)	Trials 4–6 M (SD)	Trials 1–6 M (SD)	Novelty preference	
				M (SD)	<i>t</i> ^a
Head	1.79 (1.73)	2.14 (2.18)	1.96 (1.94)	69.56 (31.81)	2.30*
Body	2.48 (1.40)	2.22 (1.38)	2.35 (1.37)	54.75 (31.52)	0.56
Head + body	4.27 (2.33)	4.36 (2.77)	4.31 (2.52)		

^aFor mean versus chance.

* $p < .05$.

a percentage that did not differ for cats versus dogs, $t(34) = 0.34, p > .20$. When the mean of the individual percentage preference scores for the head is compared to 17.67%, the difference is significant, $t(13) = 4.25, p < .001$. Moreover, when the fixation time per unit area of the head ($1.96/11.48 = 0.17$) and the fixation time per unit area of the body ($2.35/52.88 = 0.04$) are computed, the percentage preference for the head ($.17/.21 \times 100$) is 80.95%. Given that the preference did not vary from the first to the second half of familiarization, this result supports the notion that the reliance on the head for the categorical parsing of cats and dogs arises from a preexisting biasing mechanism that overwhelmingly orients infants toward the head region.

Given reports of rapid learning by infants in different domains (Markson & Spelke, 2006; Walton & Bower, 1993; Woodward, Markman, & Fitzsimmons, 1994), one might still argue that the head preference could build up over the course of the first three trials of familiarization. However, when the ANOVA on the individual looking time scores is repeated, but in this instance using the factors of Trials (1 vs. 2 vs. 3 vs. 4 vs. 5 vs. 6) \times Familiarization Category (cat vs. dog) \times AOI (head vs. body), the interaction of Trials \times AOI is still not significant, $F(5, 60) = 1.25, p > .29$, and all the other effects remain as null, $F < 1.75, p > .14$, in each case. Thus, even in the finer grained analysis by individual trials (instead of trial block), there is no evidence for a trial-to-trial buildup of a head preference. The results of this additional analysis uphold the idea that the head preference results from a bias that infants bring to the experiment.

Part 2: Preference test trials (novel category preference as calculated from head vs. body fixations). Just as the eye-tracking methodology allowed us to parse looking time performance on the familiarization trials into head versus body fixations, it can also allow one to determine how novel category preference varies when computed in terms of fixations on the head

versus fixations on the body. Given the prior evidence and argued importance of the head for the categorical partitioning of cats and dogs, one might expect the preference for the novel category to be more readily in evidence when computed just from fixations on the head. To examine whether this was the case, each infant's fixation time to the novel category head (or body) was divided by the looking time to both the familiar and the novel category head (or body) and then converted to a percentage score. The mean preference for the novel category head and the mean preference for the novel category body are shown in Table 1. A Familiarization Category (cat vs. dog) \times AOI (head vs. body) mixed-model ANOVA performed on the individual scores revealed no significant effects, $F(1, 12) < 1, p > .20$, in each instance. However, as can be seen in Table 1, only the mean preference for the novel category head was reliably different from chance. The comparison of the two preference scores to chance suggests that when one considers just those fixations on the stimulus, the novel category preference is carried by fixations on the head region. This finding accords well with the head bias observed during familiarization.

Experiment 2

The results from the Part 2 analysis of the familiarization trials from Experiment 1 provide evidence that the reliance on the head for the categorical parsing of cats and dogs arises from a preexisting biasing mechanism. However, one might argue that infants are simply orienting to the head because it contains high contrast internal features, and infants are attracted to the most visible portion of the stimulus (Banks & Salapatek, 1981). To address this possibility, a control study was undertaken that replicated the Experiment 1 procedure with inverted stimulus images. If the head preference results from infants'

simply orienting to the most visible portion of the stimulus, then it should still be observed despite inversion, given that inversion preserves the sensory power generated by the head region of the stimulus. However, if the infants are orienting to the head because of a bias that is in place to facilitate face recognition (e.g., Johnson & Morton, 1991), then one would not expect it to be present with stimulus inversion, given that inversion changes the normal configuration of facial features, and faces are believed to be recognized on a configural basis by infants in the age range under study (Cohen & Cashion, 2001).

Method

Participants. The participants were 14 healthy, full-term 6- to 7-month-old infants with a mean age of 196.21 days ($SD = 14.44$). Seven additional infants were tested but two failed to complete the procedure due to fussiness and five were lost due to unsuccessful calibration. None of the infants were reared in a household in which there was a cat or dog pet.

Stimuli and apparatus. The stimuli and apparatus were the same as those used in Experiment 1, except that all images were inverted.

Procedure. Experiment 2 was conducted in exactly the same manner as Experiment 1.

Results and Discussion

As was the case with Experiment 1, results from the familiarization and test trials of Experiment 2 are reported in two parts with Part 1 focusing on the standard analysis of overall looking time data, and Part 2 focusing on the breakdown of fixations that were on the image into those on the head versus those on the body.

Part 1: Familiarization trials (overall looking time). Mean looking time on Trials 1–3 was 5.90 ($SD = 3.31$) and on Trials 4–6 was 4.93 ($SD = 2.70$). A Trial Block (1–3 vs. 4–6) \times Familiarization Category (cat vs. dog) mixed-model ANOVA performed on the individual looking time scores did not reveal any reliable effects, $F(1, 12) < 2.50$, $p > .14$, in each instance. As was true for the upright stimuli, the infants did not show a significant decline in looking time from the first to the last half of the trials. However, as was also the case for the upright stimuli, the absence of habituation does not imply a lack of processing, as the test trial data will show.

Part 1: Preference test trials (novel category preference as calculated from overall looking time). The mean novel category preference score was 59.56% ($SD = 11.15$), a value that was reliably above the chance preference

of 50%, $t(13) = 3.21$, $p < .01$, and not dependent on whether the infants were familiarized with cats or dogs, $t(12) = 0.89$, $p > .20$. The above-chance preference indicates that the infants could categorize cats and dogs as distinct from each other, even when the stimuli were inverted, thereby replicating prior behavioral results when 3- to 4-month-old infants were presented with the inverted cat versus dog contrast (Quinn & Eimas, 1996b).

Part 2: Familiarization trials (head vs. body fixations). Table 2 shows the fixation times for the head versus the body for the first and last half of the familiarization. A comparison of the mean looking times to the head + body with the overall looking times to the stimuli reported in the Part 1 analysis of the familiarization trials indicates that approximately 40% of the fixations associated with looking time to the stimulus region depicting the image are actually on the image itself. The 40%–50% fixation rate on the stimulus as opposed to the stimulus region immediately surrounding the image across Experiments 1 and 2 is consistent with the “on stimulus” fixation rate reported for the rod and box elements of an eye-tracking investigation of how infants represent continuity in a partial occlusion display (Johnson, Slemmer, & Amso, 2004).

A Trial Block (1–3 vs. 4–6) \times Familiarization Category (cat vs. dog) \times AOI (head vs. body) mixed-model ANOVA performed on the individual scores revealed only a significant effect of AOI, $F(1, 12) = 30.89$, $p < .001$, indicating higher fixation times on the body relative to the head region of the image. Moreover, if one computes a percentage preference for the head by dividing the mean fixation time to the head by mean fixation time to the head + body averaged across the trials (0.23/2.06, values taken from Table 2), and multiplies by 100 to yield a percentage score, the resulting value is 11.16%. This percentage preference for the head is close to the percentage of the head as a function of the overall area of the image (17.67%), and when the mean of the individual percentage preferences for the head was compared to 17.67%, the difference was not significant, $t(13) = -1.72$, $p > .10$. This outcome suggests that when the images are inverted, the relative distribution of fixations to the head and body regions is proportional to the relative areas of these regions. Therefore, the current results indicate that the bias to fixate on the head over the body in Experiment 1 is not because the head contains high contrast features. When the images were inverted, the fixation time to the head was substantially reduced despite the same sensory power emanating from the head region across the two experiments.

Table 2
 Mean Fixation Times (in Seconds) to the Head and Body During the Familiarization Trials and Mean Novel Category Preferences for the Head and Body for Experiment 2

Region	Trials 1–3 M (SD)	Trials 4–6 M (SD)	Trials 1–6 M (SD)	Novelty preference	
				M (SD)	<i>t</i> ^a
Head	0.28 (0.42)	0.18 (0.25)	0.23 (0.34)	49.22 (36.86)	–0.08
Body	1.79 (1.11)	1.87 (1.48)	1.83 (1.28)	60.44 (21.85)	1.79 [†]
Head + body	2.07 (1.40)	2.05 (1.43)	2.06 (1.39)		

^aFor mean versus chance.

[†] $p < .10$.

Part 2: Preference test trials (novel category preference as calculated from head vs. body fixations). The mean preference for the novel category head and the mean preference for the novel category body are shown in Table 2. A Familiarization Category (cat vs. dog) \times AOI (head vs. body) mixed-model ANOVA performed on the individual scores revealed no significant effects, $F(1, 12) < 1$, $p > .20$, in each case. However, as shown in Table 2, the mean preference for the novel category body was found to be marginally different from chance, whereas the mean preference for the novel category head was not significantly different from chance. The comparison of the two preference scores to chance is consistent with the idea that when one considers just those fixations on the stimulus, the novel category preference is carried by fixations on the body region.

General Discussion

Two experiments employing an eye-tracking methodology were used to investigate the time course of attention to the head in the categorization of cat and dog images by 6- to 7-month-old infants. In Experiment 1, infants were familiarized with cats or dogs and tested with a novel cat and a novel dog. Throughout the course of the familiarization trials, infants' distributions of fixations to the head and body regions were approximately equal. However, by taking into account the relative size differences between the head and the body regions, and computing the distribution of fixation time to the head versus the body per unit area, the infants were shown to have a marked preference for fixating the head that was present during the whole of familiarization.

The results of the Experiment 1 familiarization trials support the notion that infants use the head to categorize the cat and dog images because of a preexisting biasing mechanism that orients them to the

head region of the stimulus images rather than an online learning mechanism that determines over the course of the trials that the head is diagnostic of the category distinction. However, there was still a question concerning the source of the bias. The bias could reflect a mechanism that attends to face information (Johnson & Morton, 1991) or it could arise because of a preference to attend to the most visible portion of the stimulus (Banks & Salapatek, 1981). Experiment 2 was therefore undertaken as a replication of Experiment 1 but with inverted images. The head region of the inverted images contains all the sensory power as the head region of the upright images but is harder to recognize as a facial stimulus. Thus, if the bias reflects a face-orienting mechanism, then it should not be observed with the inverted images. Alternatively, if the bias has a sensory basis, then it should remain in evidence with the inverted images. The major finding from the familiarization trials of Experiment 2 is that fixations to the head region of the stimuli were small when compared with fixations to the body. In point of fact, the fixations to the head and body were proportional to the areas of the head and body, suggesting that when the images were inverted, the infants were distributing their fixations evenly throughout the entire region of each stimulus. This finding provides evidence that infants use the head to categorize upright cat and dog images because of a preexisting biasing mechanism that responds to face information.

Although we have characterized the bias as "pre-existing," we have thus far been careful not to argue that the bias is "innate." Our use of the term *preexisting* implies only that the infants have knowledge prior to participation in an experiment that influences their performance in the experiment. This knowledge could be innate or it could be acquired. For example, research on how infants respond to gender and race information in human faces suggests that by 3 months of age, there is a bias to respond preferentially to

same-race faces and faces depicting the gender of the primary caregiver, but this bias has been acquired from experience (Kelly et al., 2005, 2007; Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). Whether biases are innate or acquired is a debate that also exists in the contemporary literature on the mechanisms that guide word learning (Booth, Waxman, & Huang, 2005; Smith & Samuelson, 2006).

With regard to the present findings, the fact that none of the infants had a cat or dog as a pet in their household would be consistent with the idea that the bias to attend to the head is not dependent on environmental experience. However, one might counterargue that through experience, human faces may come to be particularly salient because they speak, and portray emotion, identity, gender, and race information, and that infants could generalize from human heads to cat heads. Although we cannot rule out this latter possibility, we would note that even newborn infants are drawn to human faces (Johnson & Morton, 1991) and that while infants do seem to respond to nonhuman animals based on their similarity to humans, the similarity seems to be computed from the global structure of the stimuli (i.e., head + body + skeletal appendages; Quinn, 2004b). Together, these considerations lead us to lean toward believing that the head bias reflects a core mechanism that orients infant attention to the face information in a visual display and that it is not dependent on environmental experience for its operation.

The results of the preference test trials are also revealing regarding the mechanisms that enable infants to categorize cats versus dogs. For the upright images in Experiment 1, using the traditional measure of overall looking time to the left and right stimulus regions containing the images, the infants displayed a novel category preference, indicating that they had formed individuated category representations for cats and dogs and providing consistency with the results of a number of previous studies (Oakes & Ribar, 2005; Quinn et al., 1993; Quinn, Westerlund, et al., 2006; Younger & Fearing, 2000; Younger & Furrer, 2005). Interestingly, with the eye-tracking methodology, when one considers just those fixations on the stimulus, the preference for the novel category was observed in the fixations on the novel category head over the familiar category head; there was no novel category preference observed for fixations on the body. With the inverted images used in Experiment 2, a novel category preference was observed in the traditional overall looking measure, and in this instance, when considering just fixations on the stimulus, the novel category preference was only revealed in the fixations on the body region of the

images; a novel category preference was not observed for fixations on the heads of the images.

The pattern of fixations recorded on the preference test trials provides further evidence suggesting that infants' categorization of upright cats versus dogs is the result of a core mechanism that biases infants to attend to face information present in upright heads. Specifically, in the context of the upright images, the biasing mechanism pushes infants to attend to the heads, and infants use the information contained in the heads to categorize the cats and dogs. However, when the images are inverted and there is no head bias, the distribution of fixations mirrors the relative sizes of the two regions, and the infants utilize the larger region that has elicited the majority of the infants' visual attention to the images. The switchover from the head to the body as the basis for categorization with the inversion manipulation speaks to flexibility in the category formation processes of infants, an observation that has been made by others (e.g., Ellis & Oakes, 2006; Mareschal & Quinn, 2001; Mareschal & Tan, 2007; Quinn, Schyns, et al., 2006; Ribar, Oakes, & Spalding, 2004).

One might ask whether the results from the familiarization and preference test trials could be explained by an alternative mechanism that biases infants to attend to the upper region of a stimulus rather than heads/faces per se (Simion, Valenza, Cassia, Turati, & Umiltà, 2002). By this account, the heads were useful in the upright orientation when they were at/near the top of the image but not in the inverted orientation when they would be closer to the bottom of the image. However, this alternative explanation runs into difficulty because the animals from the two categories were depicted in different poses such that 8 of the 18 cats had body parts that appeared above the head, whereas this was true for only one of the dogs. An account of the findings based on the idea of a bias to attend to the upper region of a stimulus would therefore have predicted more fixations on the head than the body for the dogs relative to the cats in the upright condition and the reverse in the inverted condition. However, in none of the analyses was there an interaction between AOI (head vs. body) and familiar category (cat vs. dog). We also undertook an additional analysis of the upright cat familiarization data and for each infant calculated a head preference for the cat stimuli where the head was the highest body part (head highest) versus the cat stimuli where another body part appeared above the head (other-body-part highest). The mean preference for the head highest stimuli was 43.23% ($SD = 19.04$) and the mean preference for the other-body-part highest stimuli was 42.28% ($SD = 16.77$) a difference that was

not significant, $t(7) = 0.38$, $p > .20$. This result demonstrates that the head preference was not carried by those stimuli where the head was the highest part. The outcomes of the experiments and supplementary analysis are therefore more consistent with a head bias than an upper region bias.

Another question that arises is whether what we have called a head bias might be more properly termed a face bias. Our view is that the head bias is the phrasing that stays closer to the data. That is, we contrasted fixations on the head versus the body, thereby providing a further probe to prior behavioral work that contrasted the head with the body, without looking into what aspects of the head (other than its sensory power) were responsible for the bias toward it. Because the inversion manipulation caused the loss of the head preference in Experiment 2, the evidence points toward a head bias that we would suggest pushes infants to attend to faces. This idea is consistent with the notion of a conspec mechanism of the sort proposed by Johnson and Morton (1991), although note that even in the conspec formulation, the internal facial features are enclosed by external contour in the shape of a head. Additional experimental work would be needed to determine what aspects of the head are necessary to elicit the bias and whether the conspec formulation provides an appropriate accounting of the bias. For example, one could (a) invert just the heads, keeping the bodies in their canonical orientation; (b) remove the facial features altogether, keeping just the featureless heads; or (c) seek a finer resolution for the AOIs with the whole animal stimuli to determine if the fixations within the head are focused on the internal features in the upright condition.

As proposed by Johnson and Morton (1991), a bias to attend to face information present in a visual display may play a facilitative role in terms of allowing infants to attend to and recognize members of their own species and also specific persons such as the primary caregiver. The present studies suggest that the bias could more broadly assist conceptual development by allowing infants to differentiate categories that have faces (e.g., animals) and those that do not (e.g., furniture), as well as partition classes marked by distinctive facial make ups (e.g., cats vs. dogs). The bias may also aid infants in selecting from among various features that are potentially available in the input (i.e., head or body) and in this way "set the system on the trajectory of learning" (Thelen & Smith, 1994, p. 315). Such biases may be especially important in determining the course of concept acquisition in a system that is otherwise characterized by flexibility.

It is interesting to consider the possible functional consequences of the fixations that were on the image versus the fixations that were in the stimulus region containing the image, but not on the image itself. Ruff (1986) has argued that only a portion of infant exploratory behavior is associated with active processing, sometimes called a state of focused attention or examining, that is marked behaviorally by less distractibility (Oakes & Tellinghuisen, 1994) and physiologically by heart rate deceleration (Colombo, Richman, Shaddy, Greenhoot, & Maikranz, 2001; Lansink & Richards, 1997; Richards & Casey, 1992). It would be informative in future work to combine eye-tracking measures of fixation with heart rate measures of visual attention to determine if the periods of "on stimulus" fixation are associated with the heart rate deceleration that characterizes focused attention.

The findings from the present study point to the utility of an eye-tracking methodology that can supplement overall looking time as a measure of processing in studies of infant categorization. This additional measure of processing can in turn provide fine-grained information about the mechanisms underlying infant performance that is not available from an overall looking time measure. In the current experiments, overall looking time could be used to determine whether the infants showed a reliable decline in responsiveness during the course of familiarization that would be consistent with the presence of habituation. Overall looking time can also be used to determine whether the infants displayed a novel category preference that would provide evidence that they had separated the categories. What the eye-tracking methodology allowed for was a determination of where on the stimulus the infants were fixating during familiarization, which could then be used as a basis for making inferences about the mechanism that appears to be driving the categorization (i.e., the head bias). In addition, the eye-tracking methodology revealed that some stimulus regions carried the novel category preference over others (i.e., the head vs. the body) depending on whether images were upright or inverted, thereby demonstrating that infants can flexibly use different attributes as a basis for categorization depending on the stimuli that were presented. Eye tracking thus joins with computational modeling (Mareschal, French, & Quinn, 2000) and the recording of event related potentials (Quinn, Westerlund, et al., 2006) as technologies that can complement overall looking time to provide convergent measures of the processes underlying infant categorization.

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