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Dichotomous Perception of Animal Categories in Infancy

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Abstract

Although there is a wealth of knowledge on categorization early in life, there are still many unanswered questions about the nature of category representation in infancy. For example, it is unclear whether infants are sensitive to boundaries between complex categories, such as types of animals, or whether young infants exhibit such sensitivity without explicit experience in the lab. Using a morphing technique, we linearly altered the category composition of images and measured 6.5-month-olds' attention to pairs of animal faces that either did or did not cross the categorical boundary, with the stimuli in each pair being equally dissimilar from one another across the two types of image pairs. Results indicated that infants dichotomize the continua between cats and dogs and between cows and otters, but only when the images are presented in their canonical, upright orientations. These findings demonstrate a propensity to dichotomize early in life that could have implications for social categorizations, such as race and gender.

Keywords

dichotomization in infancy; categorical perception; animal knowledge in infancy; early conceptual development

Dichotomous Perception of Animal Categories in Infancy

Knowing a novel object's category membership allows an individual to automatically apply his or her previous knowledge of the category without further investigation (Sutherland & Cimpian, 2015). The immediate availability of information is just one illustration of the way in which categories are beneficial for mental economy and rapid responding. Given the adaptive value of categorization and the ubiquitous nature of its application by adults, it is no surprise that a considerable amount of research has examined the development of categorization in infancy (for reviews, see Madole & Oakes, 1999; Quinn & Eimas, 1986; Rakison & Lawson, 2013; Younger, 2010). Yet, many unanswered questions remain about the nature of category representation in infancy.

For example, do infants treat linear continua between complex categories, such as types of animals, as dichotomies? Is this dichotomization specific to categories with which infants are likely to have rich experience, or does it extend to categories with which infants have no, or minimal, exposure? The latter possibility would indicate that some perceptual feature of images depicting animal categories lends them to clear classification based on discrete boundaries, and sensitivity to such boundaries is present early in life. This sensitivity could result from underlying perceptual characteristics of animal categories whereby they inherently lend themselves to dichotomization; alternatively, or additionally, this sensitivity could result from a mechanism that predisposes humans to efficiently respond to biological kinds after no or only minimal exposure to specific types of animals. The current experiment addressed these issues by using morphed stimuli and a spontaneous preference procedure to determine whether infants find pairs of animal faces that cross the boundary between categories to be more salient than those that do not, even when the degree of differences between images in the two types of pairs is equated.

Category Structure

The nature of category structure is an essential question when considering both category formation and decision making processes. This is because a category, by nature, involves a group of non-identical objects being treated in a systematic way (Mervis, 1980), and this requires the presence of some type of decision rule to separate category members from non-members. Analyzing the presence or absence of clear boundaries, or borders, between categories is thus a necessary step to understanding category, and subsequently conceptual, development in infancy.

When considering the nature of category structure, three options immediately come to mind. The categories could be discrete, as would be conceptualized by a Venn diagram with no overlap, meaning that the categories are mutually exclusive. It is also possible that there is an area of overlap, i.e., the middle section of a Venn diagram with overlapping circles. This section can be thought of as an area of dual or ambiguous category membership. Finally, it is possible that the categories have a gradient structure with no definite borders. By determining whether infants are sensitive to a distinct boundary between categories, it is possible to distinguish the first option from the remaining two possibilities.

Studies attempting to differentiate between discrete and continuous categorization have been conducted in many areas of research, including language and color perception. For example, Hu, Hanley, Zhang, Liu, and Roberson (2014) found that when color category membership (as defined by a word label) is linearly manipulated, adults' same/different judgments between two different shades of green (within-category condition) took longer than contrasts between a green and a blue shade (between-category condition). This occurred in spite of the fact that the physical difference between the two green shades was equal to the difference between the green and the blue shade, suggesting that the discrepancy in response times can be attributed to a salient, discrete, category boundary (see Witzel & Gegenfurtner, 2016 for an alternative perspective). Similarly, evidence of categorical perception of hue was found in 4-month-old infants using a dishabituation paradigm (Bornstein, Kessen, & Weiskopf, 1976). Infants showed greater dishabituation to hues from novel categories compared to the familiar category even when differences in wavelength were equated. This study demonstrates sensitivity to boundaries between simple categories early in life that manifests as heightened looking to stimuli that cross a category boundary. However, it is unknown whether young infants are sensitive to discrete boundaries when it comes to more complex stimuli such as animal categories.

Categorization in Infancy

Given the pervasive nature of categorization and its adaptive value in many contexts, it is not surprising that the ability to classify objects develops early in life and across widely varied domains (Madole & Oakes, 1999; Quinn & Eimas, 1986; Younger, 2010). For example, 5-month-olds form categories representative of 3-dimensional objects (Mash & Bornstein, 2012). Additionally, infants have been found to form categories based on spatial relations regarding position (above/below) by 3.5 months of age (Quinn, 1994) and fit (inside/outside) by 10 months of age (Casasola & Cohen, 2002). Evidence of categorization has also been found with social stimuli. Bornstein and Arterberry (2003) found evidence of categorization of emotional facial expressions as early as 5 months of age, and infants categorize human faces based on race by 9 months of age (Anzures, Quinn, Pascalis, Slater, & Lee, 2010). Additionally, by 7 months of age infants' neural activation, evidenced by event-related-potentials, indicates adult-like categorical processing of humans as opposed to animals (Marinovi, Hoehl, & Pauen, 2014). Furthermore, the development of category knowledge is quite complex early in life. For example, infants' categorical representations of male and female faces differ within the first six months of life, possibly as a function of differences in exposure among other factors (for review, see Ramsey, Langlois, & Marti, 2005).

The current study focused on animal categories because they offer unique benefits as basic level categories that are treated by adults as discrete and are socially relevant. One well-documented phenomenon in categorization research is the primacy of categories at the basic level over superordinate or subordinate categories (i.e., pants over clothing or dress pants). Basic categories are found to be the most quickly identified by adults (e.g., Jolicoeur, Gluck, & Kosslyn, 1984; Murphy & Smith, 1982). Compared to subordinate categories, basic level categories are also the more commonly used in language (dog over boxer; Brown, 1958), as well as the most commonly used words by adults when talking to children (Anglin, 1977; Callanan, 1985). Furthermore, they are thought to have an ideal balance of within-group

similarity and between-group differences (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). This means that members of these categories are readily grouped together and easily excluded from other categories. These findings highlight the importance of basic categories in cognition.

One advantage to studying biological categories specifically, such as animals, is that they are socially relevant. Humans interact with a great number of plants and animals in their daily lives; thus, accurate sensitivity to biological kinds would be adaptive. Such sensitivity early in life would be consistent with the animate monitoring hypothesis which posits that humans' evolutionary history has predisposed them to attend to humans and other animals over plants and objects (New, Cosmides, & Tooby, 2007). Furthermore, the study of animal categories is also useful in that it could provide insights into the development of "naïve biology" which is considered a core domain of thought by some theorists and is a critical step toward understanding the world in which we live (Hanto & Inagaki, 2013).

A second benefit of studying animal categories is that they are treated by adults as being mutually exclusive such that a single animal cannot be a member of multiple species-level categories. Even hybrids of two species, such as mules, are not considered to hold dual category membership (Mishler & Brandon, 1987). In essence, this means that distinctions between types of animals are not arbitrary; thus, early sensitivity to sharp boundaries between categories could increase later categorization accuracy and efficiency. However, given the physical similarities between certain types of animals, such as cats and dogs, it is conceivable that infants are not sensitive to discrete boundaries and it takes more extensive experience and greater development before such sensitivity is apparent.

In the current study, we were specifically interested in testing infants on two continua spanning between types of animals with which infants may have varying experience: extensive experience (cat/dog) and minimal experience (cow/otter). The novel category contrast (cow/otter) was included to both increase confidence in the generalizability of the results beyond one animal contrast and to examine whether extensive experience is necessary to dichotomize categories.

Previous Work on Animal Categories

One could argue that in the Western culture, after humans, there are few or no animals that infants are exposed to more than cats and dogs. Given that fact, it is not surprising that infants have been found to categorize these types of animals early in life. Quinn and Eimas (1996) found that 3- to 4-month-old infants formed a category of cats that excluded dogs. Furthermore, infants were capable of forming and/or recognizing these categories when only the internal features of the face were present. This is consistent with previous work demonstrating that not only are faces and face-like images highly salient stimuli shortly after birth (Goren, Sarty, & Wu, 1975), but also that focusing infants' attention on internal features through training (Galati, Hock, & Bhatt, 2016) or simply removing the external features (Kangas, 2013) can improve processing of subtle distortions in faces. Furthermore, it has been suggested that the head region of cats and dogs is the most informative area for stimulus comparisons (Kovack-Lesh, McMurray, & Oakes, 2014). In accordance with the

findings presented above, stimuli in the current study were restricted to the internal features of the face.

It should be noted that Quinn and Eimas (1996) used a familiarization-visual preference procedure in their cat/dog categorization study. Indeed, the vast majority of research on categorization in infancy has used familiarization followed by a visual preference test. In this paradigm, infants are familiarized to a number of exemplars from category A over many trials. Following this, the infants are tested for their preference between a novel exemplar of category A and an exemplar of category B. A novelty preference for the stimulus from category B is interpreted as evidence of categorization. While this procedure has been extremely useful in determining what types of categories infants are capable of forming, it is unable to answer questions about a priori sensitivity to categories as it is possible that the familiarization trials could serve as a learning period for infants whereby they aggregate the exemplars they are being shown to create a category (Quinn & Eimas, 1996).

Furthermore, in the familiarization/visual preference paradigm the critical test is based on a novelty preference for an image from category B after being exposed to exemplars from category A. It is possible that the test image from category B is arbitrarily more novel than the test image from category A. For example, it is likely that any dog will be perceptually more dissimilar to a cat than two cats are to each other. This means that, after being familiarized to cat exemplars, infants could show a novelty preference for the dog based on low-level similarity without being sensitive to the discrepancies between categories. By using morphing techniques in the current study, we removed this obstacle by precisely controlling the composition of each image and thus ruled out arbitrary physical differences as a mechanism of performance. Additionally, by creating a linear continuum between categories we were able to examine the nature of boundaries between categories.

The Current Study

In the current study, we linearly altered the category ratio of images and observed how infants attended to image pairs that either did or did not cross over the categorical boundary between animal types. This was accomplished via a morphing technique that allowed us to specify the percentage of each type of animal present in an image and thus create image pairs that either did or did not cross the boundary between animals at the 50% point in the resulting continuum. It should be noted that it is possible that the boundary between animal categories is not centered at 50%, but, given that, to our knowledge, no previous research has determined where the boundary between the animal categories used in this study is likely to fall, the center of the continua is the most logical place to start. Accordingly, in this study, we examined whether infants looked longer at a pair of images from different categories (e.g., 40% cat and a 60% cat) than a pair from the same category (e.g., 60% cat and an 80% cat). The linear manipulation enabled us to equate visual differences in the two types of pairs. If infants exhibit an attentional bias to the between-category pair compared to the within-category pair, despite the equivalent degree of differences in the two types of pairs, then it would be evidence of a salient categorical boundary. Such a finding would suggest that infants are sensitive to perceptual boundaries that render animal categories discrete and mutually exclusive. Note that visual differences between image pairs that crossed the

boundary between animal types or stayed within a single type of animal were equated. Thus, any preferences observed cannot be explained by discrepancies in within-category versus between-category similarity.

We were additionally interested in examining infants' pre-existing sensitivity to category boundaries. While Quinn and Eimas (1996) documented animal categories in infancy using the familiarization/visual preference procedure discussed above, infants in that study could have learned the category during the familiarization phase of the procedure. Thus, it is yet unclear whether infants are sensitive to distinctions between the categories of cats and dogs without any training in the laboratory. To examine this possibility, we used a spontaneous preference procedure to test infants' sensitivity to a discrete boundary between cats and dogs in Experiment 1. While infants have been found to categorize cats and dogs by 3.5 months of age (Quinn & Eimas, 1996), to ensure that participants had enough exposure to cats and dogs to spontaneously categorize exemplars, the present study included 6.5-month-olds. Previous research suggests that by this age even infants with no pets in the home show sophisticated scanning of images of cats and dogs (Quinn, Doran, Reiss, & Hoffman, 2009).

Sensitivity to categorical boundaries in this procedure would indicate either that infants' early experience with these types of animals is sufficient to form such categories, or there is something about biological categories that predispose humans to group them systematically even without training.

Additionally, in Experiment 2 we examined whether infants are similarly sensitive to a discrete boundary between cows and otters. This allowed us to generalize the findings pertaining to cats and dogs to an additional animal contrast. Moreover, it is a contrast between animal types that are less ubiquitous in Western society and unlikely to reside within the home; this allowed us to examine the robustness of dichotomous perception of complex continua in infancy. Finally, in Experiment 3 we tested infants on inverted images to rule out the possibility that some low-level artifact of the morphing procedure was driving performance in Experiments 1 and 2.

Experiment 1

Experiment 1 assessed 6.5-month-olds' sensitivity to the categorical boundary between cats and dogs using a spontaneous visual preference procedure to ensure that experience in the lab did not impact performance. Infants viewed two images simultaneously that differed systematically in the proportion of cat or dog. In one pair, the images spanned the 50% cat/dog category boundary (e.g., 40% Cat/60% Dog and 60% Cat/40% Dog), while in the other pair, both images were within the same category (e.g., 60% Cat/40% Dog and 80% Cat/20% Dog). If infants look longer at image pairs that differed in category membership than those that belonged to the same category, despite the fact that the images' compositional differences were equal in magnitude in the two pairs, this would provide evidence of infants' sensitivity to a discrete categorical boundary.

Method

Participants

The a priori exclusion criteria were as follows (1) looking to the test stimuli for less than 20% of the duration of the study (calculated by dividing infants looking across all trials by the total trial length), (2) missing data on two or more trials, and (3) being an outlier on the dependent measure (more than 1.5 x the interquartile range below the 25th quartile or above the 75th quartile). Sixteen 6.5-month-olds (mean age = 193.50 days, $SD = 7.75$; 9 female) successfully completed the study and were included in the final sample. Four additional infants participated, but their data were excluded due to looking at the stimuli for less than 20% of the duration of the study ($n = 2$), equipment failure ($n = 1$), or being an outlier on the dependent measure ($n = 1$, more than 1.5 x interquartile range below the 25th quartile). Participants in this study were recruited from birth announcements and the local hospital, and they were predominantly from middle-class, Caucasian families.

Stimuli

This experiment utilized eight stimulus sets, each consisting of two image pairs. One image pair (hereafter referred to as the *within-category* pair) consisted of two images on the same side of the category boundary that was assumed to be at 50% (e.g., 80% Cat/20% Dog and 60% Cat/40% Dog). The second pair (hereafter referred to as the *between-category* pair) consisted of images spanning the 50% category boundary (e.g., 40% Cat/60% Dog and 60% Cat/40% Dog), see Figure 1. Critically, changes in image composition were equated between the two types of image pairs. For a detailed explanation of the image creation process and validation of the equality of the changes in both contrasts, please see the Appendix. To ensure that images were representative of the animal category they were meant to belong to (the majority category based on the morphing percentages), adult participants rated the images. Sixteen adults viewed each stimulus image (randomly presented) one at a time on a computer monitor with the question “What kind of animal is this?” and the options “Cat” and “Dog”. The mean percent correct was 93.75% ($SE = 1.56$), which is significantly different than the chance level of 50%, $t(15) = 28.00$, $p < .001$, $d = 7.00$. Thus adults could reliably identify the species category of the stimuli based on the majority portion of their features. This finding indicates that the morphing resulted in clearly identifiable cat/dog images even though they shared characteristics of both species.

Apparatus and Procedure

During the study, infants sat on their parent’s lap in a darkened chamber, approximately 60 cm in front of a 58 cm computer monitor. Parents wore opaque glasses to prevent them from seeing test images and potentially biasing their infant’s looking patterns. Each infant viewed only one stimulus set: a within-category image pair with two images of the same type of animal, and a between-category image pair consisting of that same type of animal and the contrast animal type. For example, if an infant saw two cats for the within-category image pair, he/she would see a cat and a dog for the between-category image pair. Across infants, each type of animal served equally often as the within-category image pair. Infants were tested on four eight-s trials. For two trials, infants saw the between-category contrast. The remaining two trials were within-category contrasts. The left/right location of each face, type

of first trial (between-category pair or within-category pair), and type of animal used as the within-category pair (cat or dog) were counterbalanced across infants. For each infant, trial type switched from trial 1 to trial 2, and the pattern reversed for the remaining two trials. For example, the pattern of between-category pair trials (B) and within-category pair trials (W) for half of infants was (BWVB). The counterbalancing of the left/right locations of each image type within the image pairs and the order of trials across infants ensured that any preference exhibited by the infants cannot be due to side-bias. Preceding every trial, an attention getter consisting of alternating colorful shapes appeared on the screen to re-focus the infant's attention to the center of the screen. Once there, as judged via live video feed, the experimenter pushed a key to present the pair of the stimuli for that trial.

Data were collected by a Tobii TX300 eye-tracker. The eye-tracker's cameras record the reflection of an infrared light source on the cornea relative to the pupil from both eyes at a frequency of 300 Hz. According to the manufacturer, the average accuracy of this eye-tracking system is in the range of .5 to 1 degree, which approximates to a .5–1 cm area on the screen with a viewing distance of 60 cm. When both eyes cannot be measured (e.g., due to movement or head position), data from one eye were used to determine the gaze coordinates. The eye-tracker compensates for robust head movements, which typically result in a temporary accuracy error of approximately 1 degree and a 100 ms recovery time to full tracking ability after movement offset.

Prior to data collection, each infant completed a 5-point infant calibration procedure in which a 23.04 cm² red and yellow rattle coupled with a rhythmic sound appeared sequentially at five locations on the screen (i.e., the four corners and the center). An experimenter controlled the calibration process with a key press to advance to the next calibration point after the infant was judged (via a live video feed) to be looking to the current calibration point. The calibration procedure was repeated if calibration was not obtained for both eyes in more than one location. Tobii Studio 3.3.1 software (Tobii Technology AB; www.tobii.com) controlled the eye-tracker calibration and stimulus presentation. An I-VT fixation filter removed noise from the data. This filter is a velocity threshold identification algorithm that removes noise from the eye-tracking data, fill in gaps where tracking was temporarily lost, and define fixations to remove saccadic looking in favor of more intentional focused fixations (Olsen, 2012). This is similar to filters used in previous infant eye-tracking studies (Hunnius, de Wit, Vrins, & von Hofsten, 2011; Papageorgiou et al., 2014; Xiao, Quinn, Pascalis, & Lee, 2014; Xiao et al., 2015), and the exact filter that has been used in infant eye-tracking studies across various paradigms (e.g., Heck, Hock, White, Jubran, & Bhatt, 2016, 2017; White, Hock, Jubran, Heck, & Bhatt, 2018).

Areas of interest (AOIs) were defined around the white boxes surrounding each face included in the image pair, see Figure 1. Collectively, the AOIs encompassed 18.06% of the screen and a horizontal and vertical visual angle of 20.20° and 12.46°, respectively. Values were obtained for total fixation duration to both AOIs for each type of stimulus (between-category image pair, within-category image pair). As in a number of prior infant eye-tracking studies (e.g., Heck et al., 2016, 2017; Hunnius, et al., 2011; Papageorgiou et al.,

2014; White et al., 2018; Xiao et al., 2014; Xiao et al., 2015), fixation duration was defined as the sum of all looks exceeding 60 ms while remaining within a 0.5° radius.

The dependent measure was the proportion fixation duration to the between-category image pair trials. Proportions, unlike raw fixation durations, remove variability in the data resulting from individual differences in overall look durations and are commonly used in infant visual preference procedures (e.g., Bornstein, & Arterberry, 2003; Galati, Hock, & Bhatt, 2016; Quinn & Eimas, 1996). This was calculated by summing fixations during the two between-category image pair trials and dividing this number by the total fixation duration across all four trials. Since there is no habituation period in this study, there is no reason to expect infants would look more to any specific image, only to image pairs as a whole driven by differential contrast between the two faces in each type of contrast. Therefore, looking to individual faces within an image pair was not analyzed, only overall looking to both faces across image pairs. If infants are not sensitive to discrete category boundaries, then there should be no systematic differences in looking to the two contrast types, which would be reflected in a proportion score that is not significantly different from chance. If, however, infants are sensitive to a discrete boundary at the midpoint of the continuum, they should show an attentional bias to between-category image pairs and exhibit greater than chance (50%) proportion fixation durations to the between-category image pairs. Given that the predictions of the discrete boundary model involved an attentional bias to one kind of contrast while the alternative (lack of a discrete boundary) did not predict any kind of preference, we used one-tailed tests to analyze infants' performance on these tasks.

Results

Prior to participating in the study, parents reported on the presence of cats and dogs in the infant's home. Eight infants lived with dogs only, four lived with a cat only, and one lived with both a cat and a dog. Due to small sample sizes in each pet category and unbalanced distribution of these variables, we did not analyze the effects of having a pet in the home on performance.

See table 1 for mean fixation durations to each image pair type. A paired sample *t*-test comparing average proportion fixation durations to the between-category image pair in the first half of the test period ($M = 52.71\%$, $SE = 2.11$) to the second half of the test period ($M = 56.06\%$, $SE = 3.75$) indicated that performance did not significantly improve across the test period, $t(15) = -0.74$, $p = .47$, $d = 0.19$. A one-sample *t*-test compared the average proportion fixation duration to the between-category image pair trials to chance (50%) and revealed that infants' performance differed significantly from chance [$M = 53.61\%$, $SE = 1.53$; $t(15) = 2.36$, $p = .03$]¹. While the magnitude of the effect may seem small, it should be noted that this effect was medium in size ($d = 0.59$). The effect was also consistent across infants such that 12 out of 16 infants displayed above chance performance (binomial $p = 0.04$). Thus, 6.5-month-olds looked longer at stimuli during the between-animal category trials than during the within-animal category trials, even though the degree of differences

¹When the data are restricted to only include pairs of trials in which infants fixated on every face, infants' performance remains significantly above chance, $M = 52.48\%$, $SE = 0.85\%$, $t(10) = 2.93$, $p = .02$, $d = 0.89$.

between the stimuli was equal across each type of contrast. This finding indicates that 6.5-month-old infants are sensitive to a discrete category boundary between cats and dogs.

Experiment 2

To test the generalizability of the findings in Experiment 1, Experiment 2 included a new pair of animal types with which infants are unlikely to have much experience. Cows and otters served as the less familiar species as they are similar enough to allow for morphing, but also have distinct featural differences, such as nose shape and size. If the sensitivity to a discrete categorical boundary in Experiment 1 was due either to the high level of exposure human infants have to cats and dogs or to something specific about cats and dogs that leads to categorization, one would expect no preference for between- versus within-category cow/otter image pairs in Experiment 2. If, however, the propensity to dichotomize animal types is due to a tendency to take advantage of inherent physical differences between types of animals or if infants are able to transfer their acquired knowledge of faces and familiar types of animals to novel ones, then performance in Experiment 2 should be similar to that in Experiment 1 and infants should display a preference score for the between-category image pairs that is significantly above chance.

Participants

The exclusion criteria were the same as those used in Experiment 1. Sixteen 6.5-month-olds (mean age = 192.69 days, $SD = 8.33$; 10 female) successfully completed the study and were included in the final sample. One additional infant participated, but was excluded due to failing to look on more than two test trials. As in Experiment 1, participants in this study were recruited from birth announcements and the local hospital, and were predominantly from middle-class, Caucasian families.

Stimuli, Apparatus, and Procedure

Stimuli were created in the same way as in Experiment 1 (outlined in the Appendix), except the degree of change between images in both contrast types was increased by 10%. That is, while infants in Experiment 1 saw 40%–60% and 60%–80% image pairs, infants in Experiment 2 saw 30%–60% and 60%–90% image pairs; see Figure 3. This change served to increase the discriminability between the images in the within- and between-category contrasts as infants are unlikely to have the same level of experience with cows and otters that they do with cats and dogs. Eight images of cows and eight images of otters were used to construct the stimuli. All images were obtained through a Google Image search.

As in Experiment 1, adult participants rated the images. Sixteen adults viewed each stimulus image (randomly presented) one at a time on a computer monitor with the question “What kind of animal is this?” and the options “Cow” and “Otter.” The mean percent correct was 91.99% ($SE = 1.27$), which is significantly different than the chance level of 50%, $t(15) = 32.94$, $p < .001$, $d = 8.23$. This finding indicates that the morphed images were accurately identified as a member of their majority species category.

The study used the same equipment and procedure utilized in Experiment 1, except for the addition of four trials. That is, while infants viewed four trials in Experiment 1, they viewed

eight trials in Experiment 2. This additional block of trials allowed infants more time to process the novel cow/otter images given that participants were likely to have less exposure to these types of animals than to cat/dog categories used in Experiment 1. Trials were arranged following the same pattern as in Experiment 1.

Results and Discussion

Prior to participating in the study, parents reported on their infants' exposure to cows and otters. No infant lived with a cow or otter in the home. Parents also reported on indirect exposure to cows and otters (e.g., on TV/computer/phone, while playing with toys). Indirect exposure data were not reported for three infants. For the remaining infants, four had been exposed to both species, seven had been exposed to cows only, and two had been exposed to neither species.

See table 1 for mean fixation durations to each image pair type. A one-sample t-test compared the average proportion fixation duration to the between-category image pair trials to chance (50%) and revealed that infants' performance differed significantly from chance [$M = 52.93\%$; $SE = 1.37$, $t(15) = 2.14$, $p = .050$]². As in Experiment 1, this effect was medium in size ($d = 0.53$). Furthermore, this preference increased as infants had more time to process the images, as evidenced by a significant improvement in performance in the last four trials compared to the first four trials, $t(15) = -2.38$, $p = .03$, $d = 0.60$. Performance in the last four trials was also significantly above chance [$M = 55.97\%$; $SE = 1.85$, $t(15) = 3.23$, $p = .006$]³, with a large effect size ($d = .81$). Additionally, 13 out of the 16 infants displayed above chance performance in the last four trials (binomial $p = 0.01$). These results indicate that 6.5-month-olds are sensitive to the categorical boundary between cows and otters, animal types to which infants had no direct exposure.

Experiment 3

In the first two experiments, infants exhibited greater attention to image contrasts that crossed a category boundary than to contrasts that did not, even though the physical differences in the contrasts were the same. The fact that the degree of differences was the same in the two types of contrasts is supported by compositional, pixel and color analyses detailed in the Appendix. It is possible, however, that infants in Experiments 1 and 2 were responding to some idiosyncratic features of the morphed images that were not captured by the presented analyses which made the between-category contrast more salient than the within-category contrast. To address this possibility, infants in Experiment 3 viewed inverted images. Inversion often serves as a control condition in infant work to rule out low-level stimulus features as the driving factor of infants' preferences (Hayden et al, 2007; Pascalis, Demont, de Haan, & Campbell, 2001; Zieber et al, 2010). The rationale is that if processing of inverted images is disrupted, then infants' preferences for upright images was unlikely to be due to some artifact from the morphing procedure since the low-level features of the

²When the data are restricted to only include pairs of trials in which infants fixated on every face, infants' score is no longer significantly different from chance, $M = 51.43\%$, $SE = 1.54\%$, $t(15) = 0.93$, $p = .37$, $d = 0.23$.

³When the data are restricted to only include pairs of trials in which infants fixated on every face, infants' score is marginally above chance, $M = 53.79\%$, $SE = 1.82\%$, $t(15) = 2.07$, $p = .06$, $d = 0.52$.

stimulus remain across both orientations. Thus, if infants in Experiment 3 fail to display a significant preference for the between-category image pair, then it is unlikely that performance in the preceding experiments was due to low-level artifact of the morphing procedure.

Participants

The exclusion criteria were the same as were used in Experiment 1 and 2. Thirty-two 6.5-month-olds (mean age = 196.44 days, $SD = 8.33$; 11 female) successfully completed the study and were included in the final sample. Power analyses conducted in G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that the sample of 32 infants in the present experiment will yield over 80% power to detect the smallest effect documented in the Experiments 1 and 2 ($d = 0.53$). Ten additional infants participated, but their data were excluded due to looking less than 20% of the study duration. As in Experiments 1 and 2, participants in this study were recruited from birth announcements and the local hospital, and were predominantly from middle-class, Caucasian families.

Stimuli, Apparatus, and Procedure

The images were identical to those used in Experiments 1 and 2, except that they were rotated 180°. Half of the infants viewed four trials of the cat/dog contrasts with identical apparatus, procedure, and counter-balancing as described in Experiment 1. The remaining half viewed eight trials of the cow/otter contrasts with identical apparatus, procedure, and counter-balancing as described in Experiment 2.

Results and Discussion

As in Experiment 1, prior to participating in the study, parents whose infants were in the cat/dog condition reported on the presence in the infant's home of cats and dogs. Seven infants lived with dogs only, three lived with a cat only, and none lived with both a cat and a dog. As in Experiment 2, parents whose infants were in the cow/otter condition reported on their infants' exposure to cows and otters. No infant lived with a cow or otter in the home. Parents also reported on indirect exposure to cows and otters (e.g., on TV/computer/phone, while playing with toys). Indirect exposure data were not reported for two infants. For the remaining infants, five had been exposed to both species, three had been exposed to cows only, two had been exposed to otters only, and four had been exposed to neither species.

See table 1 for mean fixation durations to each image pair type. A one-sample t -test comparing the average proportion fixation duration, collapsed across condition, to the between-category image pair trials to chance (50%) revealed that infants' performance was not significantly different from what would be expected by chance [$M = 51.05\%$; $SE = 1.27$, $t(31) = 0.83$, $p = .42$, $d = 0.14$]⁴. Separating performance by condition, follow-up one-sample t -tests revealed that performance did not significantly differ from chance in the cat/dog condition, $M = 52.87\%$, $SE = 1.84$, $t(15) = 1.55$, $p = .14$, $d = 0.39$, or in the cow/otter condition, $M = 49.23\%$, $SE = 1.67$, $t(15) = -0.45$, $p = .66$, $d = 0.07$. Furthermore, only

⁴When the data are restricted to only include pairs of trials in which infants fixated on every face, infants' mean score is still not significantly different from chance, $M = 51.47\%$, $SE = 1.44\%$, $t(29) = 1.02$, $p = .32$, $d = 0.19$.

13 out of 32 infants (8 of 16 in the cat/dog condition and 5 of 16 in the cow/otter condition) displayed above chance performance (binomial $p = 0.89$). Thus, there is no evidence to suggest that infants were sensitive to the category boundary between types of animals when presented with inverted images.

Independent samples t -tests comparing performance with upright images (Experiments 1 and 2) to performance with the inverted images in the current investigation revealed a non-significant difference when collapsing performance across both contrasts, $t(62) = 1.37$, $p = .18$, $d = 0.34$, a non-significant difference in the cat/dog contrast, $t(30) = 0.31$, $p = .76$, $d = 0.11$, and a marginally significant difference in the cow/otter contrast, $t(30) = 1.70$, $p = .10$, $d = 0.61$. However, consistent with the analyses of binomial probabilities presented above and in Experiments 1 and 2, a chi-squared test of independence revealed a significant association between orientation (upright, inverted) and infants preference for the between-category image pair (above chance, below chance), $X^2(1, N = 34) = 4.01$, $p = 0.05$, such that more infants in the upright condition than in the inverted condition exhibited above chance preference for the between-category image pair.

In conjunction with the previous experiments, these results indicate that 6.5-month-olds are sensitive to the categorical boundary between cats and dogs and between cows and otters, but only when the images are presented in their upright, canonical orientations.

General Discussion

This study demonstrates that the tendency to dichotomize continua between types of animals emerges early in life. Specifically, 6.5-month-olds demonstrated sensitivity to the categorical boundary between cats and dogs and between cows and otters. These results suggest for the first time that animal categories are such that even young infants are sensitive to discrete boundaries between them. Thus, even in the absence of extensive experience, infants are sensitive to sharp breaks between animal categories, which presumably allows them to maximally benefit from the certainty that accrues from definitive classification. Furthermore, the failure of infants to display such sensitivity when the stimuli were inverted demonstrates that performance in the upright conditions was unlikely to be due to some artifact of the morphing procedure. The present results have implications for theories of the interplay between language and concept and language development by demonstrating that infants process complex categories as discrete and mutually exclusive before they acquire the ability to label those categories.

Similar results across the cat/dog and cow/otter contrasts used in this study suggest that dichotomization of categories generalizes beyond categories with which infants have direct experience. It is possible that infants' experience with human and animal faces facilitated their performance on the less familiar cow/otter contrast. For example, if an infant has learned certain "rules" such as, some people and animals have large noses, while others have small noses, and they have internalized nose size as a critical feature, then they could have extrapolated that knowledge and distinguished between cows and otters on the basis of nose size. It important to note that in this example, based on the results of this study, there would be a sharp break between what would be considered a "short-nose," indicating otter, and

what would be considered a “long-nose,” indicating cow. Thus, the fact that infants may have been using critical features to guide their performance does not detract from the finding that infants treated continua as dichotomies and were sensitive to discrete boundaries between complex categories.

Relatedly, while similar performance was documented on the cat/dog and cow/otter contrasts, the current investigation is unable to answer questions regarding the relative precision or width of said category boundaries. Namely, given that the source images were not rated on typicality and it is unclear whether the perceptual difference between cats and dogs is comparable to the perceptual difference between cows and otters, even if 20% steps in the morphing procedure were used in both cases the physical differences may not be equated. Thus, it is possible that the width of the cat/dog boundary may differ from the width of the cow/otter boundary. The present results do indicate, however, that in both cases infants are treating the contrasts as dichotomies, which is the core issue addressed by the current investigation.

A propensity to dichotomize early in life, as found in this study, could have implications not only for understanding how infants mentally organize biological kinds, but also for issues in social development. One example is developing an understanding of sex categories. Infants as young as 3.5 months of age have been found to be sensitive to sex information present in faces (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002) and in bodies (White et al., 2018). It is possible that this early knowledge of sex categories includes a discrete male/female boundary. This and other such discrete social categories could enable the infant to economically organize and interact with the social world. Future research should apply the current procedure to socially relevant category structures. This could lend insight into questions about the categorization of humans as a type of animal and the nature of within-human categorizations such as race and gender.

It is important to note that while infants likely had negligible exposure to cows and otters, the role of experience cannot be ruled out. Previous research has clearly documented how experience with pets can systematically impact performance (Kovack-Lesh, McMurray, & Oakes, 2014). Although no parent in Experiment 2 reported that their infant had direct experience with cows or otters, there were hints of indirect exposure. In the upright cow/otter condition, roughly 25% of parents reported that their infant was exposed in some way (toys, books, cartoon, farm/zoo, etc.) to both animals and approximately 50% reported exposure to cows. It is possible that even this limited exposure was sufficient for infants to develop sensitivity to category boundaries. As it is hard to precisely control the quality and quantity of exposure to any given type of animal, future research needs to use artificial categories to fully understand the link between familiarity and dichotomization. This would allow researchers to directly control the amount of time an infant is exposed to a category as well as the amount of variability within that category.

Furthermore, it will also be important to examine category structures at subordinate (e.g., specific breeds of dogs) and superordinate levels (e.g., more inclusive animal categories, such as mammals). Given the primacy of basic level category perception in adults and children (Anglin, 1977; Jolicoeur et al., 1984; Murphy & Smith, 1982; Rosch et al.,

1976), it is possible that categories at lower and higher levels fundamentally differ from basic level categories. Namely, superordinate categories, which share fewer perceptual features, may not be represented as discrete and mutually exclusive in infancy. Future work should also examine non-face representations of animal categories and non-animal categories to determine how the findings of the present investigation generalize beyond processing of animal faces.

It is unclear whether infants in this study were responding to an animal type A/not-animal type A dichotomy rather than an animal type A/animal type B dichotomy. This is somewhat likely in the cat/dog contrast as previous work has shown asymmetries in the categorization of cats and dogs early in infancy (Furrer & Younger, 2005). However, as the purpose of the current work was to determine if infants spontaneously dichotomize the boundaries between animal types, the question of how the infants are representing the categories (cat/not-cat vs. cat/dog), is tangential to the current investigation.

Additionally, one should note that failure to detect differences in attention to the between- and within-category contrasts with the procedure used in this study need not necessarily indicate the lack of a discrete categorical boundary. It can only be interpreted that there is no such boundary between the percentages tested. To our knowledge, no research has investigated the location of the boundary between cats and dogs or between cows and otters, so for our purposes we assumed the boundary was near 50%. If this assumption had been incorrect, we would not have found an attentional bias to the between-category contrasts using these specific percentages. For example, if there was a discrete boundary at 90%, one would not expect bias toward any of the contrasts used in this study, as none would have spanned the boundary. Future research should consider the possibility that all boundaries may not be centered at 50%, as has been found in studies of emotional expressions in human faces (Fujimura, Matsuda, Katahira, Okada, & Okayona, 2012), and adjust the proportions used accordingly.

In conclusion, the current findings demonstrate sensitivity to a discrete boundary between animal types early in infancy. This research extends previous knowledge of infant categorical perception by demonstrating the nature of boundaries between them. Such knowledge of category relationships early in life could lead to a greater understanding of the concepts we possess as adults that allow us to mentally organize and expertly respond to the world around us.

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Appendix

Step 1: Addressing the identity confound

To determine whether infants show dichotomous perception of a boundary between two categories it is necessary to create a continuum from 100% of animal type A to 100% of

animal type B. Similar research on face categorization by adults has done this by beginning with two images and using morphing software to create the continuum (e.g., Campanella, Chrysochoos, & Bruyer, 2001; Capozza, Boccato, Andrighetto & Falvo, 2009; Walker & Tanaka, 2003). For example, two images of a single actress would be used: one when she is happy and one when she is angry. This allows a continuum from happiness to anger to be created where emotion expression is the only characteristic changing across the continuum.

However, alterations to the procedure described are necessary to create a continuum between animal types that does not confound type of animal with identity (please see Bülthoff & Newell, 2004 for a discussion of a similar issue when a continuum is created based on sex in humans). In other words, if an image of one cat (Whiskers) and one dog (Fido) generated the continuum, then there are two completely confounded characteristics changing across the spectrum; identity (Whiskers/Fido) and animal type (Cat/Dog). In the given example, it is impossible to separate effects of the two factors; thus, findings would be ambiguous. Ideally, one would remove the change in identity by using a single individual (as in the case of emotions). However, as no individual can simultaneously be both a cat and a dog, this is not a possibility when it comes to types of animals. Instead, we ruled out the effects of identity by generating an equivalent identity change in both types of image pairs used in the current study (between-category and within-category). See the following section for details on how this was achieved. If infants were responding solely to the change in identity, they should not have exhibited a difference in look durations to between- versus within-category image pairs because the change in identity was equivalent in the two cases. In contrast, because infants looked longer to between-category than within-category image pairs, it suggests that infants were responding to category changes rather than identity changes.

It is critical to note that the multiple exemplars of each type of animal were used by the morphing procedure in such a way that overall changes in composition were still equated between contrast types. In other words, the physical differences between the images in the between-category pair were the same as the differences in the within-category pairs (see steps 6 and 7 below for validation of this claim).

Step 2: Choosing exemplars

Cat images came from a database (Zhang, Sun, & Tang, 2008) and dog images were found through a Google image search. We selected animal images with forward facing eyes and predominantly solid skin color.

Step 3: Sorting into groups

A total of 16 images of different cats and dogs were used in Experiment 1 and were sorted into groups. For example, the images below constituted one image group. This group will demonstrate stimulus creation in the following steps.

Step 4: Morphing

Morphs were created for each stimulus set using FantaMorph using 73 points placed around the face, eyes, nose, and mouth as shown below.

The morphing software allows the user to export images at any point in the spectrum 0% image A (100 % image B) to 100% image A (0% image B). Recall from step 1, that the identity confound needed to be addressed. This was accomplished by generating a composite cat and a composite dog. The composite images were made by morphing Cat 1 with Cat 2 and Dog 1 with Dog 2 for a given stimulus set and using the resulting 50% image to generate the final morphs.

Each infant saw four morphed images. The table below details which images are morphed to create each image.

	Morphed images		Resulting Image
Within-category image pair	Cat 1	Dog 1	60% Cat/40% Dog
	Cat 1+2	Dog 1+2	80% Cat/20% Dog
Between-category image pair	Cat 2	Dog 2	60% Cat/40% Dog
	Cat 1+2	Dog 1+2	40% Cat/60% Dog

Step 5: Remove external features, clean images, and apply filter

Images used in the study were cleaned using Adobe Photoshop. Any distracting blemishes or shadows were removed from all images, they were cropped to an identical oval, and a

black and white filter was applied to give the appearance of even skin tone. The images below are examples from a majority cat condition in Experiment 1. The two images on the left are an example of a within-category image pair, the images on the right are a between-category image pair. Their compositions from left to right are 80% Cat/20% Dog, 60% Cat/40% Dog, 60% Cat/40% Dog, and 40% Cat/60% Dog.

Step 6: Validation by composition

Figure A1 demonstrates the fact that composition changes were equated between the between-category and within-category image pair.

Step 7: Validation by pixel and color analysis

Pixel change and color change analysis conducted by the software program ImageDiff 1.0.1 (www.ionForge.com) further validates the equality of changes in the contrast types. Across all stimulus sets, the average percentage of pixels changed between images did not differ systematically between the between-category ($M = 72.20\%$, $SD = 1.92$) and the within-category ($M = 71.86\%$, $SD = 1.63$) image pairs, [$t(30) = 0.54$, $p = .59$, $d = .19$]. Furthermore, across all stimulus sets, the average change in color did not differ between the between-category ($M = 5.88$, $SD = 1.51$) and within-category ($M = 6.07$, $SD = 1.75$) image pairs, [$t(30) = -0.31$, $p = .73$, $d = 0.13$].

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Figure 1.

Sample cat/dog images shown to participants. The labels were not visible to participants. The within-category image pair contains two images that are predominantly cat (greater than 50%): the image on the left is 60% cat and the one on the right is 80% cat. The between-category image pair contains one image that is predominantly dog (less than 50% cat) and one predominantly cat (greater than 50% cat): the image on the left is 40% cat and the one on the right is 60% cat. The examples shown depict cases in which three of four of images were predominantly cat. Half of the infants were tested with such images; the other half were tested with image sets in which three of four images were predominantly dogs.

Figure 2.

Box and whisker plots showing the distribution of proportion preference scores for the between-category image pair in Experiments 1, 2 and 3.

Figure 3.

Sample cow/otter images shown to participants. The labels were not visible to participants. The within-category image pair contains two images that are predominantly otter (greater than 50%): the image on the left is 60% otter and the image on the right is 90% otter. The between-category image pair containing one image that is predominantly cow (less than 50% otter) one predominantly otter (greater than 50% otter): the image on the left is 30% otter and the one on the right is 60% otter. The examples shown depict cases in which three of four of images were predominantly otter. Half of the infants were tested with such images; the other half were tested with image sets in which three of four images were predominantly cows.

Figure A1.

Pie charts depict image compositions (left and center panels). Bar graphs quantify changes across images of each image pair type (right panels). Note that the changes in composition of each dimension (cat 1, cat 2, dog 1, and dog 2) have been equated across the two image pair types. Only values for the majority cat condition in Experiment 1 are depicted above. Majority dog condition images in Experiment 1 and majority cow and otter conditions in Experiment 2 were created in an identical manner and followed the same pattern.

Table 1

Mean total fixation duration (sec) to each image pair type summed across all presentations.

	Between-Category Image Pair (s)	Within-Category Image Pair (s)
Condition	<i>M</i> (<i>SE</i>)	<i>M</i> (<i>SE</i>)
<u>Experiment 1</u>		
Cat/Dog, Upright	9.62 (0.84)	8.69 (0.89)
<u>Experiment 2</u>		
Cow/Otter, Upright	18.13 (1.63)	17.11 (2.00)
<u>Experiment 3</u>		
Cat/Dog, Inverted	8.53 (0.81)	7.52 (0.72)
Cow/Otter, Inverted	12.74 (1.34)	13.59 (1.49)