



2016

Categorical Perception of Species in Infancy

Hannah B. White

University of Kentucky, hannah.white@uky.edu

Digital Object Identifier: <http://dx.doi.org/10.13023/ETD.2016.258>

[Click here to let us know how access to this document benefits you.](#)

Recommended Citation

White, Hannah B., "Categorical Perception of Species in Infancy" (2016). *Theses and Dissertations--Psychology*. 90.
https://uknowledge.uky.edu/psychology_etds/90

This Master's Thesis is brought to you for free and open access by the Psychology at UKnowledge. It has been accepted for inclusion in Theses and Dissertations--Psychology by an authorized administrator of UKnowledge. For more information, please contact UKnowledge@lsv.uky.edu.

STUDENT AGREEMENT:

I represent that my thesis or dissertation and abstract are my original work. Proper attribution has been given to all outside sources. I understand that I am solely responsible for obtaining any needed copyright permissions. I have obtained needed written permission statement(s) from the owner(s) of each third-party copyrighted matter to be included in my work, allowing electronic distribution (if such use is not permitted by the fair use doctrine) which will be submitted to UKnowledge as Additional File.

I hereby grant to The University of Kentucky and its agents the irrevocable, non-exclusive, and royalty-free license to archive and make accessible my work in whole or in part in all forms of media, now or hereafter known. I agree that the document mentioned above may be made available immediately for worldwide access unless an embargo applies.

I retain all other ownership rights to the copyright of my work. I also retain the right to use in future works (such as articles or books) all or part of my work. I understand that I am free to register the copyright to my work.

REVIEW, APPROVAL AND ACCEPTANCE

The document mentioned above has been reviewed and accepted by the student's advisor, on behalf of the advisory committee, and by the Director of Graduate Studies (DGS), on behalf of the program; we verify that this is the final, approved version of the student's thesis including all changes required by the advisory committee. The undersigned agree to abide by the statements above.

Hannah B. White, Student

Dr. Ramesh Bhatt, Major Professor

Dr. Mark Fillmore, Director of Graduate Studies

CATEGORICAL PERCEPTION OF SPECIES IN INFANCY

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Arts and Sciences
at the University of Kentucky

By

Hannah B. White

Lexington, KY

Director: Dr. Ramesh Bhatt, Professor of Psychology

Lexington, KY

2016

Copyright © Hannah B. White 2016

ABSTRACT OF THESIS

CATEGORICAL PERCEPTION OF SPECIES IN INFANCY

Although there is a wealth of knowledge on categorization in infancy, there are still many unanswered questions about the nature of category representation in infancy. For example, it is yet unclear whether categories in infancy have well-defined boundaries or what knowledge about species categories young infants have before entering the lab. Using a morphing technique, we linearly altered the proportion of cat versus dog in images and observed how infants reacted to contrasts between pairs of images that either did or did not cross over the categorical boundary. This was done while equating between-category and within-category similarity. Results indicate that infants' pre-existing categories of cats and dogs are discrete and mutually exclusive. Experiment 2 found that inversion caused a disruption in processing by 6.5- but not 3.5- month-old infants, indicating a developmental change in category representation. These findings demonstrate a propensity to dichotomize early in life that could have implications for social categorizations, such as race and gender. Furthermore, this work extends previous knowledge of infant categorical perception by demonstrating a priori knowledge of familiar species categories and the boundaries between them.

KEYWORDS: Infant Development, Categorical Perception, Visual Perception, Species Perception

Hannah Burgess White

May 16, 2016

CATEGORICAL PERCEPTION OF SPECIES IN INFANCY

By

Hannah B. White

Dr. Ramesh Bhatt
Director of Thesis

Dr. Mark Fillmore
Director of Graduate Studies

May 16, 2016

TABLE OF CONTENTS

List of Tables	v
List of Figures	vi
Chapter One: Introduction	1
Chapter Two: Experiment One	8
Method	8
Participants.....	8
Stimuli.....	9
Apparatus and Procedure.....	10
Results and Discussion	12
Chapter Three: Experiment Two	20
Method	20
Participants.....	20
Stimuli, Apparatus, and Procedure	21
Results and Discussion	21
Chapter Four: General Discussion	23
References.....	28
Vita.....	33

LIST OF TABLES

Table 2.1, Composition of the Stimuli used in Experiments 1 and 2	14
Table 2.2, Composition of high-within and low-within images presented on a within-species contrast trial	15
Table 2.3, Composition of low-within and across images presented on a between-species contrast trial.....	16

LIST OF FIGURES

Figure 2.1, Rectangular images depict original images.....	17
Figure 2.2, Double sided arrows denote boundaries crossed between images.....	18
Figure 2.3, Sample stimuli shown to participants.....	19

Chapter One:

Introduction

Imagine you are confronted with a large, brown, hairy animal. What do you do? Your reaction would most likely differ depending on how you categorize the new stimulus. If you classify it as a bear, you may try to hide. If you classify it as a dog, you may try to take it home with you. This is one, exceedingly oversimplified, example of how categories are essential in everyday life. By knowing a novel object's category membership, an individual can automatically apply his or her previous knowledge of the category without further investigation. The immediate availability of information is just one illustration of how categories are beneficial for mental economy and rapid responding. The human propensity to categorize is also an important factor impacting many, if not all, forms of out-group bias. One example is racial bias, which is evident in various contexts, ranging from teacher expectations of students (McKown & Weinstein, 2008) to police officers deciding whether or not to use deadly force (Cano, 2010).

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). For example, 5-month-olds form categories representative of 3-dimensional objects (Mash & Bornstein, 2012), and 10- and 3.5-month-olds form categories based on spatial relationships regarding fit (inside/outside; Casasola & Cohen, 2002) and position (above/below; Quinn, 1994), respectively. Evidence of categorization has also been found with social stimuli, specifically human faces. Bornstein and Arterberry (2003) found evidence for categorization of emotional facial expressions as early as 5 months of

age. Furthermore, infants categorize human faces based on race by 9 months of age (Anzures et al., 2010). The current study focused on species categories because, as will be discussed below, they offer unique benefits as basic level categories that are both biologically discrete and socially relevant.

Despite the fact that there is a wealth of knowledge on categorization in infancy, there are still many unanswered questions about the nature of category representation in infancy. For example, how do species categories in infancy, once formed, relate to one another? Are they discrete and mutually exclusive, reflecting the state of the world, or is there perceptual overlap? What knowledge about species categories do young infants have before entering the lab? To answer these questions, we developed a spontaneous visual preference procedure using morphed images. This allowed us to examine category knowledge without training in the lab, control for perceptual differences between stimuli, and test whether species categories in infancy have definite boundaries.

Species categories provide some unique benefits when studying categorization. First they are biologically mutually exclusive, but they also have a good deal of perceptual overlap. In essence, this means that for a category structure of a species to reflect underlying biology it must be discrete. A single animal cannot be a member of multiple species categories. Even hybrids of two species, such as mules, are not considered to hold dual category membership. However, given the perceptual similarities between certain species, such as cats and dogs, it is conceivable that infants' representations of these species would be continuous rather than discrete. It is a tall order to assume that infants have learned that part of being a cat is not being a dog, so the boundaries between species may not be well-defined in infancy. Another advantage to

studying biological categories is that they are socially relevant. Humans interact with a great deal of plants and animals in their daily lives, thus accurate sensitivity to biological kinds would be adaptive.

Studying species categories is additionally beneficial in that they are basic level categories. 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). These categories are found to be the most quickly identified by adults (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). This highlights the importance of basic categories in cognition. They are thought to have an ideal balance of within-group similarity and between-group differences (Rosch, Simpson, & Miller, 1976). This means that members of these categories are readily grouped together and easily excluded from other categories.

One could argue that in the western culture, after humans, there are few to no species infants are exposed to more than cats and dogs. Given that fact, it is not surprising that infants have been found to categorize these species early in life. Quinn and Eimas (1996) found that 4-month-old infants formed a category of cats that excluded dogs. It should be noted, however, that the cited study used a familiarization-visual preference procedure. Indeed, the vast majority of research on categorization in infancy has used a familiarization procedure 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 pre-existing categories and the relationships between them. To begin addressing these constraints, we developed a new paradigm for testing categorical perception.

Critically, the new procedure sheds light on the relationships between categories in infancy. When considering category borders, two 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. By determining whether infants are sensitive to a sharp boundary between categories, it is possible to distinguish between these possibilities. If the categories are discrete and mutually exclusive, one would expect differences in performance on comparisons that cross the categorical boundary compared to those that do not. If the categories overlap, however, one would not expect such differences.

Studies attempting to differentiate between discrete and continuous categorization have been conducted in many areas of research, including language and color perception. Hu and colleagues (2014) found that when color category membership is linearly manipulated, adults' response times are slower with comparisons that are within a category (as defined by a word label) compared to those that cross the categorical

boundary. Test stimuli were square patches of color, and adults' same/different judgments between two different shades of green took longer than contrasts between a green and blue shade. This occurred in spite of the fact that the physical difference between the two green shades was the same as the difference between the green and the blue shade, meaning that the discrepancy in response times can be attributed to a salient, discrete, category boundary. Similarly, evidence of categorical perception of hue was found in 4-month-old infants using a dishabituation paradigm (Bornstein, Kessen, & Weiskopf, 1977). Infants showed greater dishabituation to hues from novel categories compared to the familiar category even when the differences in wavelength were equated. This demonstrates discrete category structures early in life. Evidence of discrete category boundaries in infancy could shed light on social issues surrounding false dichotomization. Namely, if infants show a predisposition for dichotomizing categories (as adults do, incorrectly, with race and gender), even when stimuli are altered continuously, it may be possible to develop early interventions that promote more flexible and continuous social category representations.

In the current study, we linearly altered the proportion of cat versus dog in images and observed how infants reacted to contrasts between images that either did or did not cross over the categorical species boundary. Specifically, we examined whether infants looked longer at a pair of images from different categories than a pair from the same category. The linear manipulation enabled us to equate visual differences in the two contrast types. If infants exhibited an attentional bias to between-species contrasts compared to within-species contrasts, it would be evidence of a salient categorical boundary. Such a finding would suggest that infants treat species categories as discrete

and mutually exclusive. Recall that in the habituation/visual preference paradigm typically used in infant categorization studies, the critical test is based on a novelty preference for an image from category B after being exposed to category A exemplars. 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 cat will be perceptually more dissimilar to a dog than two dogs are to each other. This means that infants could show a novelty preference for the cat based on low-level similarity without being sensitive to the discrepancies between categories. By using morphing techniques in this study we removed this obstacle. Visual differences between image pairs that crossed the species boundary or stayed within a single species were equated. Thus, any preferences observed cannot be explained by differences in within-category versus between-category similarity.

We were additionally interested in examining infants' pre-existing category knowledge. The habituation period in the habituation/visual preference procedure discussed above could serve as a learning period for the infants (Quinn & Eimas, 1996). We wanted to determine if infants formed discrete categories of cats and dogs without priming or training in the laboratory. If so, it would indicate either that infants' early experience with these species is sufficient to form such categories, or there is something about biological categories that predispose humans to group them systematically. To examine this issue, a spontaneous preference procedure, with no familiarization, was used in this study. While Quinn and Eimas (1996) documented species categories by 4 months of age using the habituation/visual preference procedure discussed above, infants in that study could have learned the category during familiarization. Thus, it is yet unclear

whether infants have pre-existing categories for cats and dogs. Given that, we used a spontaneous preference procedure to test 3.5- and 6.5-month-old infants in Experiment 1 with morphed, upright images of combinations of cats and dogs.

Additionally, Experiment 2 was conducted with inverted images to examine possible effects of expertise. Disruptions in perception caused by inverting images are typically explained by familiarity or expertise. For example, Yin (1969) demonstrated that the impact of inverting stimuli on adults' performance in discrimination tasks was greater for human faces than analogous houses. As inverting images does not remove low-level information, this effect is attributed to humans being expert processors of upright human faces. An impaired ability to perceive discrete category boundaries in the inverted condition, but not in the upright, would indicate category knowledge beyond low-level perceptual features.

Chapter Two:

Experiment 1

Experiment 1 assessed the sensitivity of 3.5- and 6.5-month-olds to the categorical boundary between cats and dogs. This was done using a spontaneous visual preference procedure to ensure that experience in the lab did not impact performance. Infants were shown two images at a time that differed systematically in the proportion of cat or dog. In one pair, the images spanned the 50% cat/dog category boundary (40%Cat/60%Dog and 60%Cat/40%Dog), while in the other pair, both images were within the same category (60%Cat/40%Dog and 80%Cat/20%Dog). If infants looked longer at image pairs that differed in category membership than those that belonged to the same category, in spite of the fact that the images' compositional differences were equal in magnitude in the two pairs, it would be evidence of a discrete categorical boundary.

Method

Participants. Sixteen 3.5-month-olds (mean age = 108.00 days, $SD = 9.05$; 8 female) and 16 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. Three additional 3.5-month-olds participated but their data were excluded due looking to the stimuli for less than 20% of the duration of the study ($n=1$), equipment failure ($n=1$), or being an outlier on the dependent measure ($n=1$, more than $1.5 \times IQR$ below the 25th quartile). Data from three 6.5-month-olds were excluded for looking for less than 20% of the study duration ($n=1$), failing to look on a test trial ($n=1$), or being an outlier on the dependent measure ($n=1$). Participants in this study were recruited from birth announcements and the local hospital, and were predominantly from middle-class, Caucasian families.

Stimuli. Eight images of cats and eight images of dogs were used in this study. Dog images were obtained through a Google Image search and cat images came from an image bank (Zhang, Sun, & Tang, 2008). All images had predominantly solid coloring and forward facing eyes. Using FantaMorph software, three types of images were created with varying proportions of cat and dog characteristics.

The cat/dog percentages outlined in Table 1 were selected as they resulted in equal changes in image composition from across-species to low-within species images (between-category contrasts) and from low-within to high-within species images (within-category contrasts). Thus, between-category similarity and within-category similarity were equated.

Minor editing was done using Adobe Photoshop. Morphed images were cropped to an oval (12.42 cm x 14.25 cm) to equate for differences in face shape, and a black and white filter was applied to give the appearance of even coloring. Slight touch-ups were made to reduce variability in image clarity and brightness. Any distracting blemishes or shadows were removed.

Previous morphing studies have typically started with two images (e.g., pictures of two different individuals, or the same individual displaying two different emotions) when creating stimuli (e.g., Campanella, Chrysochoos, & Bruyer, 2001; Capozza, Boccato, Andrighetto & Falvo, 2009; Walker & Tanaka, 2003). If one were to apply the same process to the current research question and morph a single cat (“Fluffy”) with a single dog (“Fido”), a potential confound is introduced. Specifically, the transition from 40% to 60% crosses the 50% species boundary (half cat/half dog), but also an individual boundary at 50% between the identities of the animals used (half “Fluffy”/ half “Fido”).

In other words, the between-species contrast crosses two boundaries (identity and species) and the within-species contrast crosses none. Thus, if infants were to exhibit an attentional bias toward the between-species contrast compared to the within-species contrast, it would not be possible to ascertain whether this is due to crossing a boundary between categories, identities, or both.

Given that there is no way to remove the identity boundary from the between species contrast (one individual cannot be both a cat and a dog), an identity boundary was added to the within-species contrast by using multiple exemplars of each species, see Figure 1. That is, now both the within-species contrast and the between-species contrast include an identity boundary, see Figure 2. Thus, differences in look duration to the between-species versus within-species contrasts cannot be attributed to identity boundaries, only to category boundaries. At the same time, the changes in image composition between the stimuli were kept consistent in the two contrast types (see Tables 2 and 3). The important thing to note is that the far right columns (detailing changes in image composition) are identical in Tables 2 and 3. This ensured that any preference for one pair over another was not a function of the dissimilarities between the images in each pair, as the degree of differences was equated.

Apparatus and Procedure. During the study, infants were seated 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 the infant's looking patterns. Infants were tested on 4 trials, each 8 s long. A trial consisted of two images displayed side by side on a grey background, see Figure 3. For two test trials, the across image (e.g., 40% cat) and a low-within image (e.g., 60% cat)

were paired. This is the between-species contrast. The remaining trials were within-species contrasts where a low-within image (e.g., 60% cat) was paired with the high-within image (e.g., 80% cat). The left/right location of the low-within face on the first trial, type of first trial (between-species contrast or within-species contrast), and majority species condition (cat or dog) were counterbalanced across infants. For each infant, trial type switched from trial 1 to trial 2, and the pattern reversed for trials 3 and 4. For example, if an infant's trial 1 was a between-species contrast, trial 2 would be a within-species contrast, trial 3 would be a within-species contrast, and trial 4 would be a between-species contrast. 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. After the infant's attention was centered on the screen, 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. The average accuracy of this eye tracking 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 the other 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.

Before starting data collection, each infant's eyes were calibrated using a 5-point infant calibration procedure in which a 23.04 cm² red and yellow rattle coupled with a rhythmic sound was presented 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. Eye-tracker calibration and stimulus presentation were controlled by Tobii Studio 3.3.1 software (Tobii Technology AB; www.tobii.com). An I-VT fixation filter was used to remove noise from the data.

Areas of interest (AOIs) were defined around each face included in the contrast, as shown in Figure 3. 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 (sum of all looks exceeding 60 ms while remaining within a 0.5° radius) to both AOIs for each type of stimulus (between-species contrast, within-species contrast). Similar criteria pertaining to fixation duration are often used in infant eye-tracking studies (e.g., Hunnius, de Wit, Vrins, & von Hofsten, 2011; Papageorgiou et al., 2014; Xiao et al., 2014; Xiao et al., 2015).

Results and Discussion

Prior to participating in the study, parents were asked to report on the presence of cats and/or dogs in the home. Four 3.5-month-olds and eight 6.5-month-olds lived with dogs only, two 3.5-month-olds and four 6.5-month-olds lived with a cat only, and two 3.5-month-olds and one 6.5-month-old 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 a pet in the home on performance.

The dependent measure was the proportion of fixation duration to the between-species contrast trials. This was calculated by summing fixations to AOIs (each face in the contrast, see Figure 3) during both between-species contrast trials and dividing this number by fixations to all AOIs across all trials. An independent samples *t*-test indicated no effect of age group, $t(30) = 0.07, p = .948, d = 0.02$. A one-sample *t*-test was conducted comparing proportion fixation duration to the between-species contrast trials ($M = 53.69\%, SE = 1.12$) to chance (50%). Infants fixated proportionally longer to between-species stimuli than chance, $t(31) = 3.27, p = .003, d = 0.58$. To ensure that 3.5-month-olds' performance was not being artificially inflated by being combined with the older age group, data from each age group were also analyzed separately. Proportion fixation duration to the between-species contrast trials differed significantly from chance at both 3.5 months [$M = 53.76, SE = 1.71; t(15) = 2.20, p = .044, d = 0.55$] and at 6.5 months [$M = 53.61, SE = 1.53; t(15) = 2.36, p = .032, d = 0.59$]. Thus, both 3.5-month-olds and 6.5-month-olds looked longer at stimuli during the between-species category trials than during the within-species category trials, even though each type of contrast was equated in the degree of differences between the stimuli. This indicates that infants' pre-existing knowledge of cats and dogs includes a discrete category boundary even by 3.5 months of age.

Table 2.1

Composition of the Stimuli used in Experiments 1 and 2

Image Type	Percent Species A	Percent Species B	Overall Category of Image (based on greater than 50% of category)
Across Species	40	60	B
Low-Within Species	60	40	A
High-Within Species	80	20	A

Table 2.2

Composition of high-within and low-within images presented on a within-species contrast trial

Dimension	High-Within Image (80% Cat/20% Dog*)	Low-Within Image (60% Cat/40% Dog)	Compositional change between images
Cat 1	40%	60%	20%
Cat 2	40%	0%	40%
Dog 1	10%	40%	30%
Dog 2	10%	0%	10%

*The values depicted represent a majority cat condition. Percentages were swapped for majority dog conditions (i.e., 80% Dog/20% Cat).

Table 2.3

Composition of low-within and across images presented on a between-species contrast trial

Dimension	Low-Within Image (60% Cat/40% Dog*)	Across Image (40% Cat/60% Dog)	Compositional change between images
Cat 1	0%	20%	20%
Cat 2	60%	20%	40%
Dog 1	0%	30%	30%
Dog 2	40%	30%	10%

*The values depicted represent a majority cat condition. Percentages were swapped for majority dog conditions (i.e., 80% Dog/20% Cat).

Figure 2.1 Rectangular images depict original images. Oval images depict morphed stimuli that were presented to participants. Every image shown to the infants had a different majority identity. This means that both types of contrast (across versus low-within and low-within versus high-within) crossed identity boundaries, but only one contrast (across to low-within) crossed the species boundary.

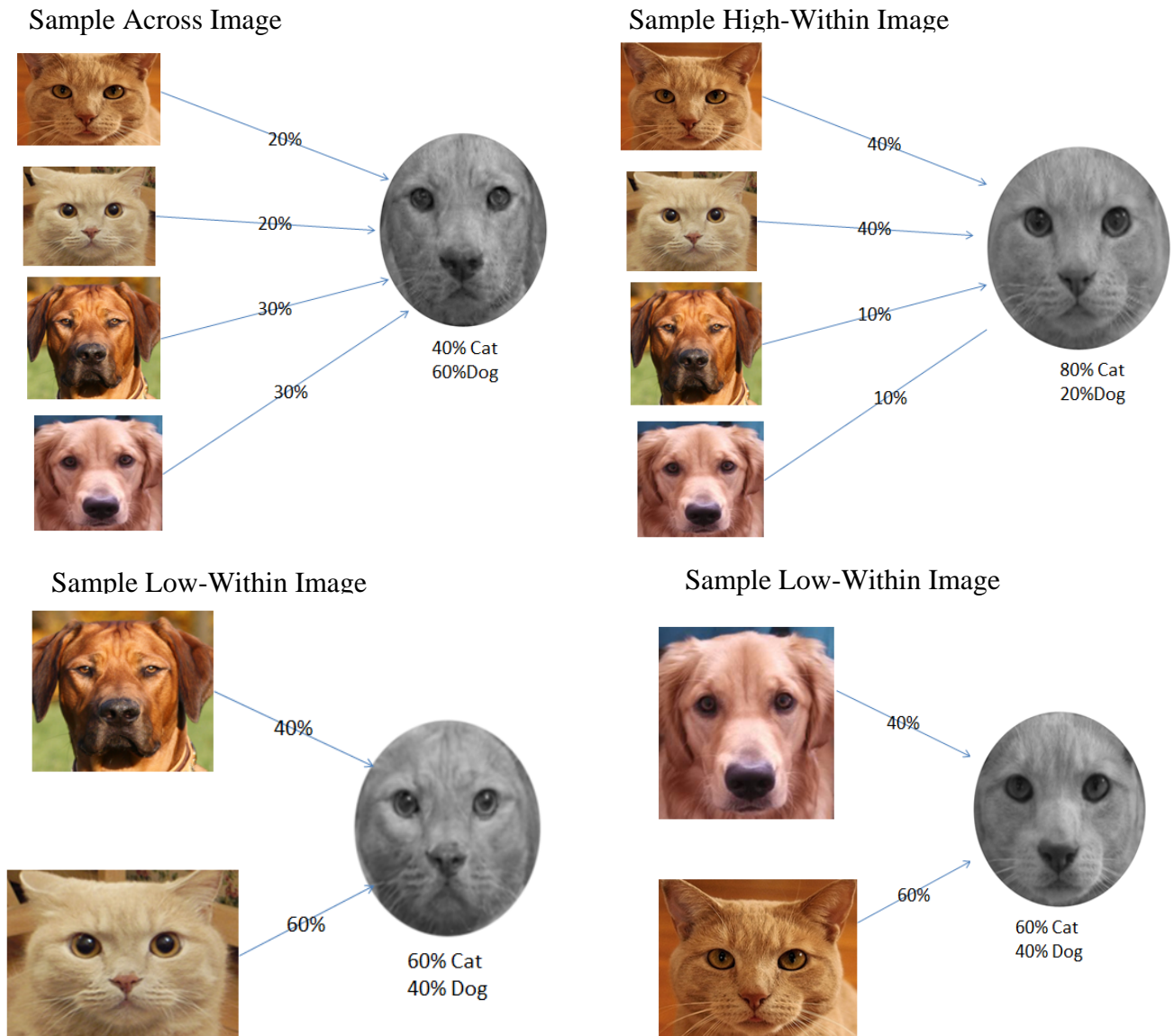


Figure 2.2 Double sided arrows denote boundaries crossed between images. Values below arrows depict changes of each contributing exemplar between images in the indicated direction.

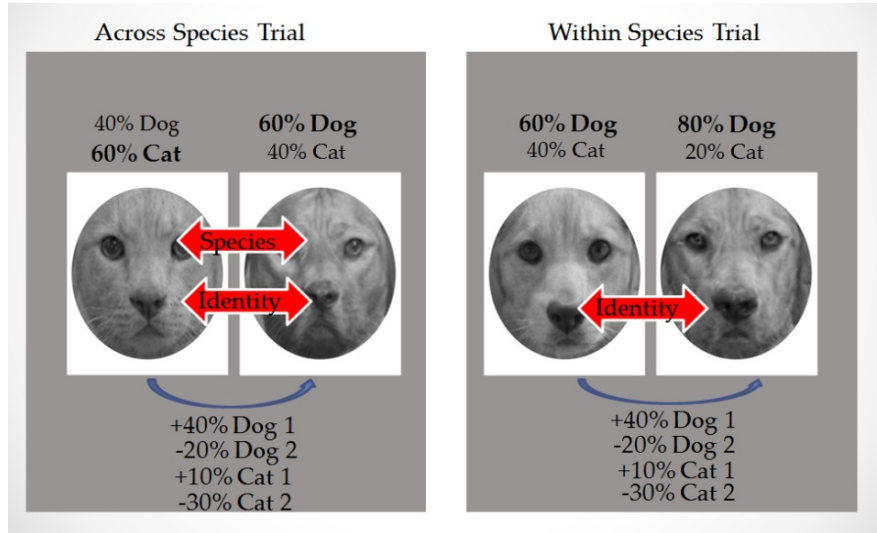
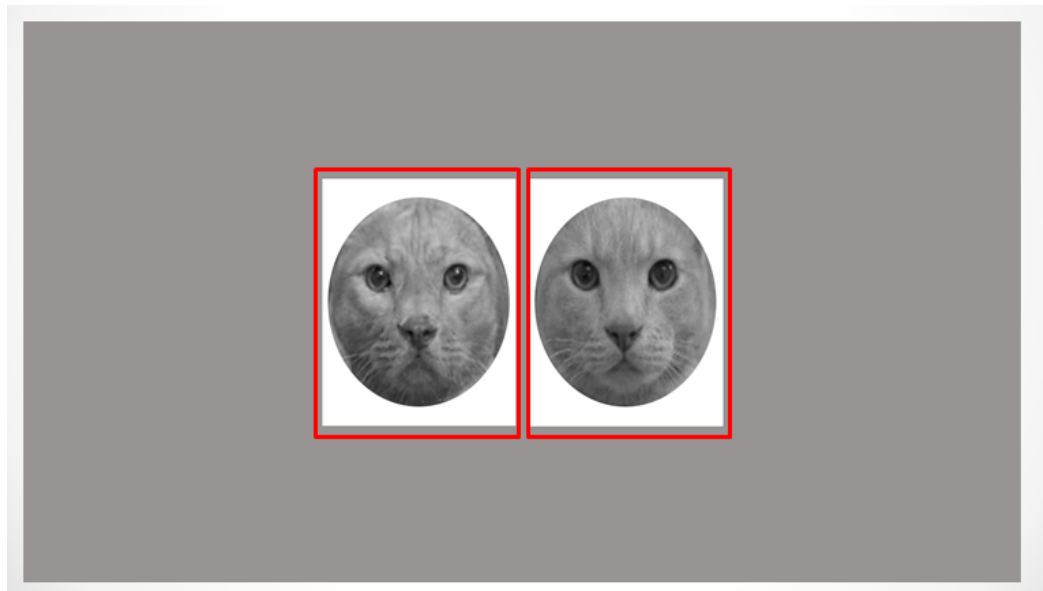


Figure 2.3. Sample stimuli shown to participants. Rectangles imposed on images depict areas of interest (AOIs) used in data collection. These were not visible to infants during test.



Chapter Three:

Experiment 2

Experiment 2 was conducted identically to Experiment 1 except all images were flipped vertically. Inversion conditions are commonly used in infant cognition studies to examine the role of experience or expertise (Yin, 1969). As all of the low-level features of an image are still present after inverting the image, an impaired ability to discriminate between stimuli when they are inverted compared to when they are upright is thought to indicate specialized processing of that type of stimulus (Hayden et al, 2007; Pascalis, Demont, de Haan, & Campbell, 2001; Zieber et al, 2010). Thus, a failure by infants to exhibit differential looking to between-species category versus within-species category stimulus contrasts in this experiment would indicate that the category sensitivity exhibited in Experiment 1 was driven by more than just low-level perceptual information.

Method

Participants. Sixteen 3.5-month-olds (mean age = 103.75 days, $SD = 9.21$; 9 female) and 16 6.5-month-olds (mean age = 195.00 days, $SD = 9.32$; 7 female) successfully completed the study and were included in the final sample. Two additional 3.5-month-olds participated but were excluded for not looking during at least one test trial ($n=1$) or sleeping ($n=1$). Three 6.5-month-olds were excluded for looking for less than 20% of the study duration. Participants in this study were recruited in the same manner as in Experiment 1, and they were predominantly from middle-class, Caucasian families.

Stimuli, Apparatus, and Procedure. The images used in Experiment 1 were flipped vertically. No additional changes were made. The same equipment and procedures were used as in Experiment 1.

Results and Discussion

The dependent measure was the proportion of fixation duration to between-species contrast trials. In the case of 3.5-month-olds, a one-sample t -test comparing proportion fixation duration to the between-species contrast trials ($M = 54.58\%$, $SE = 2.01$) to chance (50%) found that infants fixated proportionally longer on between-species contrast trials than chance [$t(15) = 2.28$, $p = .038$, $d = 0.57$]. Thus, 3.5-month-olds' performance on inverted stimuli in this experiment was similar to their performance on upright stimuli in Experiment 1, indicating that their performance was not impacted by inversion. However, 6.5-month-olds' proportion of fixation duration to between-species contrast trials ($M = 52.86\%$, $SE = 7.36$) did not significantly differ from chance [$t(15) = 1.56$, $p = .140$, $d = 0.39$]. Furthermore, 12 out of 16 3.5-month-old infants proportion fixation to between-species contrast trials was above chance (binomial $p = .040$), as compared to only 8 out of 16 (binomial $p = .500$) for 6.5-month-old infants. Thus, unlike 3.5-month-olds, 6.5-month-olds' performance was impaired by stimulus inversion. This finding indicates that there is a level of expertise impacting 6.5-month-olds' categorical perception of cats and dogs. Namely, the fact that infants only show a preference for the between-species contrast when images are upright, in spite of the fact that all features are still present in the inverted condition, suggests category knowledge beyond perceptual features. However, an independent samples t -test indicated no effect of age group [$t(30) =$

0.63, $p = .533$, $d=.22$]. Thus, caution must be exercised when interpreting a developmental change.

Chapter 4:

General Discussion

In this study, it was found that by 3.5 months of age infants' representations of cat and dog categories include a discrete boundary. Infants looked longer at image pairs that crossed the categorical species boundary than at those that remained within one species category, in spite of the fact that within-category and between-category similarity was equated. This replicates the finding that infants can form categories for cats and dogs (Quinn & Eimas, 1996). Furthermore, this finding extends previous work by demonstrating that species categories in infancy are discrete, rather than continuous, and that infants possess these categories without any form of priming or training in the lab. Finally, by 6.5-months of age the documented discrete category perception of cats and dogs involves some amount of expertise or specialized processing, as shown by the disruption in processing caused by inversion in Experiment 2. In contrast, 3.5-month-olds performed similarly on both upright and inverted images.

This study demonstrates that infants are able to form discrete representations of biological kinds before acquiring language to label such categories. As the number and variety of exemplars of cats and dogs 3.5-month-old infants are likely to be exposed to is very limited, this suggests that little to no experience, and no explicit training, is necessary to form rigid category structures. Such a propensity to dichotomize early in life 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). It is possible that this early knowledge of sex categories contains a discrete boundary. Given trends in society to move toward a more continuous representation of gender, one can imagine that rigid mental representations of sex could become problematic, given that it is not always correlated with gender.

This work also suggests a developmental change in category knowledge within the first half of the first year of life. This could be a form of perceptual narrowing driven by 6.5-month-olds' increased exposure to animals in their upright orientations. As noted by Cashon and Cohen (2004), who documented the onset of inversion effects to the integral processing of faces between 4 and 7 months of age, it is plausible that 3.5-month-olds are spending more time in positions that allow them to see faces in varied locations than 6.5-month-olds (who are possibly sitting or crawling, meaning their exposure to faces is more often in upright orientations). Another possibility is that the younger infants do not have enough experience with cats or dogs (regardless of orientation) to develop specialized processing. It is also conceivable that infants are undergoing a shift in the content of their categories for cats and dogs between the age groups in this study. Namely, rather than containing exclusively perceptual information (such as size and color), 6.5-month-olds category knowledge could include conceptual information (such as "thing that bites") that may be more sensitive to disruption by inversion. Regardless of mechanism, this change highlights the fact that category perception is rapidly changing in infancy.

A limitation of this study is that we were unable to examine the role of experience in discrete category formation. While it is likely that every infant in the study was exposed to cats or dogs in some capacity before participating, regardless of whether they

live with them, one cannot be sure what role this exposure played in their performance. As it is difficult to assign participants levels of exposure to cats and dogs in their daily lives, another avenue for examining the impact of experience is to use novel species categories that infants are unlikely to have seen. If infants display sensitivity to discrete category boundaries between species they have no experience with, it would seem that humans are predisposed to organize the world of biological kinds into discrete categories with definite boundaries between species.

It is possible that during this study infants were weighing certain features more than others. For example, if the cat category representation in infancy included a critical feature such as “short-nose,” the decision regarding the presence or absence of the feature may be digital. In this example, there could be a sharp break between what would be considered a “short-nose” indicating cat, and what would be considered a “long-nose,” indicating dog. Thus, while the morphing procedure used in this study does not differentially weight features, judgments based on critical features would also yield the same pattern of results. However, there is evidence to suggest that young children respond based on overall similarity judgments rather than specific dimensions. For example, research has indicated that even preschoolers treat separable dimensions, such as hue and shape, as integral in sorting tasks and perform in ways predominated by total similarity (Kemler, 1983). Therefore, it is possible that infants respond to the overall similarity between images rather than the presence or absence of a critical feature.

A note to future researchers wishing to use this procedure is that failure to detect differences in attention to the between and within-species contrasts 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 40% and 60%. To our knowledge, no research has investigated the location of the boundary between cats and dogs, 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 across species contrasts using these specific percentages. For example, if there was a discrete boundary exactly at 60% you would not expect bias toward either condition. Future research with this paradigm should consider the possibility that all boundaries may not be as centered, as has been found in studies of emotional expressions in human faces (Fujimura, Matsuda, Katahira, Okada, & Okayona, 2012), and adjust the proportions used accordingly.

It is worth noting that while the question of mental representations of categories (e.g., whether they involve prototypes or a list of exemplars) is of great interest to researchers (for review see, Murphy, 2002), it can be separated from the question of relationships between categories. The current study was concerned with the borders between categories, not the exact nature of their representations. In other words, regardless of whether the categories of cat and dog possessed by the infant are represented by exemplars (multiple specific examples) or prototypes (a summary or single “best case”), they either have a discrete border between them or they do not. One way to conceptualize this border is that it is based on dichotomous decisions regarding category membership based on distance in cognitive space. This applies equally well to categories represented by prototypes as by exemplars. Thus, the findings of this study are consistent with either theory of mental representations of categories.

Future research should apply this procedure to socially relevant category structures. This could lend insights into questions about the categorization of humans as a

species, or the false dichotomization of racial categories and gender. It will also be important to examine category structures at subordinate and superordinate levels. Given the primacy of basic level category perception in adults and children, it is possible that categories at lower and higher levels dichotomize later in development or are qualitatively different.

In conclusion, the current findings demonstrate a discrete boundary between the categories of cat and dog early in infancy. Furthermore, this work extends previous knowledge of infant categorical perception by demonstrating a priori knowledge of familiar species categories and the boundaries between them. This 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.

References

- Anglin, J. M. (1977). *Word, Object, and Conceptual Development*. New York: W. W. Norton.
- Anzures, G., Quinn, P.C., Pascalis, O., Slater, A.M., & Lee, K. (2010). Categorization, categorical perception, and asymmetry in infants' representation of face race. *Developmental Science*, 13(4), 553-564.
- Bornstein, M.H., & Arterberry, M.E. (2003). Recognition, discrimination and categorization of smiling by 5-month-old infants. *Developmental Science*, 6(5), 585-599.
- Bornstein, M.H., Kessen, W., & Weiskopf, S. (1977). The categories of hue in infancy. *Annual Progress in Child Psychiatry & Child Development*, 44-50.
- Brown, R. (1958). How shall a thing be called? *Psychological Review*, 65, 14-21.
- Burns, B. (1992). Perceived similarity in perceptual and conceptual development: The influence of category information on perceptual organization. In B. Burns, B. Burns (Eds.), *Percepts, concepts and categories: The representation and processing of information* (pp. 175-228). Oxford, England: North-Holland.
- Callanan, M.A. (1985). How parents label objects for young children: The role of input in the acquisition of category hierarchies. *Child Development*, 56, 508-523.
- Campanella, S., Chrysochoos, A., & Bruyer, R. (2001). Categorical perception of facial gender information: Behavioural evidence and the face-space metaphor. *Visual Cognition*, 8(2), 237-262.
- Cano, I. (2010). Racial bias in police use of lethal force in Brazil. *Police Practice & Research: An International Journal*, 11(1), 31-43.

- Casasola, M., & Cohen, L. (2002). Infant categorization of containment, support and tight-fit spatial relationships. *Developmental Science*, 5(2), 247-264.
- Cashon, C.H., & Cohen, L.B. (2004). Beyond U-shaped development in infants' processing of faces: An information-processing account. *Journal of Cognition and Development*, 5(1), 59-80.
- Fujimura, T., Matsuda, Y., Katahira, K., Okada, M., & Okanoya, K. (2012). Categorical and dimensional perceptions in decoding emotional facial expressions. *Cognition and Emotion*, 26(4), 587-601.
- Hayden, A., Bhatt, R.S., Reed, A., Corbly, C.R., & Joseph, J.E. (2007). The development of expert face processing: Are infants sensitive to normal differences in second-order relational information? *Journal of Experimental Child Psychology*, 97(2), 85-98.
- Hu, Z., Hanley, J.R., Zhang, R., Liu, Q., & Roberson, D. (2014). A conflict-based model of color categorical perception: Evidence from a priming study. *Psychonomic Bulletin & Review*, 21(5), 1214-1223.
- Hunnus, S., de Wit, T.C., Vrins, S., & von Hofsten, C. (2011). Facing threat: Infants' and adults' visual scanning of faces with neutral, happy, sad, angry, and fearful emotional expressions. *Cognition and Emotion*, 25(2), 193-205.
- Jolicoeur, P., Gluck, M.A., & Kosslyn, S.M. (1984). Pictures and names: Making the connection. *Cognitive Psychology*, 16(2), 243-275.
- Kemler, D.G. (1983). Exploring and reexploring issues of integrality, perceptual sensitivity, and dimensional salience. *Journal of Experimental Child Psychology*, 36(3), 365-379.

- Kovack-Lesh, K.A., McMurray, B., & Oakes, L.M. (2014). Four-month-old infants' visual investigation of cats and dogs: Relations with pet experience and attentional strategy. *Developmental Psychology, 50*(2), 402-413.
- Madole, K.L., & Oakes, L.M. (1999). Making sense of infant categorization: Stable processes and changing representations. *Developmental Review, 19*(2), 263-296.
- Mandler, J.M. (1997). Development of categorisation: Perceptual and conceptual categories. In G. Bremner, A. Slater, G. Butterworth, G. Bremner, A. Slater, G. Butterworth (Eds.), *Infant Development: Recent Advances* (pp. 163-189). Hove, England: Psychology Press/Erlbaum (UK) Taylor & Francis.
- Mash, C., & Bornstein, M.H. (2012). 5-month-olds' categorization of novel objects: Task and measure dependence. *Infancy, 17*(2), 179-197.
- McKown, C., & Weinstein, R.S. (2008). Teacher expectations, classroom context, and the achievement gap. *Journal of School Psychology, 46*(3), 235-261.
- Murphy, G.L. (2002). Theories. In *The big book of concepts* (pp. 41-71). Cambridge, MA, US: MIT Press.
- Murphy, G.L., & Smith, E.E. (1982). Basic-level superiority in picture categorization. *Journal of Verbal Learning and Verbal Behavior, 21*(1), 1-20.
- Papageorgiou, K.A., Smith, T.J., Wu, R., Johnson, M.H., Kirkham, N.Z., & Ronald, A. (2014). Individual differences in infant fixation duration relate to attention and behavioral control in childhood. *Psychological Science, 25*(7), 1371-1379.
- Pascalis, O., Demont, E., de Haan, M., & Campbell, R. (2001). Recognition of faces of different species: A developmental study between 5 and 8 years of age. *Infant and Child Development, 10*(1-2), 39-45.

- Quinn, P.C. (1994). The categorization of above and below spatial relations by young infants. *Child Development*, 65(1), 58-69.
- Quinn, P.C., & Eimas, P.D. (1986). On categorization in early infancy. *Merrill-Palmer Quarterly*, 331-363.
- Quinn, P.C., & Eimas, P.D. (1996). Perceptual cues that permit categorical differentiation of animal species by infants. *Journal of Experimental Child Psychology*, 63(1), 189-211.
- Quinn, P.C., Yahr, J., Kuhn, A., Slater, A.M., & Pascalis, O. (2002). Representation of the gender of human faces by infants: A preference for female. *Perception*, 31(9), 1109-1121.
- Rosch, E., Simpson, C., and Miller, R.S. (1976). Structural bases of typicality effects. *Journal of Experimental Psychology: Human Perception and Performance*, 2, 491-502.
- Walker, P.M., & Tanaka, J.W. (2003). An encoding advantage for own-race versus other-race faces. *Perception*, 32(9), 1117-1125.
- Xiao, N.G., Quinn, P.C., Liu, S., Ge, L., Pascalis, O., & Lee, K. (2015). Eye tracking reveals a crucial role for facial motion in recognition of faces by infants. *Developmental Psychology*, 51(6), 744-757.
- Xiao, W.S., Quinn, P.C., Pascalis, O., & Lee, K. (2014). Own-and other-race face scanning in infants: Implications for perceptual narrowing. *Developmental Psychobiology*, 56(2), 262-273.
- Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology*, 81(1), 141.

Zhang, W., Sun, J., & Tang, X. (2008). Cat head detection - How to effectively exploit shape and texture features. *Proceedings from the European Conference on Computer Vision*, 4, 802-816.

Zieber, N., Bhatt, R.S., Hayden, A., Kangas, A., Collins, R., & Bada, H. (2010). Body representation in the first year of life. *Infancy*, 15(5), 534-544.

Curriculum Vitae

Hannah Burgess White

Education

B.S. Psychology, December 2014
Biology, May 2014
University of Kentucky
Magna Cum Laude

Professional Positions Held

Fall 2015 Research Assistant, Department of Psychology, University of Kentucky

Scholastic and Professional Honors

2015-2016 Research Challenge Trust Fund (RCTF) Travel Award
2015-2016 University of Kentucky Graduate School Travel Award
2014-2016 Lipmann Fellow

Professional Publications

Journal Articles

Bhatt, R.S., Hock, A., White, H., Jubran, R., Kangas, A. (2016). The development of body structure knowledge in infancy, *Child Development Perspectives*, 10(1), 45-52.

Heck, A., Hock, A., White, H., Jubran, R., & Bhatt, R.S. (in press). The development of attention to dynamic facial emotions. *Journal of Experimental Child Psychology*.

Hock, A., White, H., Jubran, R., & Bhatt, R.S. (2016). The whole picture: Holistic body posture recognition in infancy, *Psychonomic Bulletin & Review*, 23, 426-431.

Conference Posters

Hock, A., Jubran, R., White, H., & Bhatt, R.S. (2015). *Infants' Attention to Emotion in Bodies*. The Society for Research in Child Development, Philadelphia, PA. March 19-21, 2015. (poster presentation).

Hock, A., White, H., Jubran, R., & Bhatt, R.S. (2015). *Development of Body Representation in Infancy: Scanning of Specific Body Regions of the Different Sexes*. The Society for Research in Child Development, Philadelphia, PA. March 19-21, 2015. (poster presentation).

Hock, A., Jubran, R., White, H., & Bhatt, R.S. (2016). *Configural Face Processing in Newborn Infants*. The International Conference on Infant Studies, New Orleans, LA. May 26-28, 2016. (poster presentation).

Jubran, R., Hock, A., White, H., Heck, A., & Bhatt, R.S. (2016). *Attraction of Infants' Attention by Emotional Body Stimuli*. The International Conference on Infant Studies, New Orleans, LA. May 26-28, 2016. (poster presentation).

White, H., Hock, A., Jubran, R., Heck, A., & Bhatt, R.S. (2016). *Categorical Perception of Species in Infancy*. The International Conference on Infant Studies, New Orleans, LA. May 26-28, 2016. (poster presentation).