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# BODY PROCESSING AND ATTENTIONAL PATTERNS IN INFANCY

Rachel Lynn Jubran
*University of Kentucky*, rachel.jubran@uky.edu
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Rachel Lynn Jubran, Student

Dr. Ramesh S. Bhatt, Major Professor

Dr. Mark T. Fillmore, Director of Graduate Studies

# BODY PROCESSING AND ATTENTIONAL PATTERNS IN INFANCY

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DISSERTATION

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A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Arts and Sciences
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By

Rachel Lynn Jubran

Lexington, Kentucky

Director: Dr. Ramesh S. Bhatt, Professor of Psychology

Lexington, Kentucky

ABSTRACT OF DISSERTATION

BODY PROCESSING AND ATTENTIONAL PATTERNS IN INFANCY

Bodies provide important social information, and adults benefit from this information by recognizing and responding appropriately to bodies. Body recognition is enabled by the fact that human bodies are defined by parts, such as the limbs, torso, and head, arranged in a particular configuration. To understand the development of social cognition, it is important to analyze and document how infants come to recognize bodies. Infants are sensitive to distortions to the global configurations of bodies by 3.5 months of age, suggesting an early onset of body knowledge. It was unclear, however, whether such sensitivity indicates knowledge of the location of specific body parts or solely reflects sensitivity to the overall gestalt or outline of bodies. The current study addressed this by examining whether infants attend to specific locations in which parts of the body have been reorganized. Results of Experiments 1 and 2 show that 5-month-olds, but not 3.5-month-olds, are sensitive to the location of specific body parts, as demonstrated by a difference in allocation of attention to the body joint areas that were normal (e.g., where the arm connects to the shoulder) versus ones that were reorganized. Furthermore, to examine whether this kind of processing is driven by information from the face/head, in Experiment 3 I tested infants on images in which the face/head was removed. Infants no longer exhibited differential scanning of normal versus reorganized bodies. To further assess whether infants were responding to critical information provided by the face/head or whether their processing was disrupted solely because the headless images were incomplete bodies, Experiment 4 examined infants' performance on body images missing limbs. Once again, infants failed to exhibit differential scanning of typical versus reorganized bodies. Together, these results suggest that 5-month-olds are sensitive to the location of body parts. However, the presence of the face/head (Experiment 3) and limbs (Experiment 4) are necessary for 5-month-olds to exhibit differential scanning of reorganized versus intact body images. Overall, by 5 months of age, infants are sensitive to precise locations of body parts, and thus demonstrate a rather sophisticated level of knowledge about the structure of the human body. The role that the face/head and limbs play in body structure knowledge development is still unclear, and future studies need to address this question.

KEYWORDS: Infancy, Body Structure Knowledge, Visual Scanning, Socio-Cognitive Development

________Rachel L. Jubran______

________May 02, 2019________
Date

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By

Rachel Lynn Jubran

Ramesh S. Bhatt, Ph.D.
Director of Dissertation

Mark T. Fillmore, Ph.D.
Director of Graduate Studies

May 02, 2019

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# Chapter 1: Introduction

The human body is important for conveying social information in a variety of ways (Aviezer, Trope, & Todorov, 2012; Fast, 1988). For instance, bodies relay people's goals and desires, sometimes unintentionally, through "body language" (Fast, 1988). Bodies are also good indicators of emotion, and in some cases, they are even better at conveying peak emotions than faces (Aviezer et al., 2012). Moreover, bodies are larger than faces, and therefore can be processed from a greater distance, making the ability to obtain socially relevant information from bodies highly adaptive.

Given the importance of the human body as a significant source of social information, the question arises as to how bodies are recognized and information from them processed. The human body is recognizable because of the presence of specific parts arranged in particular configurations. Understanding how these body parts are arranged is an early step in body processing (Gliga & Dehane-Lambertz, 2005). Infants are sensitive to distortions to the global configurations of bodies by 3.5 months of age (Zieber, Kangas, Hock, & Bhatt, 2015), suggesting an early onset of knowledge of body configurations. Specifically, infants in Zieber et al. (2015) exhibited a preference between typically configured body images and those in which the parts were reorganized (e.g., arms protruding from the waist region rather than from shoulders) when images were presented upright but not when they were inverted. This finding indicates that infants are sensitive to the overall organization of human body parts at an early age. It is unclear, however, whether such sensitivity indicates knowledge of the location of specific body parts or solely reflects sensitivity to the overall gestalt or outline of bodies. To determine the nature and developmental trajectory of infants' representation of the human form, the current study added to the existing literature on body knowledge development by examining whether infants are sensitive to specific locations of the body in which parts are reorganized. Specifically, I documented infants' fixation durations to locations of body parts that are missing or incorrectly located. If infants look longer at specific locations of part dislocations, then one can infer that infants' knowledge of the human form goes beyond having just a basic template of the configuration to being sensitive to the location of specific parts.

Additionally, I also addressed the role of the face/head in infants' processing of body information. While it is true that bodies and heads are both rich sources of information in their own right, not much is known about the nature of the relationship between infants' processing of information from the face/head and bodies. It is possible that infants would not perceive a figure as a human if the face/head were missing from the body. For instance, previous research has found that viewing a body without a head affects adults' ability to identify changes in body postures (Yovel, Pelc, & Lubetzky, 2010). Therefore, the absence of a face/head might affect the way in which infants process a body. I addressed this issue in the current study by testing infants on body images with and without the face/head present. The absence of the face/head could affect infants' performance in one of two ways: 1) the face/head may provide some specific information that influences infants' scanning patterns, or 2) the face/head may not necessarily provide any critical information compared to other body parts and yet may affect infants' scanning because the image of the human is now incomplete. To address this latter possibility, a follow-up study was conducted in which infants viewed stimuli missing a body part other than the face/head (e.g., leg or arm), thus rendering the form incomplete while having the face/head present.

**Previous Research on Configural Processing of Bodies**

Before any higher-level social processing, such as categorization based on sex, race, or emotion can occur, one must identify the individual as human. As noted earlier, adults use the specific configuration of the body (i.e., two arms protruding from the upper part of the torso and two legs extending out from the bottom of the torso) to identify bodies. Such configural processing was found to be an early step in the processing of bodies when the N1 amplitudes of event-related potential (ERP) responses of adults viewing typical and reorganized body images were analyzed (Gliga & Dehaene-Lambertz, 2005). In this respect, bodies are like faces in that configural information is important to identify both (Carey, 1992; Diamond & Carey, 1986; Maurer, Le Grand, & Mondloch, 2002; Reed, Stone, Bozova, & Tanaka, 2003; Reed, Stone, Grubb & McGoldrick, 2006; Slaughter & Heron, 2004). Furthermore, deviation from the typical configuration disrupts body processing in adulthood (Reed et al., 2003; Reed et al., 2006). Specifically, Reed and colleagues (2006) found that adults recognize typically configured bodies faster than bodies that have been scrambled.

Like adults, infants are also sensitive to the configuration of the body. Three-month-olds exhibit differing ERP responses to typical versus reorganized bodies, indicating that knowledge of the specific structure of the human body is available early in life (Gliga & Dehaene-Lambertz, 2005). Further, Zieber et al. (2015) found that infants at 3.5 months of age exhibit a preference for bodies with parts in wrong locations over typically configured bodies, providing further evidence that infants at 3.5 months of age are sensitive to the global configuration of bodies. However, as noted earlier, while the aforementioned studies demonstrate knowledge of the typical configuration of a human body early in life, it is not yet known whether infants' representation of bodies includes knowledge about the location of the specific features (i.e., body parts) that make up the human template. This question is important to answer because theories differ on the extent and trajectory of body knowledge development in early infancy.

**Theories of Body Knowledge Development**

While there is a general consensus that adults exhibit expert processing of bodies, extant theories pertaining to the *development* of such expertise are often in conflict (Bhatt, Hock, White, Jubran, & Galati, 2016; Marshall & Meltzoff, 2015; Meltzoff, 2011; Slaughter & Heron, 2004; Slaughter, Heron-Delaney, & Christie, 2012). The theory proposed by Slaughter and colleagues (Slaughter & Heron, 2004; Slaughter et al., 2012) argues that visuo-spatial knowledge of bodies is slow to develop and that it takes until the second year of life for infants to exhibit robust body knowledge. Slaughter and colleagues (2012) also posit that there is a significant gap in the development of knowledge about bodies versus faces. They theorize that the difference in the timing of development for knowledge of faces and bodies is because the two systems are driven by separate mechanisms. Namely, while face knowledge is innate or served by a dedicated mechanism that is biologically specified, knowledge about bodies is acquired gradually through general learning mechanisms, and adults become experts through high levels of exposure over time. Such a theory would suggest that sensitivity to structural information in bodies and the location of individual parts would not be evident early in life.

However, not all researchers agree with the view that there is a large gap in the development of knowledge about faces and bodies. Bhatt et al. (2016) suggest that body knowledge develops along a similar trajectory as facial knowledge, possibly through a general social cognition system that arms the infant with the ability to process critical social information from a variety of sources, like faces and bodies. Such a mechanism would be highly adaptive as it would allow the infant to maximally benefit from the redundancy of information across various sources. Bhatt and colleagues (2016) also acknowledge that, rather than a fully integrated social cognition system, early acquisition of body knowledge could emerge through a body-specific knowledge system that benefits from relevant information from the rapidly developing face-processing system. That is, infants' face knowledge could facilitate their knowledge of bodies because of the close association between faces and bodies.

Relatedly, the "like-me" theory states that body knowledge is either innate or develops early in life due to observation and imitation (Marshall & Meltzoff, 2015; Meltzoff, 2011). Specifically, newborns isolate certain organs from birth (Meltzoff & Moore, 1997), and after observing a particular gesture or movement, newborns activate that same area on their own body (Meltzoff, 2011). Additionally, Meltzoff and colleagues (Meltzoff, Murray et al., 2018; Meltzoff, Ramírez et al., 2018) report systematic neural responses in infants as young as 60 days in response to touch to both their own and others' body parts (i.e., hand, foot, and lip). This notion of organ identification early in life suggests that infants as young as 3.5 months of age would allocate their attention to specific regions of change on the body in the current study because they are able to isolate those specific body parts as well as showing systematic neural responses. Thus, Bhatt et al. (2016) and the "like-me" theory proposed by Meltzoff and his colleagues

(Marshall & Meltzoff, 2015; Meltzoff, 2011; Meltzoff & Moore, 1997) are in agreement that knowledge about body parts is available early in life.

There is some empirical evidence to suggest that body knowledge emerges early in life and along a similar trajectory as face knowledge. As mentioned above, it has been found that infants as young as 3 months of age recognize the specific organization of bodies (Gliga & Dehaene-Lambertz, 2005) and that 3.5-month-olds are also sensitive to the global configuration of bodies (Zieber et al., 2015). Additionally, it has been found that infants are capable of matching bodies with voices (Zieber, Kangas, Hock, & Bhatt, 2014) and faces (Hock, Kangas, Zieber, & Bhatt, 2015) within the first year of life, demonstrating that infants' knowledge of bodies includes fairly sophisticated emotion processing abilities.

**The Role of the Head in Body Information Processing**

In addition to examining whether infants are sensitive to locations of specific body parts in the first few months of life, the role of the face/head in body knowledge development was also explored in the current study. Given that the head has been found to contribute to the way in which adults process body postures (Yovel et al., 2010), it is possible that the face/head is a necessary component of body processing even early in life. The intersensory redundancy hypothesis proposed by Bahrick, Lickliter, and Flom (2004) is relevant to this issue. Bahrick et al. (2004) posit that redundant information within a stimulus influences how infants allocate attention and also provides infants with additional knowledge about what is being perceived. If intersensory redundancy enables infants to obtain knowledge about the human form by allowing them to integrate information from both the face/head and the body, then the face/head may facilitate body processing early in life. This possibility was tested in the following experiments by documenting infants' scanning patterns to typical and reorganized body images in the presence versus absence of faces/heads.

Additionally, a follow-up experiment was conducted to investigate the mechanism underlying the effects of the absence of the face/head on infants' performance. Specifically, I examined whether there is something special about the face/head signaling the presence of a human figure or whether the face/head is just like any other body part in the makeup of a human figure. This issue was studied by removing other body parts (a leg or an arm) to make the figure incomplete. If infants fail to exhibit differential scanning patterns when there is a leg or an arm missing as they did when the face/head is missing, then it would indicate that any substantially incomplete form affects the way in which infants process bodies. On the other hand, if infants exhibit differential scanning patterns in the deleted limb condition in a similar manner as in the whole body condition, but fail to do so in the headless condition, then it would support the theory that the face/head is a necessary and special component of body processing early in life.

**Scanning**

I examined infants' knowledge of bodies by documenting scan patterns to body images with distorted body configurations. Infants scan their environment in meaningful ways and this scanning is important for their representation of the visual world (Johnson, 2010). Infants at just 6 weeks of age scan images in intentional ways, and, by 13 weeks, they exhibit the ability to deliberately choose their target (Bronson, 1994). Further, Atkinson, Hood, Wattam-Bell, and Braddick (1992) found that by 3 months of age, infants exhibit more mature selective attention than 1-month-old infants, as evidenced by their ability to disengage and refixate from a central stimulus to a peripheral target. This provides evidence that 3-month-olds possess more mature systems that control eye movements than 1-month-olds. Additional studies found differing scanning patterns as a function of experience with both own- versus other-race faces (Xiao, Quinn, Pascalis, & Lee, 2014) and pets within the first year of life (Kovack-Lesh, McMurray, & Oakes, 2014). Specifically, Xiao et al. (2014) found differences in the scanning patterns of 6-month-olds versus 9-month-olds when they viewed same- and other-race faces. Not only did looking time increase from 6 to 9 months, but the older infants scanned faces more efficiently, likely due to a greater accumulation of more visual experience with age. Similarly, Kovack-Lesh et al. (2014) found that 4-month-old infants with more experience with pets exhibit more sophisticated scanning of images of pets than infants who had less exposure. Given that infants have extensive experience with bodies from birth, it is possible that infants in the current study will exhibit differences in scanning to specific regions of bodies that are typical versus containing displaced parts.

Together, the findings described above suggest that scanning could be a sensitive measure to document the development of the nature and timing of body knowledge in infancy by capturing the way in which infants allocate their attention to a typical versus a reorganized body image. Scanning would provide more detail about the specific nature of infants' knowledge of bodies and either support or contradict existing theories about the developmental trajectory of body knowledge. Scanning can be particularly useful to better understand the notion of organ identification mentioned above (Meltzoff & Moore, 1997). For example, if infants in the current study do exhibit differences in attention to specific body parts based upon their typical or reorganized location, then it would not only support the possibility that infants can identify certain body parts and organs from birth but also suggest that they can recognize when those specific body parts have undergone a change in location.

**The Current Study**

As noted earlier, Zieber et al. (2015) found that infants at 3.5 months of age are sensitive to the global configuration of bodies. However, it is unknown whether infants are attending to the specific regions on the body that have undergone a reorganization or whether they are responding to changes in the overall outline or gestalt of the body. To address this issue, the current study documents whether infants' knowledge of bodies includes exhibiting differences in attention to specific locations of reorganization in body images or they are simply responding to the global configuration.

In Experiment 1, 3.5-month-olds were tested to see if they attend specifically to areas where body parts were reorganized (see Figure 1). Infants failed to exhibit differential looking to these areas as compared to the same locations in typical bodies. Given 3.5-month-olds' failure to exhibit systematic scanning, it appears that sensitivity to the location of specific body parts develops at a later age. This possibility was examined in Experiment 2 by testing 5-month-old infants. Five-month-olds were chosen because prior research indicates developmental changes in body knowledge between 3.5 and 5 months of age. For example, Heck, Chroust, White, Jubran and Bhatt (2018) found that 5-month-olds match emotional body postures to emotional voices, but 3.5-month-olds failed to do so. Additionally, Hock, White, Jubran, and Bhatt (2016) found that 5-month-olds process body information holistically, as evidenced by superior detection of limb postures in the context of the whole body than in isolation. It is thus possible that, by 5 months, body information processing has reached a level of expertise that is sensitive enough to the structure of bodies to detect changes in the location of body parts. Thus, Experiment 2 examined 5-month-olds' sensitivity to the location of body parts.

Experiment 3 examined 5-month-old infants' performance on headless images to understand how the face/head contributes to body knowledge early in life. The headless condition also served as a control to ensure that differential scanning patterns to typical versus reorganized body images in Experiment 2 were not the result of potential low-level featural differences in the two types of images (such as changes in symmetry). The distortions in the headless images used in Experiment 3 were identical to those in the complete (headed) images in Experiment 2. Thus, if performance on complete images is due to low-level features, infants should exhibit a similar pattern of performance on headless images. If, however, infants' performance on headless bodies is different than on complete bodies, then it would suggest that low-level image features are not the basis of performance on the complete bodies.

Headless bodies were also studied because the role of the face/head in infants' knowledge of the structure of the human form is not yet known. Yovel et al. (2010) found that the absence of the head affected adults' processing of body information. Adults were asked to discriminate between body postures of both upright and inverted bodies in conditions when the head was present and when it was absent. In the presence of the head, a body inversion effect was documented in which adults discriminated between body postures of whole bodies in the upright condition, but not in the inverted condition. However, adults failed to exhibit a body inversion effect when they were shown headless bodies. That is, there was no difference in the accuracy of discrimination between body postures when the headless stimuli were presented upright versus when they were inverted. Thus, the authors conclude that the head plays an important role in the processing of body postures. It is similarly possible that, in the absence of the face/head, infants will fail to differentially scan typical versus reorganized body images. If so, it would suggest that the presence of a face/head is necessary for infants to process distortions in bodies.

Yovel et al. (2010) also report that the removal of body parts other than the face/head (i.e., legs or arms) did not affect adults' processing of body information in the manner that the removal of the head did. Thus, in Experiment 4, I examined infants' scanning of typical versus reorganized bodies when one body part (arm or leg) was deleted. If removal of the face/head in Experiment 3 disrupts processing, but the removal of other body parts in Experiment 4 does not, then it would indicate that the face/head plays some critical role in infants' body knowledge development. Alternatively, if there are no differences between performance in Experiments 3 and 4, it would suggest that infants' scanning of reorganized bodies is dependent upon a complete human form and deletion of any body part (head, leg or arm) disrupts processing. This would be contrary to the conclusion by Yovel et al. (2010) that the presence of the head is of critical importance for adults' performance. To summarize, the current study sought to determine whether infants' body knowledge development is due to recognition of the global form versus attending to the specific parts that make up the body. It also examined the role that the face/head plays in infants' representation of the human form.

Figure 1.

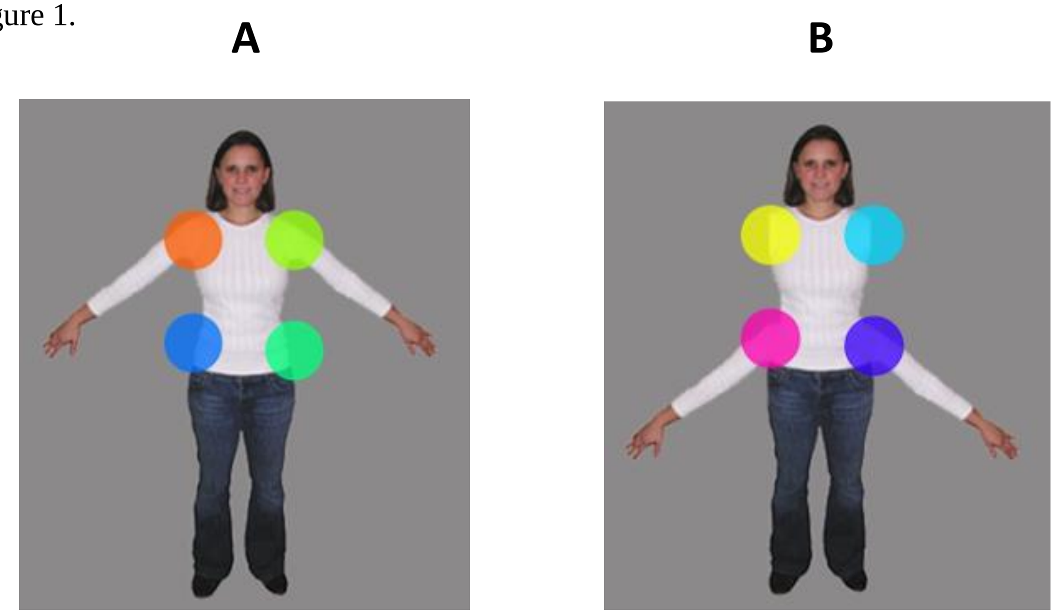


*Figure 1*. Examples of the typical (A) and reorganized (B) stimuli used in Experiments 1 and 2. Each infant saw the typical image four times and the reorganized image four times for a total of eight 12s test trials. Infants viewed one of the possible six typical-reorganized body pairs. The colored shapes represent the area of manipulation AOIs. These shapes were not visible to infants during the experiment.

## Chapter 2: Experiment 1

In Experiment 1, I examined whether 3.5-month-old infants exhibit differential scanning of typical versus reorganized body images. This allowed me to assess how fine-tuned infants' knowledge of bodies is early in life by documenting the way in which they allocate their attention to specific areas within the body. Infants at 3.5 months of age were chosen because previous research with infants this age found that they exhibit an overall preference between a reorganized body and a typical body (Zieber et al., 2015), thereby indicating that they are sensitive to at least the global configuration of the human form. However, it is unclear whether infants at this age are sensitive enough to the typical configuration of the human form to display systematic attention to specific locations of distortions in reorganized body images. Finding that infants do allocate their attention differently to locations of distortion would indicate that young infants are sensitive to the specific changes made to the body (e.g., arms protruding from hips), rather than just responding to the overall gestalt of the body (e.g., top/bottom balance). Such an outcome would suggest that infants are sensitive to the location of specific body parts such as arms and legs. In contrast, if there is no allocation of attention to reorganized locations, then it would suggest that infants are not sensitive to the location of specific body parts at 3.5 months of age.

### Method

#### Participants

A power analysis based on the average effect size in a prior study (White, Hock, Jubran, Heck, & Bhatt, 2018) that used the same procedure as the one utilized in the current experiment indicated that at least 25 infants were needed in each group to detect a large effect with 80% power. Thus, thirty 3.5-month-old infants (mean age = 104 days, *SD* = 10.10; 12 female) participated in this study. Data from additional infants were excluded for looking at the stimuli for less than 20% of the duration of the study (*n* = 4) and not looking at all of the areas of interest (*n* = 2). Infants were recruited through birth announcements in the local newspaper and a local hospital. The majority of the participants were from middle-class Caucasian families, which was representative of the surrounding area.

**Stimuli**

The body stimuli used in this experiment were photographs of females on a gray background. These images were similar to those used in Zieber et al. (2015), which found that infants exhibit an overall preference between typically organized and reorganized (body parts in wrong locations) images (see Figure 1). Images of females were used because infants show more sophisticated processing of female stimuli than male stimuli; for example, at 3 months, they discriminate among female faces under conditions in which they fail to discriminate among male faces (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002; Ramsey, Langlois, & Marti, 2005). All distortions were made using Photoshop software and the actors were all wearing similarly colored clothing, no jewelry, minimal make-up, and no glasses or hats. This study used six different pairs of bodies to increase generalizability of the findings and to ensure that scanning patterns observed were not due to something particular to a single body image. Each infant was tested on a single pair of images, a typically configured body and its reorganized version (Figure 1). Three types of biologically-impossible distortions were tested: arms attached to the body in the waist area, the positions of both arms and legs switched, and the positions of one arm and one leg switched.

**Apparatus and Procedure**

Infants were seated approximately 65 cm in front of 58 cm computer monitor in a darkened chamber. They were seated on the lap of a parent, who was wearing opaque glasses that prevented him/her from seeing the images on the screen and potentially biasing infants' looking patterns. Parents were instructed to not direct their infant's looking in any way. Infants were tested on eight 12s trials. A single image (typical or reorganized) was presented in the center of the screen on a gray background on each trial. Half of the trials contained images of typical bodies while the other half displayed images of reorganized bodies. Preceding every trial, an attention-getter consisting of alternating colorful shapes appeared on the screen to direct the infant's focus to the center of the screen. Once the infant looked toward the attention-getter, the test stimulus appeared in the center of the screen. The image type (typical or reorganized) of the stimulus presented on the first trial was counterbalanced across infants. The stimuli presented on the remaining seven trials were randomly determined with the constraint that the same image was never presented consecutively more than twice.

A Tobii TX300 eye-tracker was used to record infants' looks. The eye-tracker's cameras recorded 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-tracker according to the manufacturer 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 65 cm. The eye-tracker compensates for 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 $cm^2$ 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 at 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). Additionally, data from the first 500 ms of each trial were discarded. This adjustment removes artificially inflated looking times to the center of the stimulus as it appears directly behind the attention getter. This criterion is similar to those used in previous studies of body scanning (e.g., Kret, Stekelenburg, Roelofs, de Gelder, 2013; White et al., 2018).

Areas of interest (AOIs) were drawn on each body (see Figure 1) where the limbs met the trunk of the typical body and where the limbs met the trunk of the reorganized body. An additional AOI was drawn around the entire body. The AOIs were identical within a stimulus pair (typical, reorganized) seen by an infant; this allowed the direct comparison of fixation durations to each AOI type across stimuli without confounding AOI location with body type.

**Results and Discussion**

The dependent measure was the proportion of total looking to each kind of stimulus (typical or reorganized) that was devoted to the critical limb junctions (see AOIs in Figure 1) in which the reorganization took place. This was calculated by dividing the total fixation duration to the joints on each kind of stimulus summed across all four presentations (each kind of image was presented four times to each infant for a total of eight trials) by the total fixation duration to the overall stimulus (defined as the AOI around the whole body). The resulting number was then multiplied by 100 to obtain a percent proportion score. An outlier analysis (Tukey, 1977; using SPSS version 25.0) revealed that two infants in the current condition had scores that were outliers. Their scores were greater than 1.5 times the interquartile range above the upper quartile edge. Thus, these scores were not included in the following analysis. A paired samples *t*-test revealed no difference in looking to the joint AOIs on the typical body ($M$ = 12.54%, $SD$ = 7.25) versus the reorganized body ($M$ = 10.15%, $SD$ = 8.56); $t(27) = 1.52$, $p = .140$, $d = .30$ (Figure 2). Thus, infants at 3.5 months of age failed to exhibit differential scanning to the reorganized locations of body images. Combined with the results of the previous study by Zieber and colleagues (2015), these results suggest that although 3.5-month-old-infants discriminate between typical and reorganized bodies, they do not seem to be sensitive to the specific locations of change, at least as reflected in scanning patterns. This finding suggests that 3.5-month-olds' representation of human bodies may be more responsive to changes in overall gestalt patterns than to locations of specific body parts such as arms and legs.

Figure 2.

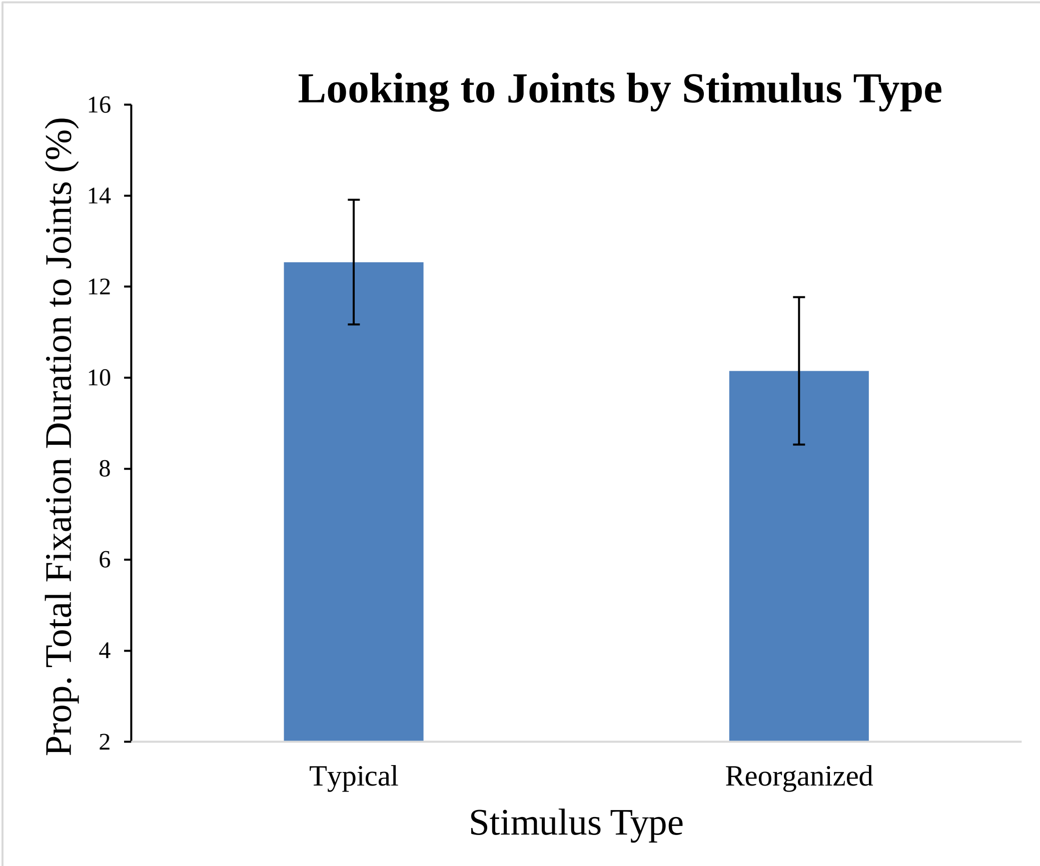


*Figure 2.* Means for the proportion of total fixation duration to the joint AOIs in Experiment 1 are displayed.

## Chapter 3: Experiment 2

Because 3.5-month-olds failed to exhibit specialized scanning patterns in Experiment 1, it is still unclear when knowledge about the location of specific body parts develops. As discussed in the Introduction, recent research on infants' processing of emotion from bodies indicates that the period between 3.5 and 5 months of age may be a critical period for the development of body knowledge (Heck et al., 2018). Specifically, using an intermodal matching task, Heck et al. (2018) found that 5-month-old infants, but not 3.5-month-olds, match emotional bodies to congruent vocalizations. In addition, infants at 5 months of age are able to discriminate between body postures in the context of a full human form, but not when only the relevant limbs are present or the limbs are present in the context of a scrambled body (Hock et al., 2016). Such evidence of holistic processing suggests that by 5 months of age infants show expert processing of at least some kinds of body information. Thus, it is possible that 5-month-olds will also show more sophisticated processing of body structure than 3.5-month-olds and scan locations on body images in which limb locations have been displaced. I tested this possibility in Experiment 2.

### Method

#### Participants

Thirty 5-month-old infants (mean age = 152 days, *SD* = 4.48; 16 female) participated in the study. Data from additional infants were excluded for looking at the stimuli for less than 20% of the duration of the study (*n* = 7) and for not looking to all of the areas of interest (*n* = 1). As in Experiment 1, infants were recruited through birth announcements in the local newspaper and a local hospital and were predominantly from middle-class Caucasian families.

**Stimuli**

The body stimuli used in this study were the same as those used in Experiment 1 (Figure 1).

**Apparatus and Procedure**

The study utilized the same apparatus and procedure used in Experiment 1.

**Results and Discussion**

The results were analyzed in the same manner as in Experiment 1. An outlier analysis (Tukey, 1977; using SPSS version 25.0) revealed no outliers. Thus, data from all participants were used in the following analysis. A paired samples *t*-test revealed that 5-month-old infants exhibited significantly less looking to the joint AOIs on the typical body ($M$ = 4.74%, $SD$ = 3.76) versus the reorganized body ($M$ = 7.37%, $SD$ = 5.80); $t(29) = -2.43$, $p = .021$, $d = .49$ (Figure 3). Specifically, this finding indicates that 5-month-olds fixate longer on the joint areas of a reorganized body, suggesting that they recognize that the reorganized body part is no longer in its canonical location. Thus, unlike 3.5-month-olds in Experiment 1, identically tested 5-month-olds in Experiment 2 exhibited sensitivity to the specific location of body parts in human images. This indicates the development of a more detailed representation of body structure between 3.5 and 5 months of age. Furthermore, this evidence of differential scanning within the first half year of life supports the proposal by Bhatt et al. (2016) and Meltzoff and colleagues (Marshall & Meltzoff, 2015; Meltzoff, 2011; Meltzoff & Moore, 1997) that body knowledge develops quite early in life.

Figure 3.

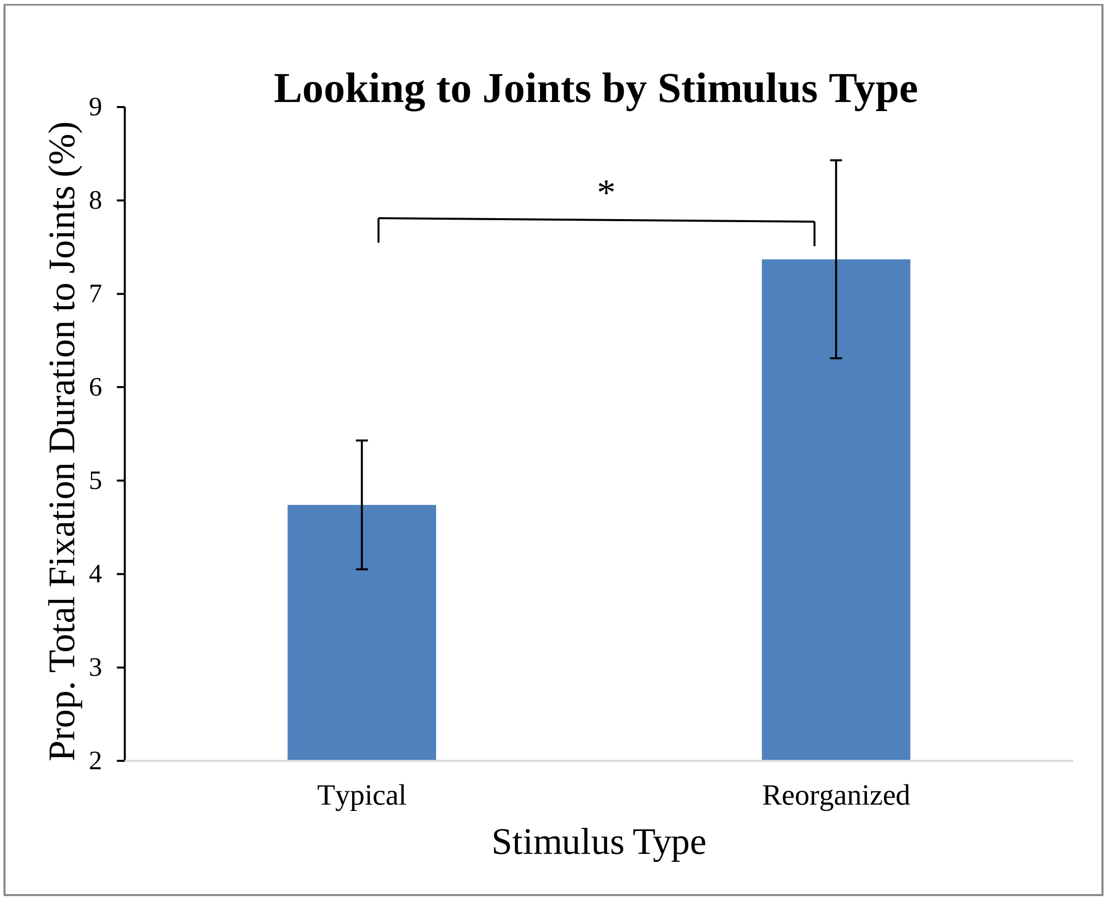


*Figure 3.* Means for the proportion of total fixation duration to the joint AOIs in Experiment 2 are displayed. $*p < .05$.

## Chapter 4: Experiment 3

Experiment 3 examined the role of the face/head in 5-month-olds' processing of body reorganizations. The function of the face/head in infants' body structure knowledge development has not been addressed previously, thus, the current study examined whether infants' scanning of typical and reorganized bodies is disrupted by the removal of the face/head. Recall that previous research has found that adults' processing of body information is affected by the presence versus absence of facial/head information, suggesting that the face/head region is a critical component of adults' representation of bodies. For example, adults discriminate between different body postures (e.g., different arm positions) more accurately when the images contain the head than when they are headless (Yovel et al., 2010). Furthermore, a recent study on infants' specialized scanning of male and female bodies demonstrated that the presence of a head is critical for infants to show adult-like scanning patterns (White et al., 2018). Therefore, it is possible that infants' ability to process body structure distortions is also dependent on the presence of the face/head.

Additionally, as detailed earlier, testing infants on headless bodies in this experiment served as a control condition because the distortions themselves were the same as on the whole body (headed) stimuli used in Experiment 2. This allowed me to examine whether performance in Experiment 2 was due to low-level featural differences (such as symmetry) between typical and reorganized body images. If infants' performance is affected by the absence of the head, then it would indicate that infants' performance in Experiment 2 was not due to low-level featural differences between typical and reorganized body images. If, however, performance is not affected by the absence of the head, then it is not possible to rule out the possibility that infants in Experiment 2 were responding on the basis of low-level features.

## Method

### Participants

Thirty 5-month-old infants (mean age = 150 days, *SD* = 5.14; 17 female) participated in the study. Data from additional infants were excluded for looking at the stimuli for less than 20% of the duration of the study (*n* = 7) and not looking to all of the areas of interest (*n* = 1). Infants were recruited in the same manner as in Experiments 1 and 2 and were predominantly from middle-class Caucasian families.

### Stimuli

The stimuli used were the same as those used in Experiments 1 and 2, with the exception that the face/head portion of the body images was removed (Figure 4). This allowed for the same low-level features that were present in the first two experiments to also be present here, thereby serving as a control condition.

### Apparatus and Procedure

The study utilized the same apparatus and procedure used in Experiments 1 and 2.

### Results and Discussion

The results were analyzed the same way as in Experiments 1 and 2. An outlier analysis (Tukey, 1977; using SPSS version 25.0) revealed that two infants in the headless condition had scores that were outliers. Their scores were greater than 1.5 times the interquartile range above the upper quartile edge. Thus, these scores were not included in the following analysis. A paired samples *t*-test revealed no difference in looking to the joint AOIs on the typical body (*M* = 10.70%, *SD* = 8.75) versus the reorganized body (*M*

= 8.87%, *SD* = 7.20); *t*(27) = 1.04, *p* = .306, *d* = .23 (Figure 5). Thus, the 5-month-olds in the current experiment failed to exhibit differential scanning of reorganized locations of the headless body images.

The results from the current study suggest that the findings from Experiment 2 were not due to low-level features drawing the infants' attention to the joint regions. If infants were just responding to some low-level features such as symmetry, then they should have responded in a similar manner as Experiment 2 because all of the differences between the typical and reorganized body images were maintained in the current experiment. However, given that infants failed to exhibit differential scanning patterns to the joint regions on the typical versus reorganized images in the headless condition, it is likely that infants in Experiment 2 were not relying on such low-level features; rather, they were likely responding on the basis of their knowledge of the configuration of the human body.

Furthermore, these results demonstrate that the face/head may be necessary for correct body recognition in infancy. Evidence of differential scanning of typical versus reorganized bodies only in the presence of the face/head is in agreement with the intersensory redundancy hypothesis (Bahrick et al., 2004). Recall that Bahrick et al. (2004) theorized that redundant information within a stimulus influences how the infant allocates their attention and provides them with additional knowledge about what they perceive. The fact that the head is necessary for infants to exhibit differential scanning suggests that, like adults, infants respond to redundant information from faces and bodies, resulting in more veridical perception of social information.

Figure 4.


*Figure 4.* Examples of the headless typical (A) and headless reorganized (B) stimuli used in Experiment 3. Each infant saw a headless typical image four times and a headless reorganized image four times for a total of eight 12s test trials. Infants viewed one of the possible six headless typical-reorganized body pairs. The AOIs were identical to those pictured in Figure 1.

Figure 5.

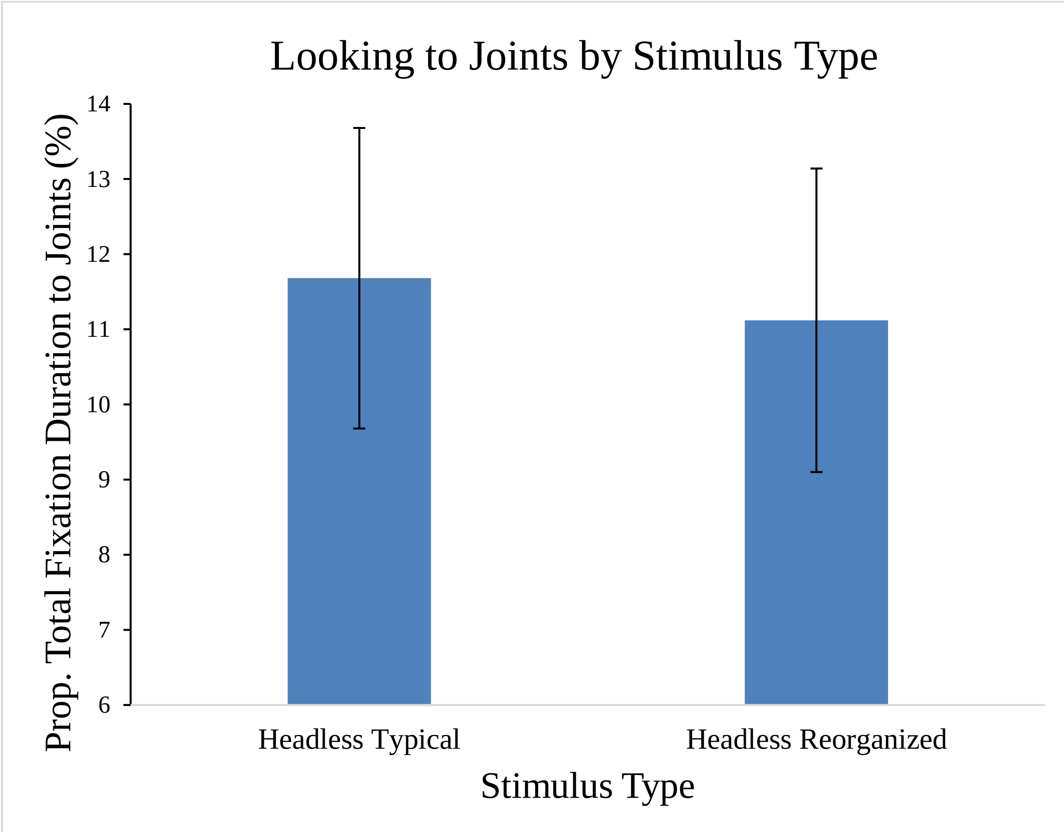


*Figure 5.* Means for the proportion of total fixation duration to the joint AOIs in Experiment 3 are displayed.

# Chapter 5: Experiment 4

The results from Experiment 3 highlight the importance of viewing a stimulus complete with the face/head region for accurate body structure processing at 5 months of age. Previous work has suggested that the face/head is an important source for infants to obtain a variety of information about people, such as gender, race, and species categorization (Kelly et al., 2007; Quinn & Eimas, 1996; Quinn et al., 2002). As described in the Introduction, Yovel et al. (2010) found that the removal of the head disrupted adults' processing of body postures, but the removal of other body parts (legs or arms) did not. It is possible that infants' body knowledge is similar to that of adults in that only the face/head is a necessary component rather than other body parts (legs or arms). On the other hand, it is possible that infants do not solely rely on the information present from the face/head region and the absence of any body part rendering the form incomplete will result in the same findings as Experiment 3, namely a failure to exhibit sensitivity to reorganized body images. To address this issue, Experiment 4 examined whether findings from Experiment 3 were specifically due to the missing face/head region, or whether viewing an incomplete form due to *any* missing body part is enough to render the stimulus non-human.

## Method

### Participants

Thirty 5-month-old infants (mean age = 151 days, *SD* = 6.17; 15 female) participated in Experiment 4. Data from additional infants were excluded for looking at the stimuli for less than 20% of the duration of the study (*n* = 5) and experimenter error

($n$ = 1). Infants were recruited in the same manner as in Experiments 1-3 and were predominantly from middle-class Caucasian families.

### Stimuli

The stimuli used were the same as those used in Experiments 1 and 2, with the exception that one limb (leg or arm) on the body images was removed (Figure 6).

### Apparatus and Procedure

The study utilized the same apparatus and procedure used in Experiments 1-3.

### Results and Discussion

The results were analyzed in the same manner as in Experiments 1-3. An outlier analysis (Tukey, 1977; using SPSS version 25.0) revealed that one infant in the deleted limb condition had a score that was an outlier. This infant’s score was greater than 3 times the interquartile range above the upper quartile edge. Thus, the score was not included in the following analysis. A paired samples *t*-test failed to reveal significant differences in infants’ attention to the joint AOIs on the typical body ($M$ = 5.67, $SD$ = 4.84) versus the reorganized body ($M$ = 7.09, $SD$ = 4.56); $t(28) = -1.43$, $p = .163$, $d = .30$ (Figure 7). Thus, in contrast to the whole-body condition of Experiment 2, the deletion of limbs affected infants’ differential scanning of reorganized versus typical body images in the current experiment. These results indicate that the presence of the limbs (Experiment 4) as well as the presence of the face/head (Experiment 3) is necessary for 5-month-olds to exhibit differential scanning of reorganized versus intact body images.

Figure 6.


*Figure 6.* Examples of the deleted limb typical (A) and deleted limb reorganized (B) stimuli used in Experiment 4. Each infant saw a deleted limb typical image four times and a deleted limb reorganized image four times for a total of eight 12s test trials. Infants viewed one of the possible six deleted limb typical-reorganized body pairs. The AOIs were identical to those pictured in Figure 1.

Figure 7.

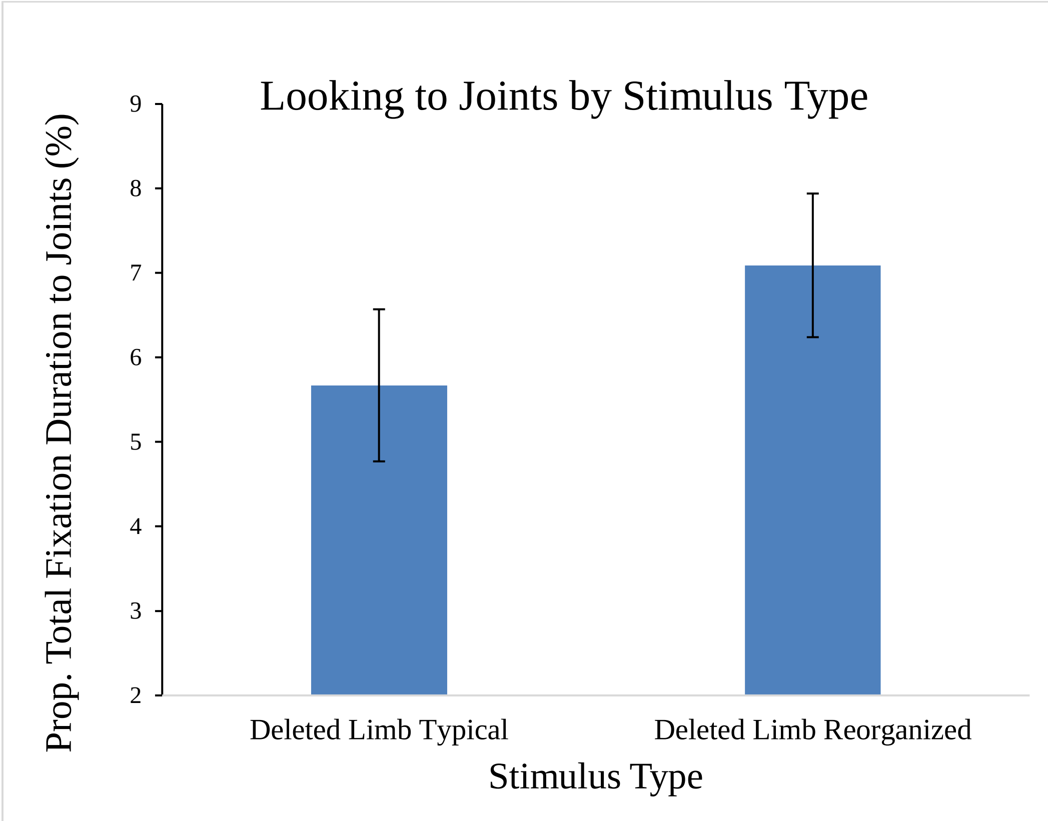


*Figure 7.* Means for the proportion of total fixation duration to the joint AOIs in Experiment 4 are displayed.

# Chapter 6: General Discussion

This study documented the nature and timing of body knowledge development in infancy by capturing the way in which infants allocate their attention to typical versus reorganized body images. Specifically, I found that 5-month-olds, but not 3.5-month-olds, attend to specific regions of body images that have been distorted versus ones that are typical. This difference in scanning patterns demonstrates that by 5 months of age, infants are sensitive to the specific locations of body parts (such as arms and legs). This sensitivity indicates a sophisticated representation of body structure knowledge early in life. However, the results also indicated that 3.5-month-olds are not similarly sensitive to the specific locations of change, although previous research (Zieber et al., 2015) suggests that 3.5-month-olds discriminate between typical and reorganized body images. This pattern of findings suggests that 3.5-month-olds may be more responsive to changes in the overall gestalt patterns than to the locations of specific body parts. Furthermore, the finding that infants have a fairly sophisticated representation of the structure of the human body by 5 months of age is consistent with the growing body of work indicating that body representation develops quite early in life.

Bhatt et al. (2016) posit that knowledge of bodies develops through a general social cognition system that gives infants the ability to process critical social information from a variety of sources, like faces and bodies. They also suggested an alternative possibility, namely that, rather than a fully integrated social cognition system, early acquisition of body knowledge could emerge through a body-specific knowledge system that benefits from relevant information from the rapidly developing face-processing system. That is, infants' knowledge of faces could in turn facilitate their knowledge of bodies because of the close association between faces and bodies. Bhatt et al. (2016) suggest that, whether or not a general social cognition system or separate face and body processing systems are prevalent during early development, face and body knowledge development follow similar trajectories. The current findings are consistent with this theory because they indicate that infants are sensitive to the structure of bodies and the locations of specific body parts by 5 months of age. However, the proposals put forth by Bhatt et al. (2016) are not detailed enough to explain why 3.5-month-olds fail to exhibit sensitivity to locations of specific body parts while 5-month-olds do.

Furthermore, the notion that knowledge of faces facilitates infants' processing of body information is in agreement with the intersensory redundancy hypothesis (Bahrick et al., 2004), which posits that redundant information within a single stimulus provides infants with additional knowledge about what they are perceiving. That is, information from faces and bodies work synergistically to facilitate infants' processing of social information. The finding in the current experiments that 5-month-olds exhibit sensitivity to the location of body parts when tested with whole body images (Experiment 2) but fail to do so when tested with headless body images (Experiment 3) thus supports the intersensory redundancy hypothesis. That is, the failure in the absence of the face/head could be the result of a lack of redundancy of information within the stimulus resulting in a failure to identify the stimulus as human.

The results of the current study are also in agreement with the "like-me" theory (Marshall & Meltzoff, 2015; Meltzoff, 2011) which assumes that body knowledge could be innate or develop early in life due to observation and imitation. According to this theory, 5-month-olds' sensitivity to detailed body structure information in the current study could be explained by the assumption that, by this age, observation and imitation enables infants' knowledge about the specific location of certain body parts. However, the fact 3.5-month-olds failed to exhibit sensitivity to specific locations of body parts indicates the necessity for a more detailed and comprehensive theory of when and how knowledge of specific aspects of bodies develops.

It is important to note that, although Experiment 1 failed to find evidence of 3.5-month-olds sensitivity to specific locations of body parts, it is possible that other dependent measures, such as duration of the longest look, might indicate sensitivity even at this age. For instance, infants could be aware of the exact location of body parts by 3.5 months of age, but lack the motivation to exhibit such knowledge as a difference in "spontaneous" scanning patterns. Also, when infants this age exhibited overall preferences between typical and reorganized body images in Zieber et al. (2015), they were tested with the two types of bodies presented side-by-side. In contrast, infants in the current experiments saw only one type of image (typical or reorganized) at a time on the screen. It is possible that young infants need to be able to compare these two types of images side-by-side in order to exhibit sensitivity to the specific differences between them. Future studies could address this issue by simultaneously presenting 3.5-month-old infants with both a reorganized and a typical body configuration to see if the viewing patterns differ when they can directly compare the two image types. If the results were to show that infants at 3.5 months of age now exhibit differential scanning patterns to the joint regions of the two image types, then it would provide evidence that knowledge about the precise location of body parts emerges as early as 3.5 months.

The current results are in contrast with the theory put forth by Slaughter and colleagues (Slaughter & Heron, 2004; Slaughter, et al., 2012), which states that there is a significant gap in the development of knowledge of bodies versus faces. Slaughter and Heron (2004) hypothesize that two differing mechanisms drive the development of face versus body knowledge, resulting in a difference in the timing of development. Specifically, while face knowledge is innate or served by a dedicated mechanism that is biologically specified, knowledge about bodies is acquired over time through general learning mechanisms, and adults become experts through high levels of exposure with age. This general learning hypothesis would have predicted that both age groups of infants in the current study would fail to exhibit differential scanning of reorganized images because the theory claims that robust body knowledge does not emerge until the second year of life. However, the results from Experiment 2 documenting 5-month-olds' ability to differentially scan the distorted areas of typical versus reorganized bodies suggest that at least certain critical kinds of knowledge about bodies develops much earlier than the second year of life.

While the current study challenges existing theories of body knowledge development, it also examined the role that the head plays in infants' body structure knowledge development. Previous studies with adults found that the removal of the head affects adults' ability to identify changes in body postures (Yovel et al., 2010). I wanted to know whether a similar outcome would occur when infants are tested on headless bodies. The findings show that, in contrast to when infants are tested on whole bodies (Experiment 2), 5-month-old infants viewing headless bodies fail to exhibit differences in their attention to typical versus reorganized bodies (Experiment 3), suggesting that the head plays a crucial role in infants' body structure information processing.

However, due to similar findings when infants were tested on other incomplete stimuli (i.e., arms or legs missing) in Experiment 4, a possible explanation for the findings of both Experiments 3 and 4 is that infants fail to view the stimulus as human when any body part (head, legs, or arms) is missing, rendering the form incomplete. This finding is consistent with previous research documenting a difference in scanning patterns to male versus female bodies when the head is present versus when it is absent (White et al., 2018), suggesting the importance of the head for infants' perception of gender in bodies. Note that Yovel et al. (2010) found that adults' processing of bodies is affected by the absence of the head but not by the absence of limbs, suggesting that the information from the face/head is especially important for adults. In contrast, given that 5-month-olds were affected by the absence of limbs as well as the face/head, infants this age may not be deriving any special information from faces/heads.

It is possible that older infants would exhibit a different pattern of performance than 5-month-olds in the deleted limb condition when the face/head is present. Previous research has documented that 9-month-olds exhibit knowledge of certain aspects of bodies under conditions in which 5-month-olds do not. For example, Zieber et al. (2010) found that 9-month-olds, but not 5-month-olds, exhibit a preference for a typical body image versus one in which the parts are proportionally distorted (e.g., torsos shortened and legs lengthened unnaturally). Additionally, Christie and Slaughter (2010) found that 9-month-olds, but not 6-month-olds, exhibit a spontaneous preference for a typical human body that is moving in a biologically possible way as opposed to one that has been scrambled. Therefore, it is possible that 9-month-olds would exhibit differential scanning patterns to areas of distortion on reorganized versus typical bodies containing the face/head but missing other limbs. By testing infants at an older age, it will be possible to document the precise age in which infants view an incomplete form containing the face/head in a similar manner to adults and further provide evidence for the role that the head plays in infants' body structure knowledge development. If older infants succeed when a body part other than the face/head is missing, but continue to fail when viewing headless stimuli, it would provide evidence that the face/head provides infants with significant information.

Additionally, the use of headless images in Experiment 3 served as a control condition to examine whether the difference in scanning patterns found in Experiment 2, in which infants were tested with whole bodies, were simply due to low-level features between typical versus reorganized body images (e.g., differences in symmetry) drawing attention to specific areas, rather than due to infants' knowledge of the structure of bodies. Because the stimuli remained identical in Experiments 2 and 3 except for the presence/absence of the face/head, if infants were responding to low-level featural differences between typical and reorganized body images, then the same pattern of results would have been expected in Experiment 3 as in Experiment 2. However, infants failed to exhibit differential scanning patterns in Experiment 3 when the heads were removed. This finding indicates that performance in Experiment 2 was likely due to infants' sensitivity to the structure of the human body, rather than a response to some low-level featural differences between typical and reorganized body images.

Recall that infants in the current experiments were tested only on female stimuli. Future research should examine whether similar results would be obtained if they were tested on male stimuli. Research indicates that infants perform better on female faces than on male faces in a variety of tasks if they have a primary female caregiver (Quinn, et al., 2002; Ramsey et al., 2005; Ramsey-Rennels & Langlois, 2006). These findings demonstrate the role of experience on the development of facial knowledge. If infants' primary caregivers are female, and prior experience with a particular gender impacts their knowledge of the structure of a human body, then it would be expected that infants would no longer exhibit differential scanning patterns even when presented with male stimuli. However, if infants' knowledge of the structure of the human body generalizes to include both genders, infants should perform equally well on male and female bodies. Such studies would shed light on infants' general knowledge of the structure of the human body regardless of sex.

Overall, the findings from the current study add to the existing literature on infant cognition and body knowledge development. By 5 months of age, infants' knowledge of bodies is sophisticated enough to include knowledge about the specific location of the parts that make up the body. It is possible that infants younger than this are also sensitive to the precise locations of body parts, but that was not evident in the current study. This suggests a higher level of cognition in infancy when it comes to body structure knowledge at 5 months than at 3.5 months. Similarly, previous research has documented other instances of developmental change in cognition (Bhatt, Bertin, Hayden, & Reed, 2005; Heck, Hock, White, Jubran, & Bhatt, 2016) within the first year of life. Bhatt et al. (2005) documented a developmental change in face processing abilities in which 5-

month-olds, but not 3-month-olds, were sensitive to subtle spatial information (like the space between the eyes) in faces, thus suggesting the later development of at least one face processing mechanism. Further, Heck et al., (2016) found that infants at 5 months, but not 3.5 months, looked longer to a face in the presence of a checkerboard distractor when the face was fearful compared to when it was happy or neutral. This finding indicates the development of a mechanism designated to increase infants' attention to negative emotions, which could be a survival mechanism developing early in life. Such developmental changes indicate that social cognition develops between 3.5 and 5 months of age and the developmental change documented in the current study in which 5-month-olds, but not 3.5-month-olds, exhibited sensitivity to specific locations of body parts is another manifestation of such a change.

In conclusion, there were multiple findings of interest in the current study. First, it was found that 5-month-olds, but not 3.5-month-olds, exhibit differential scanning patterns to the specific areas of distortion on images of reorganized versus typically configured bodies. This finding suggests that infants by 5 months of age have enough of a sophisticated representation of the structure of the human body to be able to discern when body parts are not in their canonical locations. Second, it was found that when 5-month-olds viewed headless stimuli, they no longer exhibited such differences in scanning, supporting the notion that infants may benefit from redundant information within a stimulus (i.e., from the face and the body), and rely on such redundancy in order to cue a stimulus as human (Bahrick, et al., 2004; Bhatt et al., 2016). Third, because infants also failed to exhibit differential scanning patterns when the stimuli were missing a body part other than the face/head (arm or leg; Experiment 4) versus when they viewed a whole body, it appears that a complete form is needed in order for 5-month-olds to exhibit differential scanning patterns. Overall, infants at 5 months of age are sensitive to precise locations of body parts, and thus demonstrate a rather sophisticated knowledge of the structure of the human body; however, the role that the face/head and limbs play in body structure knowledge development is still unclear and future studies need to address this question.

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# RACHEL L. JUBRAN

## Education

| | |
|---|---|
| Ph.D. | Experimental Psychology<br>Expected August 2019<br>Dissertation: "*Body processing and attentional patterns in infancy*"<br>University of Kentucky, Lexington, KY<br>Advisor: Dr. Ramesh S. Bhatt, Ph.D. |
| M.S. | Experimental Psychology<br>December, 2016<br>Thesis: "*Body part structure knowledge in infancy"*<br>University of Kentucky, Lexington, KY<br>Advisor: Dr. Ramesh S. Bhatt, Ph.D. |
| B.S. | Psychology<br>May, 2014<br>Georgia Southern University, Statesboro, GA<br>Cum Laude |

## Professional Positions

Research Assistant, Department of Psychology, University of Kentucky
Under Ramesh Bhatt (Fall 2014, Spring 2015, Spring 2016, Fall 2016, Spring 2018, Fall 2018, Spring 2019)

## Awards

**<u>Received</u>**

| | |
|---|---|
| 2018 | Arts and Sciences Certificate for Outstanding Teaching |
| 2015-2018 | Research Challenge Trust Fund (RCTF) Travel Award |
| 2015-2016 | University of Kentucky Graduate School Travel Award |

**<u>Nominated</u>**

| | |
|---|---|
| 2018 | Psychology Department's Nominee for Provost's Outstanding Teaching Assistant Award |

**Submitted**

2018 American Psychological Foundation Graduate Research Scholarship

## Professional Publications

**Peer-Reviewed Manuscripts**

12. White, H., **Jubran, R**., Heck, A., Chroust, A., & Bhatt, R.S. (2019). Sex-specific scanning in infancy: Developmental changes in the use of face/head and body information. *Journal of Experimental Child Psychology. 182*, 126-143.

11. White, H., **Jubran, R.,** Chroust, A., Heck, A., & Bhatt, R. S. (2018). Dichotomous perception of animal categories in infancy. *Visual Cognition. 26(10)*, 764-799.

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