Biological Motion and Human Morphology Prime Infants' Categorization of Basic-Level Categories

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Abstract

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Infants as young as 9 months of age categorize objects at a global level of inclusiveness (i.e., animals versus vehicles [Mandler & McDonough, 1993; Oakes, Madole, & Cohen, 1991]) but not at the basic level (i.e., dogs versus fish [Mandler & McDonough, 1993]). To test the hypothesis that priming infants with morphological and dynamic cues could influence their ability to categorize, 10-month-olds were exposed to either a point-light display video of a human walking, a video containing a rotating image of a human body, or a control video of randomly moving point-light dots. Following priming, infants completed a basic-level categorization task as well as gaze following and object retrieval tasks. Results revealed that only biological motion and human morphology primed infants' ability to categorize animate, but not inanimate pairs, nor gaze following or object retrieval abilities. These findings suggest that both dynamic and morphological features are used by infants for categorization within the animate domain.

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Biological motion and human morphology prime infants' categorization of basic-level categories

Categorization is one of the most fundamental cognitive processes infants engage in when they first begin to explore the world around them. Over the last two decades, empirical investigations have demonstrated that infants are remarkably successful at forming categories at varying levels of inclusiveness (Mandler, 2000, 1993; Oakes, Madole, & Cohen, 1991; Pauen, 2002; Quinn & Eimas, 1996). At the broadest level, the animate-inanimate (A/I) distinction requires the ability to differentiate animates, such as humans and animals, from inanimates, such as furniture and vehicles. This important ontological distinction provides the building blocks for the mind's representation of all objects and beings in the world (Rakison & Poulin-Dubois, 2001). Superordinate categories include a subset of objects from the A/I domain, for example, animals and furniture or humans and vehicles. At a less inclusive level, basic-level categories contrast different types of superordinate level objects, for example dogs and birds.

Empirical examinations of infants' categorization abilities to date support the notion that infants learn categories in a top-down manner, from superordinate to basic-level **(**Mandler, Bauer, & McDonough, 1991; Pauen, 2002; Poulin-Dubois, Graham, & Sippola, 1995**).** Using the sequential touching and object examination procedures, several cross sectional and longitudinal studies conducted with infants 7 to 30 months of age have shown that superordinate categories are a prerequisite for the development of less inclusive basic-level categories (Mandler & Bauer, 1988; Mandler, Bauer & McDonough, 1991; Mandler & McDonough, 1993, 1998; Poulin-Dubois, Graham & Sippola, 1995; Pauen, 2002). While these studies provide strong evidence for a superordinate-to-basic-level shift in category development, additional evidence suggests that the sequence of categorization development in infancy may begin at the animate-inanimate level (i.e. an animate-inanimate-to-superordinate-to-basic-level sequence).

Using a familiarization-novelty preference procedure Quinn and Eimas (1998) found that 3- and 4-month-olds' categorization of humans tended to be too broad as it included members of the animal kingdom (e.g. cats, horses and fish). Although infants possessed a broader concept of 'humans' than older children and adults they differentiated the human category from inanimate objects such as cars. Thus, this finding provides an important basis for the current study as it suggests that by 3 and 4 months of age, infants are tuned into the various perceptual features (e.g. morphology and motion) which differentiate animates from inanimates.

In a first study to investigate infants' ability to generalize motion properties of people across the animate domain, Poulin-Dubois, Frenkiel-Fishman, Nayer, and Johnson (2006) examined whether infants generalize animate motion properties (e.g. self-propelled motion, etc.) from humans to non-human animals. Using an imitation procedure, the experimenter demonstrated various actions using people. Infants were next given the choice to either use animals or vehicles to imitate the actions. It was found that both 16- and 20-month-old infants were more likely to use animals, than vehicles, to imitate actions demonstrated by the experimenter. This research provided the first evidence to suggest that infants as young as 16 months of age possess knowledge regarding the common motion properties of animates.

In another investigation, Rostad, Yott and Poulin-Dubois (submitted) tested 14- and 18-month-old infants' animate-inanimate categorization abilities using the sequential touching procedure. It was found that 18-month-olds successfully categorized at the A-I level, while 14-month-olds possessed an emerging appreciation for the animate-inanimate distinction. A second experiment using a modified sequential touching procedure revealed that 14-month-old infants' successfully differentiated animate-inanimate categories. This task used an array of hybrid switched-parts objects, including a person with wheels, and a vehicle with legs. Fourteen month-old infants' preferred to categorize hybrid objects according to their ontological animate-inanimate status, rather than their parts (e.g. legs vs. wheels). Taken together, these studies provide preliminary evidence that animate-inanimate categorization abilities emerge before, or at least around the same time as, superordinate level abilities.

While the developmental sequence of different category contrasts in infancy has been well researched (e.g. the global-to-basic-level shift), much less is known about the types of information infants use to accomplish the challenging task of forming category concepts. It has been hypothesized that infants form conceptual categories by extracting both static morphological and dynamic features of objects and use this information to determine an object's category membership (Mandler, 1992; Rakison & Poulin-Dubois, 2001). While it may be possible to categorize perceptually dissimilar objects using morphology alone (e.g. differentiation of animals and vehicles using component parts or shape), the differentiation of perceptually similar objects (e.g. birds and airplanes) likely requires more sophisticated knowledge of dynamic attributes. In an experiment designed to control for perceptual similarity of objects, Mandler and McDonough (1993) tested whether 9- and 11-month-old infants differentiate perceptually similar, but ontologically different, objects – birds and airplanes. To increase the perceptual similarity of the stimuli all birds had outstretched wings and two airplanes had markings which resembled mouths, teeth and eyes. Using the object examination procedure, both 9- and 11-month-old infants successfully categorized birds and airplanes. These results suggest that infants extract other information in addition to object morphology when making categorical distinctions. Mandler (2004) hypothesized that the perception of motion characteristics provide infants with conceptual knowledge about the "kinds of things" objects are. Specifically, she proposed that infants' animate-inanimate conceptual categories are formed on the basis of differentiating objects capable of self-starting, moving non-linearly, and causing action at a distance from those which cannot.

Building on the work of Mandler and her predecessors (Premack, 1990; Leslie, 1995), Rakison and Poulin-Dubois (2001) proposed that the foundation for the animate-inanimate distinction in infancy relies on the following five animate motion cues: a) onset of motion (self-propelled vs. caused motion), b) type of causal role (agent vs. recipient), c) form of causal action (action at a distance vs. action from contact), d) pattern of interaction (contingent vs. non-contingent), and e) line of trajectory (irregular vs. smooth). The current research was designed to examine the proposition that an additional animacy cue – type of motion (biological vs. non biological) also facilitates A-I categorization in infancy. Biological motion is defined as "the motion patterns characteristic of living organisms in locomotion" (Johansson, 1973). Humans' perception of biological motion has been studied using both point-light displays (e.g. Bertenthal, Proffitt, & Cutting, 1984; Johansson, 1973; Simion, Regolin, & Bulf, 2008; Troje & Chang, 2010; Troje & Westhoff, 2006), and animated schematics of ordinary shapes (Schlottmann & Ray, 2010; Schlottmann & Surian, 1999). Although both types of stimuli capture the essence of biological motion (e.g. non-rigid, rhythmic motion), point-light displays also contain discernible structure-from-motion features as well as local gravitational features (Troje, 2008).

Evidence suggesting that infants are sensitive to biological motion has been found in two day-old newborn infants who are able to discriminate between biological motion point-light displays depicting the movement of a hen and random motion (Simion, Regolin, & Bulf, 2008). Infants in this study also preferred to look at upright, as opposed to up-side-down, biological motion displays. The fact that neonates preferred to look at the upright motion of hens suggests that humans are innately sensitive to the particular motion signatures of biological motion. According to Troje and Westhoff (2006) the human visual system is sensitive to the gravity-defined dynamic characteristics of terrestrial animals in locomotion. At a local level, the rhythmic, pendulum-like motion of limbs is unlikely to be produced by inanimate objects. Thus, both structure-from-motion and local movement of point-light features (e.g. limbs) provides sufficient cues for infants to differentiate biological and non-biological motion.

Research testing older infants has shown that by one year of age infants are able to extract important social-cognitive information from biological motion. Yoon and Johnson (2009) found that 12-month-old infants follow the "gaze" of a human point-light figure who turned to observe a target, despite the absence of morphological features such as eyes or a face. This research suggests that early on biological motion perception is closely integrated with the development of social-cognitive abilities.

Additional evidence that infants extract animacy cues from biological motion has been provided by Schlottmann and Ray (2010) who used animated schematics of biological motion. In this study, 6-month-old infants were habituated to a square moving toward one of two targets. When the targets switched locations at test, infants looked longer when the square moved toward a new goal than a new location, but only if the square moved non-rigidly and rhythmically. These results suggest that infants as young as 6 months of age already link biological motion and goal directedness, thus demonstrating an emerging understanding that things which move biologically possess various animate characteristics (e.g. goal directedness, intentionality, etc.). Taken together, the research discussed above provides confirmatory evidence that in the first year of life infants perceive biological motion as animate and are capable of extracting rich social information, including internal states such as goals and intentions. However, the notion that biological motion perception is integral to infants' differentiation of animate and inanimate concepts has received little empirical attention.

In one of the only studies to examine infants' use of biological motion information in a categorization task Arterberry and Bornstein (2002) found that 9-month-old infants categorize at the global level (animals vs. vehicles) when stimuli combine both static and dynamic attributes. In this study, a series of habituation-transfer experiments examined whether 6- and 9-month-old infants categorize animals and vehicles based on static or dynamic attributes of stimuli. Infants were either habituated to static images and tested with dynamic point-light displays containing one same-category and one out-of-category stimulus, or habituated to dynamic point-light displays and tested with static images containing one same-category and one out-of-category stimulus. Results revealed that only 9-month-olds were able to transfer dynamic category information to static images, however, they were not able to transfer static category information to dynamic displays. Thus, infants who generalized the habituation response from point-light displays of animal motion to static images of animals were believed to do so on the basis of conceptual knowledge of both animal morphology and biological motion properties. This experiment provides a background for the current study in that it demonstrates that biological motion point-light displays can be used in categorization tasks with infants as young as 9 months of age. While Arterberry and Bornstein were able to demonstrate the sophistication of infants' category concepts by showing that 9-month-olds already associate static and dynamic attributes of objects, their experiment did not address the question of whether infants' ability to categorize animate and inanimate objects is facilitated by the use of dynamic information.

The main goal of the current experiment was to shed light on the object features that help infants form taxonomic categories. In order to do so, we examined whether priming infants with biological motion or human morphology would facilitate their performance on an animate, but not inanimate, object categorization task. For this investigation, a task assessing infants' basic-level categorization was selected in order to allow for improvement following administration of the priming stimuli. Previous research using the object examination procedure suggests that global categories are already mastered by 10 months of age, however, basic-level categories are just beginning to emerge (Mandler & McDonough, 1993, 1998). In this study, 80% of 9-month-old infants were successful at global contrasts (animals vs. vehicles) while infants' performance on basic-level contrasts (types of animals or furniture) ranged from 30-50%.

We hypothesized that infants' categorization of basic-level animate pairs (dog vs. fish or dog vs. bird) would be facilitated by human biological motion and human morphology priming conditions, while categorization of basic-level inanimate pairs (chair vs. bed or chair vs. table) would be unaffected by the priming conditions. Furthermore, we hypothesized that this facilitation effect would be specific to categorization abilities, and thus, neither the biological motion nor the morphology condition would influence infants' performance on control tasks measuring socio-cognitive and executive functioning abilities. If categorization of animal contrasts was facilitated by human biological motion and morphology this would demonstrate that infants generalize biological motion characteristics across the animate domain (including both animals and humans). In addition, these results would suggest that infants possess a conceptual understanding of animates as consisting of both human and animal exemplars.

Method

Participants

A total of 97 infants were recruited using birth lists from a public health-service agency. All infants were born within the normal gestational period and experienced no birth complications or reported hearing difficulties. The first language spoken at home was either English (n=42) or French (n= 55) and infants were tested in their respective mother tongue. Of the original sample, 64 infants were included in the final analysis (M_{age}= 10.23 months [*SD*= 0.53]; 32 male). Thirty-three additional infants were excluded due to: fussiness (n= 11), failure to habituate to priming stimuli (n= 20; Biological Motion [n=3], Human Morphology [n=7], Random Motion [n=10]) and parental interference (n= 2).

Materials

MCDI-SF. The short version of the MacArthur-Bates Communicative Development Inventory – Level II (MCDI-SF; Fenson et al., 2000) is an 89-item vocabulary checklist used by parents to indicate words their infant comprehends and produces. A French translation of the MCDI was used to assess language development in infants primarily exposed to French (Trudeau, Frank, & Poulin-Dubois, 1999). The total number of words the infant comprehends is used as an estimate of receptive vocabulary, while the total number of words the infant produces is used as an estimate of expressive vocabulary. A total score is calculated by summing the number of words used both expressively and receptively.

Video Prime Stimuli.

Biological Motion. The human point-light walker video was composed of 11 point-light dots placed on all the major joints of the body (Figure 1). The walker moved rightward with no horizontal translation, as if walking on a treadmill. In the creation of the human walker, motion capture data consisting of 20 steps (10 gait cycles) was taken from a human subject who walked at a comfortable pace on a treadmill. Eleven marker positions were used to capture the subject's motion at all the major joints of the body. These markers convey important information about both the structure of the body (where the various joints and bones are located) and the dynamic movements of each part (e.g. the velocity of the arm swing vs. the stability of the trunk). Next, the dimensionality of the subject's postures were reduced using principal components analysis and the final video was rendered using BODYBUILDER software (Oxford Metrics) (see Troje, 2002, for a detailed description of the creation of the clip). The final video consisted of one 15 second trial which contained 30 complete cycles of the person walking (0.5 seconds/cycle).

Human Morphology. The human morphology video prime was created using the image of a female wearing black pants and a black sleeveless shirt (Early Cognitive Development Centre, University of Queensland)(Figure 2). The size of the figure was approximately the same height and size as the point-light walker. At the beginning of each trial the image appeared at the top-centre of the screen. The image then moved in a clockwise circle until it reached its starting location (15 seconds/ rotation).

Random Motion. The random motion control video was constructed with the same 11 point-light dots as the biological motion condition (Figure 3). Using VPixx© software (VPixx Technologies Inc.), each dot was assigned a fixed speed and a straight line of trajectory. Dots did not possess the characteristic movements of animate beings such as the ability to change speed, direction, or move contingently with any other dot. Random motion was selected as a control motion condition based on evidence that even when the motion of a human point-light walker is Random (i.e. contingencies and velocities of dots are reversed), it still contains perceptible animacy cues such as directionality (Troje & Westhoff, 2006). Thus, in the random motion condition, directionality was controlled for by having approximately equal numbers of dots move towards the left, right, up and down.

Design.

Each participant was randomly assigned to one of the following three priming conditions: Biological Motion (n=22), Human Morphology (n=21), or Random Motion (n=21).

Procedure.

For the administration of the priming task, a computer monitor measuring 61 centimeters was placed at the infant's eye level at a distance of 104 centimeters from the infant. Three tall black panels (183 centimeters in height) provided a partition between the testing area and the computers used to administer the infant-controlled video primes. Using a Samsung video camera, infants' attention to the video prime was observed on a computer monitor located behind the partition. Infants' attention to the video prime was coded on-line by the experimenter using Habit 2000© software (University of Texas). Each trial began with the presentation of an attention getter (moving green dot with bell sound), which oriented infants' gaze to the screen. If infants looked away for a duration ≥ 2 seconds or if 15 seconds had elapsed, the attention getter was presented, and a new trial began. Infants were presented with a minimum of 4 and a maximum of 14 trials to habituate. Habituation criterion was defined as three consecutive trials where the infants' looking time was less than 50% of their total looking time on the first three trials (Cohen, 2004). Infants who did not habituate in the allotted 14 trials were not included in the final analyses (n= 20).

Object Examination Task

The object examination procedure is based on the habituation-dishabituation paradigm, wherein infants are presented with several exemplars from one category (Trials 1-8), followed by a novel exemplar from the same category (Trial 9), and finally a novel out-of-category exemplar (Trial 10). During Trials 1-8 the infant is habituated to a particular category (e.g. dog) using four different exemplars, each presented two times. Categorization is inferred if infants' attention decreases during the habituation trials and increases with the presentation of the novel out-of-category object (Trial 10), but not the novel within-category object (Trial 9).

Stimuli. Plastic replicas of dogs, fish and birds were used as exemplars from the animal category, while replicas of chairs, tables and beds were used as exemplars from the furniture category (see Figure 4 and 5). All objects were made of hard plastic, wood or metal and were approximately the same size.

Design. Each infant completed two basic-level categorization tasks: one animal categorization task, consisting of either dog-bird or dog-fish contrasts and one furniture categorization task, consisting of either chair-bed or chair-table contrasts. The order of presentation (animal-furniture vs. furniture-animal) and the category of exemplars used at test (dog-bird vs. bird-dog) were counterbalanced.

Procedure. The experimenter was seated across the table facing the infant while the parent sat to the right and slightly behind the infant, in order to stay out of the infants' direct line of sight. Parents were instructed to interact with their infant as little as possible and not to name or point to any of the toys. Each categorization task consisted of 10 trials, each 20 seconds in duration. The experimenter began each trial by placing a toy in front of the infant and directing the infants' attention by saying, "Look at this." At the end of each trial the experimenter removed the toy and immediately administered the next trial. For the duration of the trial, infants were allowed to manipulate the toy as they pleased. If the infant did not show interest in the toy, no attempt was made to direct the infant. When the toy fell or was thrown out of reach, either the experimenter or the parent placed the toy back on the table in front of the infant. All trials were 20 seconds in duration and extra time was not given if the toy fell off the table.

Coding and Reliability. Infants' visual and manual examination behaviour on each trial was coded (Oakes et al., 1991; Ruff, 1986). Examination of toys was operationally defined as clearly focused attention which involved gaze direction, facial expression and object manipulation. Attention during banging or rapid waving of the object was not coded as examination. Coders recorded the duration of infants' examination on each trial by pressing a key, which recorded the total examination time. A second experimenter, blind to which priming condition infants were exposed to coded 25% of the participants. Reliability for the two coders for the 15 randomly selected infants was r= .92 across all trials and r= .96 for the two test trials (9 and 10). The mean difference in infants' examination time between coders was 1.13 seconds for trials 1 through 10 and 0.81 seconds for test trials 9 and 10 only.

Control Tasks

Gaze Following. The gaze following procedure used in this experiment was based on Brooks and Meltzoff (2002). While the infant was engaged in warm-up play at the table the experimenter placed two white cylindrical pedestals (20 centimeters) on the table at a 45 degree angle from the infants' midline**.** Pedestals were constructed so that objects placed on them would be at the infant's eye level. The experimenter knelt behind the table for the duration of the task. Two yellow ducks (16 cm X 9 cm) were placed on the pedestals and were oriented to face each other. Before the trial began, the experimenter removed the warm-up toys and said, "Hi (baby's name)" to orient the infant to look at the experimenter. Once eye contact was established, the experimenter slowly turned her head to face the duck on the right. Each trial started when the experimenter began the head turn and lasted for a duration of 6 seconds. This trial duration was selected based on previous research, which used trial lengths ranging from 5 to 7 seconds (Butterworth & Jarrett, 1991; Caron, Butler & Brooks, 2002; Moore & Corkum, 1998). Following each trial, the ducks were removed from the pedestals and the infant was given a toy to play with during the inter-trial interval (30 seconds). Four trials were administered with the experimenter alternating looking direction between right and left targets.

Coding and Reliability. In accordance with standard practice in gaze following literature (Butler, Caron & Brooks, 2000; Johnson et al., 1998; Moore & Corkum, 1998) a Looking Score was computed based on infants' performance on each trial. Infants' *first look* was used to score each trial as correct (+1) if it matched the target of the experimenter's head turn, incorrect (-1) if it was toward the opposite target, and non-look (0) if the infant did not look at either target. Infants' Looking Score was calculated as the sum of correct (+1), incorrect (-1) and non-looks (0) across the four trials. Looking Scores, thus, had a possible range of values from -4 to +4. An infant's *first look* was operationalized as the first shift in gaze from the mid-line (i.e. eye contact with the experimenter). Gaze following trials where the infant made eye contact with the experimenter, but looked away before the experimenter began the head turn were excluded. In addition, the average duration of the infants' correct first looks was calculated by summing the average duration of each correct first look and dividing by the number of correct trials. Coding for the duration of infants' correct first looks began as soon as infants shifted gaze from the mid-line and ended when infants shifted from fixating on the target. The same independent examiner coded a random sample of 15 infants (25%). Using Cohen's Kappa, inter-rater agreement was calculated for the following dependent measures: direction of infants' first gaze (K=0.93; 96.6% agreement) and looking score (K=0.82; 85.7% agreement). Coder reliability for the duration of infants' correct first looks was calculated as a correlation, r= 0.94.

Transparent Box Detour. The administration of this task, adapted from Diamond (1992), involved the retrieval of a toy from a clear Plexiglass box measuring 15 x 15 x 5 centimeters. The stimulus was constructed so that the box was missing the bottom and one side. The box was placed on the table so that there was only one open side. In order to retrieve the toy from the box, infants needed to determine the location of the open side and reach inside. Infants were presented with a choice of four attractive toys, which included a yellow rubber duck, a red truck, a key ring with fruit and a multi-coloured cube. The experimenter observed which toy the infant seemed to prefer as evidenced by the amount of time the infant spent looking at or playing with each toy, then proceeded to remove all the toys. In all trials, the box was centered in front of the infant, placed at a distance of about 10 centimeters away. The infant was permitted to push or pull the box to change its proximity and could take as long as he or she needed to retrieve the toy. To encourage the infant, the verbal cue "get the toy" was combined with pointing to the toy. The experimenter prevented the infant from lifting the box by placing two fingers on the upper back corners. If an infant was unsuccessful at obtaining the toy the experimenter provided two levels of prompting. In the first level of prompting the experimenter moved the box back and forth from left to right exposing and covering the toy (x3). If this prompt was unsuccessful the experimenter demonstrated how to retrieve the toy by reaching into the open side and taking the toy out and then placing it back inside (x3). If the infant was still unsuccessful, the trial ended and the infant was given one of the non-preferred toys to play with during the inter-trial interval (about 30 seconds). If the infant successfully obtained the toy, he or she was permitted to play with it during the inter-trial interval. The infant was administered two warm-up trials followed by four test trials. During the warm-up trials the opening of the box faced forward and the infant was expected to be able to retrieve the toy independently on at least one of these trials. Infants who were unsuccessful with the warm-up trials were not administered side-facing test trials as these trials were more difficult. Four test trials were administered in which the opening of the box alternated between facing left and right. If the infant was not successful on either of the first two trials and did not benefit from the experimenter's prompting, the second two trials were not administered to avoid unnecessary frustration for the infant.

Coding and Reliability. Trials where the infant lifted the box to obtain the toy were not coded. Additionally, trials in which the infant obtained the toy during the experimenter's prompt demonstration (i.e. when the toy was not placed in the centre of the box or when the experimenter's hand was still in the box) were not coded. All other test trials were coded using the behavioural coding scheme suggested by Diamond (1990) and Bell and Fox (1992). Strategies used by the infant to obtain the toy were coded according to four phases, which are indicative of the infants' developmental level. Infants who reached exclusively in their direct line of sight and consequently were unable to obtain the toy scored a Phase 1. Phase 1 performance included persistent hitting and scratching the closed sides or top of the box. Infants who scored Phase 2 retrieved the toy from the side openings by manipulating the box or bending forward so that the opening could be seen. Phase 2 performance also included infants who reached for the toy using their "awkward hand" (e.g. using their right hand to obtain the toy from the left side opening). In Phase 3, infants bent to look at the toy through the opening but did not need to maintain visual contact with the toy being retrieved. These infants were able to obtain the toy using their same-side hand (e.g. using their right hand to obtain the toy from a box with an opening on the right side). Infants who scored Phase 4 were able to determine the location of the open side by feeling the box and inserting their same-side hand to retrieve the toy. In Phase 4, infants did not need to look at the toy through the open side of the box in order to retrieve it. For each trial, infants were assigned a score of 1 through 4. Infants were also assigned an overall score for both the highest phase they obtained independently and the highest phase obtained with prompting. A subset of 15 infants (25%) were coded by an independent observer. Inter-rater agreement was calculated for the highest phase assigned for independent responses, *K*= 0.81 (86.6% agreement) and the highest phase assigned for prompted responses, *K*= 0.78 (86.7% agreement).

Procedure

During the administration of all four tasks, participants were seated in an infant seat attached to a table while the parent sat behind them to their left side. Infants who became fussy were placed on their parent's lap and parents were told not to look at the screen. Each participant was assigned to one of three video prime conditions where they viewed either a point-light display video of a person walking, a video of a static image of a human body or a control video containing randomly moving point-light dots (see Figures 1-3). Following priming, infants completed an animate and an inanimate object examination task, presented in counterbalanced order. The presentation of control tasks measuring infants' gaze following (Meltzoff, 2005) and executive functioning abilities (Bell & Fox, 1992) was also counterbalanced and was administered either before or after the priming and object examination tasks. That is, the object examination task always followed priming, while the control tasks were either administered before or after. The gaze following and executive functioning tasks were administered to show that a) infants assigned to each of the three groups were of approximately equal cognitive ability and b) that the effects of priming were specific to performance on the categorization task only.

Results

A one-way ANOVA revealed that infants placed in the Biological Motion, Human Morphology and Random Motion conditions did not differ with respect to age, F (2, 61)= 0.26, p= 0.77, (mean ages for the Biological Motion, Human Morphology and Random motion groups were 10.29, 10.26, and 10.26 months, respectively), or combined number of words known receptively and/or expressively, F (2, 61)=2.55, p= 0.09, (mean number of words for the Biological Motion, Human Morphology and Random motion were 15.73, 17.52, and 9.86, respectively). During the video priming infants did not differ in terms of the number of trials taken to habituate in each condition, F (2, 61)= 1.98, p=0.14, (mean number of trials for the Biological Motion, Human Morphology, and Random Motion were 8.10, 9.79, and 9.13, respectively). Whether or not infants habituated did not significantly differ across priming condition, χ^2(2, 94)= 4.45, p= 0.11, (mean proportion of infants who habituated in the Biological Motion, Human Morphology and Random motion were 0.91, 0.76, and 0.70, respectively).

Additional analyses tested whether order of presentation of the various tasks influenced infants' performance. In the Biological Motion and Human Morphology prime conditions, infants' performance on the control tasks did not significantly differ as a function of whether they completed these tasks before or after priming: gaze following looking score, t(37)= -0.18, p= 0.86 (M before= 1.48, M after= 1.57), proportion of correct gaze following trials, t(37)= 0.13, p= 0.90 (M before= 0.60, M after= 0.59), proportion of success on the detour task, t(36)= 1.48, p= 0.89 (M before= 0.27, M after= 0.25), and highest detour phase achieved independently, t(34)= 0.78, p= 0.44 (M before= 2.36, M after= 2.00). These results suggest that priming does not influence infants' performance on tasks which measure gaze following and executive functioning abilities, thought to be unrelated to infants' development of animate-inanimate concepts.

Object Examination. To analyze infants' performance during the habituation phase, the mean examination time on the first block of trials (Trials 1-4) was compared to the second block of trials (Trials 5-8) to determine whether infants habituated to each category of objects. A 2 (Habituation Block [T1-T4/T5-T8]) x 3 (Condition [BM/HM/RM]) x 2 (Category [Animate/ Inanimate]) analysis of variance revealed a significant main effect for Habituation Block, F (2, 61)= 133.92, p<0.01 (M of Block 1= 10.1, M of Block 2= 7.7). Pairwise comparisons (with Bonferroni correction) revealed significant differences in infants' examination between habituation blocks 1 and 2 (Block 1: mean difference ranged from -0.86 to -2.02; Block 2 mean difference range -0.39 to -2.39) and no significant difference in infants' habituation responses across experimental conditions (mean difference in examination between habituation blocks in the Biological Motion, Human Morphology and Random motion were 2.38, 3.07, and 1.85, respectively). A trend for a Habituation Block x Condition interaction was found, F (2,61)= 2.84, p= 0.07, however, post hoc comparisons revealed no significant interactions. No Habituation Block x Category interaction, F (2, 61)= 0.17, p=0.69, and no Habituation Block x Condition x Category interaction, F (2, 61)= 0.55, p=0.58 were found.

A mixed factorial ANOVA with Condition (BM, HM, RM) as between subjects factor and both Category (Animate/ Inanimate) and Trial (8, 9, 10) as within subjects factors was computed to test the effect of priming on infants' ability to categorize animate and inanimate object contrasts (see Table 1). This analysis revealed a significant effect for trial, F (2, 122)= 30.49, p<0.01. Follow-up comparisons for the main effect of Trial revealed that infants' examination increased significantly from Trial 8 to Trial 9 (*M Difference*= 1.42, p=<0.01), indicating that they differentiated the novel within-category object. Comparisons between Trial 9 and Trial 10 indicated that the out-of-category object was also examined longer than the novel within-category object (*M Difference* = 1.80, $p<0.01$).

A significant Trial x Category interaction was also found, F (2, 122)= 3.11, $p< 0.05$. Follow-up comparisons (with Bonferroni corrections) revealed a significant increase in infants' examination between Trial 9 and 10 (*M difference*= 3.11, $p < 0.05$) and Trial 8 and 10 (*M difference*= 2.60, $p < 0.05$) for the animate category objects (see Figure 6). These results suggest that infants were successfully able to categorize animate contrasts across priming groups. Infants, however, did not demonstrate successful categorization for inanimate category objects as evidenced by a non-significant increase in examination between Trial 9 (novel within-category) and Trial 10 (novel out-of-category), *M difference*= 1.00, $p= 0.43$. Infants, however, did respond to within-category novelty as evidenced by a significant increase in examination time between Trial 8 and Trial 9, (*M difference*= 2.33, $p< 0.05$).

Although no significant Condition x Category x Trial interaction was observed, planned comparisons (with Bonferroni corrections) of infants' performance on test trials 9 and 10 were conducted to test the hypothesis that biological motion and human morphology priming facilitate infants' ability to categorize animate, but not inanimate contrasts. The use of planned contrasts when experimental conditions have been designed to test specific a priori hypotheses is recommended (Kline, 2004). These tests revealed that both Biological Motion and Human Morphology primed infants' ability to categorize animate [BM: $t(20)= 3.57$, $p= 0.002$, Cohen's $d=0.83$; HM: $t(20)= 3.09$, $p= 0.006$, Cohen's $d= 0.86$], but not inanimate [BM: $t(20)=1.64$, $p=0.12$, Cohen's $d= 0.45$; HM: $t(20)= 0.66$, $p= 0.52$, Cohen's $d= 0.14$] pairs. In contrast, the Random Motion condition did not prime infants' ability to categorize animate [$t(20)= 0.96$, $p=$

0.35, Cohen's *d*=0.22], or inanimate [*t*(20)= 0.42, *p*=0.68, Cohen's *d*= 0.14] contrasts (see Figure 7).

Control Tasks

Infants assigned to each experimental condition (Biological Motion (n=22), Human Morphology (n=21), Random Motion (n=21)) did not differ in their performance on either the gaze following or transparent box detour task (see Figure 8). These results are described below.

Gaze Following. Infants' mean looking score on the gaze following task was 1.38 (*SD*= 1.59; possible range -4 to +4) and the average duration of correct first looks was 1.10 seconds (*SD*= 0.55). A one way ANOVA revealed no group differences in infants' looking score on the gaze following task, F (2, 53) = 0.67, p= 0.52 or infants' average duration of correct first looks, F (2, 53)=0.19, p=0.83 across the three conditions.

Detour Task. On the transparent box detour task, the highest phase level infants obtained independently was 2.23 (*SD*= 1.36) indicating that, on average, infants were able to obtain the toy without prompting from the experimenter when the box opening was oriented either to the left or right. When infants were taught how to obtain the toy, the highest phase level infants obtained with prompting was 2.63 (*SD*= 1.40), indicating that, on average, infants were better able to obtain the toy with prompting from the experimenter and did so using more sophisticated means (e.g. more infants reached with the "same side" hand). No group differences were found in infants' performance on the detour task for the highest phase level infants obtained for independent performance, F (2, 48)= 0.58, p= 0.56, and in the case of the highest phase level infants obtained for prompted performance, F (2, 48)=1.21, p=0.31.

Discussion

Results of the present study suggest that both human biological motion and morphology facilitate infants' ability to categorize animate, but not inanimate contrasts. These results support our hypothesis that infants use both object morphology and motion characteristics to differentiate object categories. That infants in the human morphology condition were better able to categorize basic-level animate, but not inanimate contrasts, is consistent with previous research demonstrating that infants use object morphology (features, parts, etc.) to make category discriminations at varying levels of abstraction (Cohen & Younger, 1983; Quinn & Eimas, 1996). However, the current research is the first to test whether animate motion cues, specifically, biological motion, also aid infants' ability to categorize.

In the biological motion condition, infants were primed with a point-light display of a human walking and subsequently completed two basic-level categorization tasks. The human point-light walker was selected to provide a conservative test of infants' understanding of biological motion as characteristic of all living beings. Using this prime, facilitation of infants' performance on the categorization task required that infants generalize principles of human biological motion to other perceptually different members of the animate category, such as dogs, fish and birds. That infants' performance on the animal categorization task was facilitated by human biological motion suggests that infants possess a broad concept of animates which includes both humans and animals. Thus, results of the current study both support and extend previous research (Arterberry & Bornstein, 2002; Cohen & Younger, 1983; Mandler, 1992; Quinn & Eimas, 1996, 1998; Rakison & Poulin-Dubois, 2001) by showing that infants as young as 10 months possess a broad concept of animate which is grounded in both morphology and motion analysis.

While it is possible that infants' ability to group humans and animals in the current experiment may be explained by the hypothesis that infants' concept of 'human' broadly includes members of the animal kingdom, as suggested by Quinn and Eimas (1998), research using the object examination procedure has shown that infants are already able to differentiate animals from humans by 10 months-of age (Oakes, Plumert, Lansink & Merryman, 1996). Since 10-month-olds are able to differentiate animals and humans, yet, infants in the current experiment preferred to treat each as members of the broader animate category, it seems likely that infants possess a basic conceptual understanding of the animate-inanimate domain.

The current experiment tested 10-month-olds' ability to categorize contrasts belonging to the superordinate animal (dog-bird, dog-fish) and furniture (chair-table, chair-bed) categories. Within the context of previous research using the object examination procedure, Pauen (2002) found that the basic-level ability to categorize dogs vs. birds and chairs vs. tables emerges between 8 and 12 months of age. In the current study, 10-month-old infants successfully categorized basic-level animal contrasts (dog-bird and dog-fish), but were not able to categorize basic-level furniture contrasts (chair-table and chair-bed). Although it may be tempting to speculate that the developmental precedence of acquiring animal categories before furniture categories can be extended to the animate-inanimate domain (e.g. infants acquire concepts of animates before inanimates), previous research does not support this hypothesis (Mandler, 1993). In a study comparing animal (dog-fish, dog-rabbit) and vehicle (car-airplane, car-motorcycle) contrasts, Mandler found that 9-month-old infants successfully categorized the vehicle contrasts but were unsuccessful in categorizing the animal contrasts. In sum, research to date suggests that by 10 months of age infants can successfully differentiate basic-level animal and vehicle pairs, however, they are not able to differentiate furniture pairs until 12 months of age.

Limitations and Future Directions. In the current study, the complexity of our design proved to be a notable limitation as it reduced our ability to satisfy the sample size required to conduct our analyses with adequate statistical power. In computing a 3 x 2 x 2 ANOVA with an estimated sample size of n=60 and an estimated effect size of 0.25 the a priori power was estimated to be about 0.6 (60% probability of detecting an effect). Given that the current study sought to use priming to boost infants' performance on tasks they were already performing with some degree of accuracy, the estimated effect of priming was thought to be relatively small. Thus, in order to test whether the desired effect was obtained, planned comparisons with Bonferroni corrections were used. To provide an estimate to the total variance explained, effect size estimates were included in the current analyses.

An additional limitation in the current study was that only one level of categorization abilities (basic-level) could be tested using the object examination procedure, given that 10-month-old infants have already mastered superordinate level categorization of animal-vehicle (Mandler & McDonough, 1993; Oakes, Madole & Cohen 1991), animal-people (Oakes, Plumert, Lansink, & Merryman, 1996), and animal-furniture (Mandler & McDonough, 1998; Pauen, 2002) contrasts using this method. The use of basic-level pairs in the current study limited our ability to make inferences concerning the question of whether biological motion facilitates infants' ability to differentiate animate from inanimate. Rather what we have shown is that infants are better able to differentiate two classes of animate objects (e.g. dogs and birds or dogs and fish) following exposure to biological motion**.** In order to show that biological motion is pivotal to the development of the animate-inanimate distinction in infancy it would be necessary that the current study be extended using a categorization procedure in which the facilitation of superordinate categorization abilities can be assessed. Ongoing research in our laboratory is currently testing whether biological motion primes 12-month-olds' ability to categorize animals and vehicles (superordinate level) using the sequential touching procedure. Replication and extension of the current study in an experiment testing whether animate motion and morphology prime infants' ability to categorize at a broader level should strengthen our ability to adopt a rich interpretation of infants' abilities. Specifically, that infants possess conceptual knowledge of the animate domain and use this knowledge to differentiate object categories at varying levels of abstraction. A thorough understanding of the components involved in the development of categorization abilities in typically developing infants will provide a basis for future investigations concerning how this process may differ among individuals with Autism Spectrum Disorder (ASD). To date, deficits in the perception of biological motion have already been identified in this population (Annaz et al., 2009; Blake et al., 2003). Thus, future research may examine whether difficulties in the perception of biological motion (e.g. showing a lack of visual preference for biological motion) predict difficulties in individual's ability to categorize at various levels of abstraction. Finally, the use of an experimental methodology to compare and contrast the process involved in category learning among typically developing infants and individuals with ASD may ultimately lead to the development of new intervention strategies to improve categorization skills in both populations.

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Figures

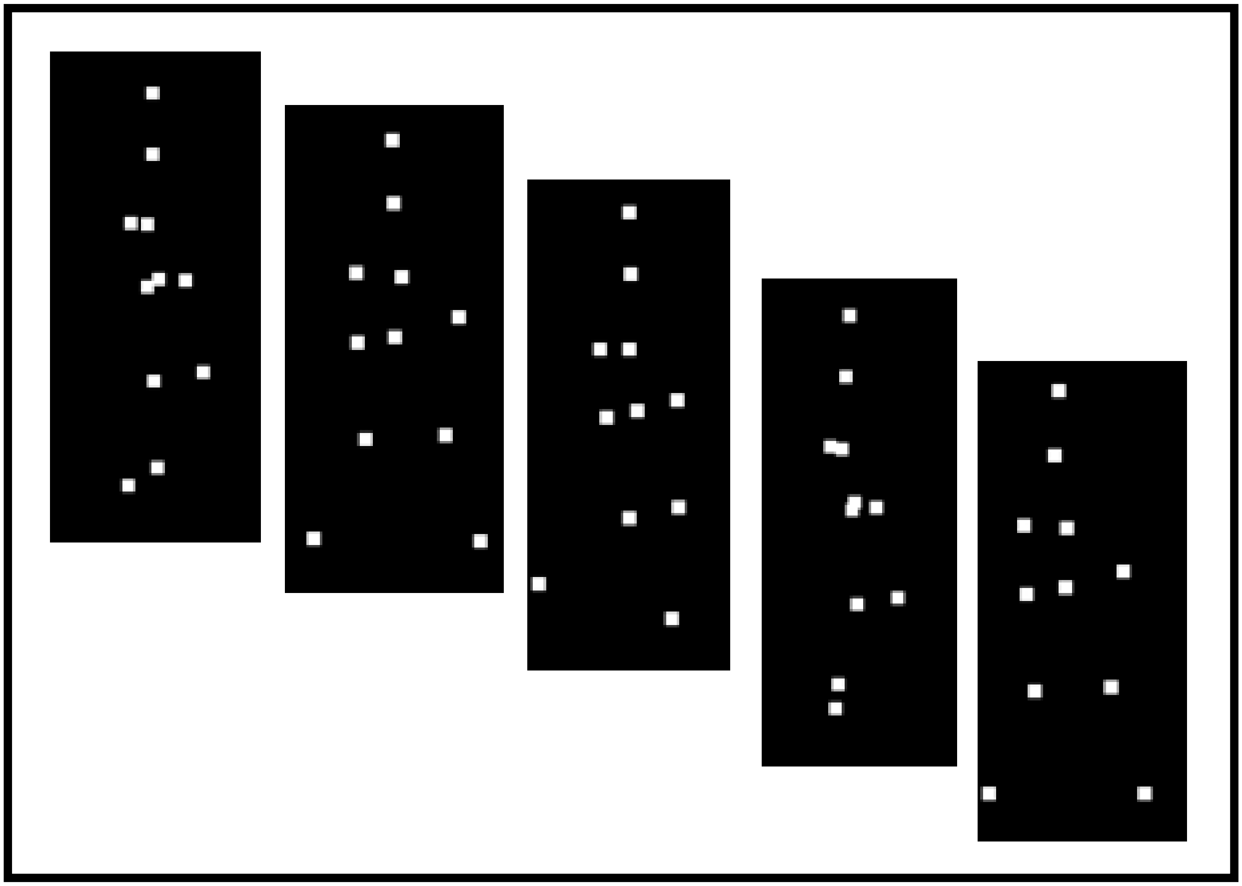

Figure 1: Biological Motion priming (5 successive frames)

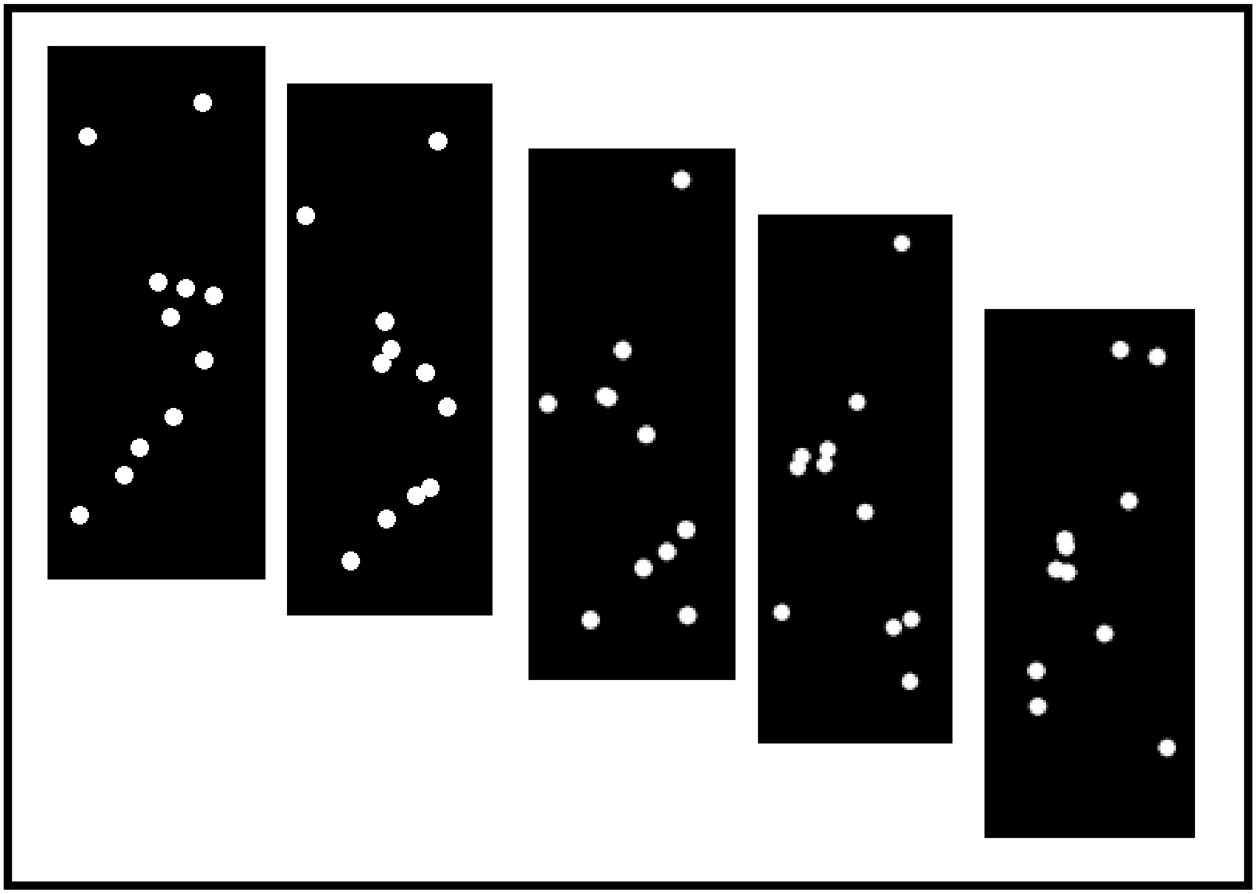

Figure 2: Random Motion control video (5 successive frames)

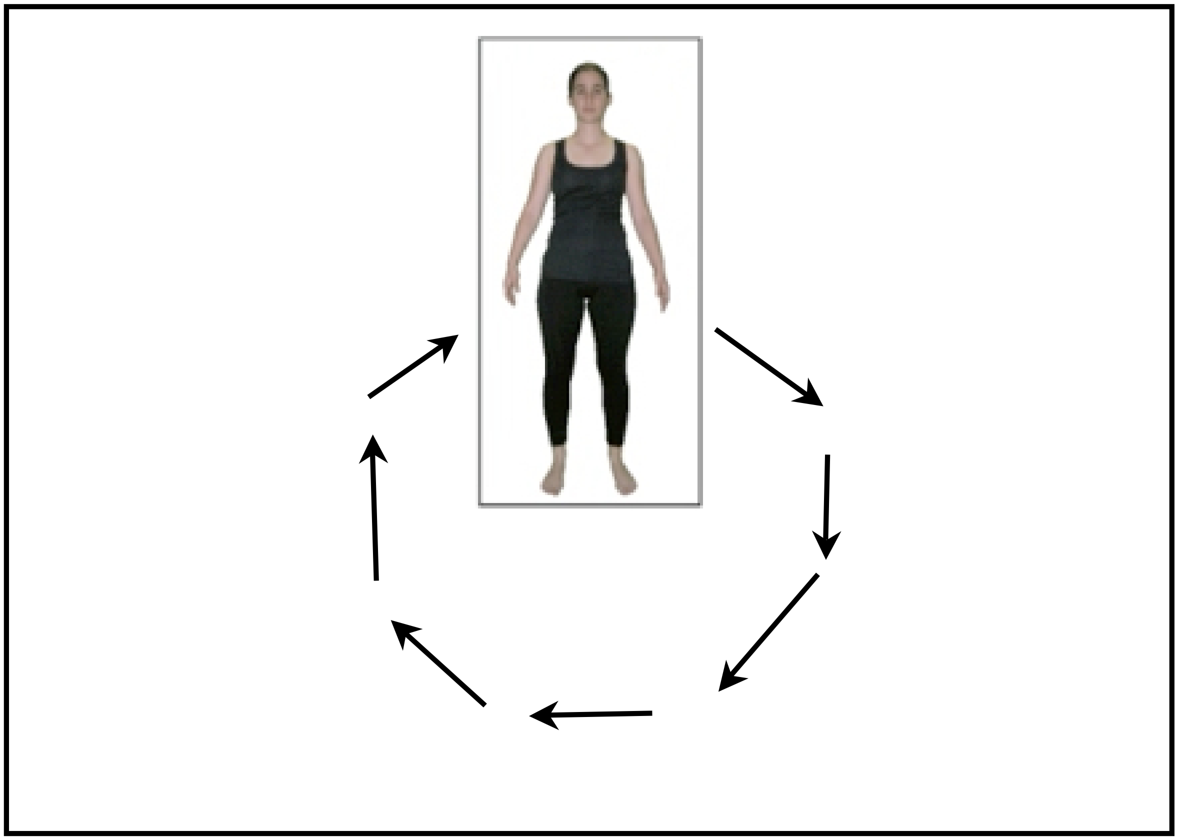

Figure 3: Human Morphology prime-presented as a static rotating image on screen

Figure 4: Object examination animate stimuli (from top left clockwise):

Dogs- standard poodle, husky, bernese, golden lab, dalmatian
Birds- duck, eagle, rooster, goose, ostrich
Fish- shark, blue and yellow fish, sperm whale, orca, dolphin.

Figure 5: Object examination inanimate stimuli (from top left clockwise):

Chairs- rocking chair, living room chair, red chair, plaid kitchen chair, velvet dining room chair
Tables- rectangular coffee table, blue kitchen table, oval coffee table, nightstand, children's table
Beds- pink and orange bed, yellow floral bed, striped bed, gold and pink bed, blue bed

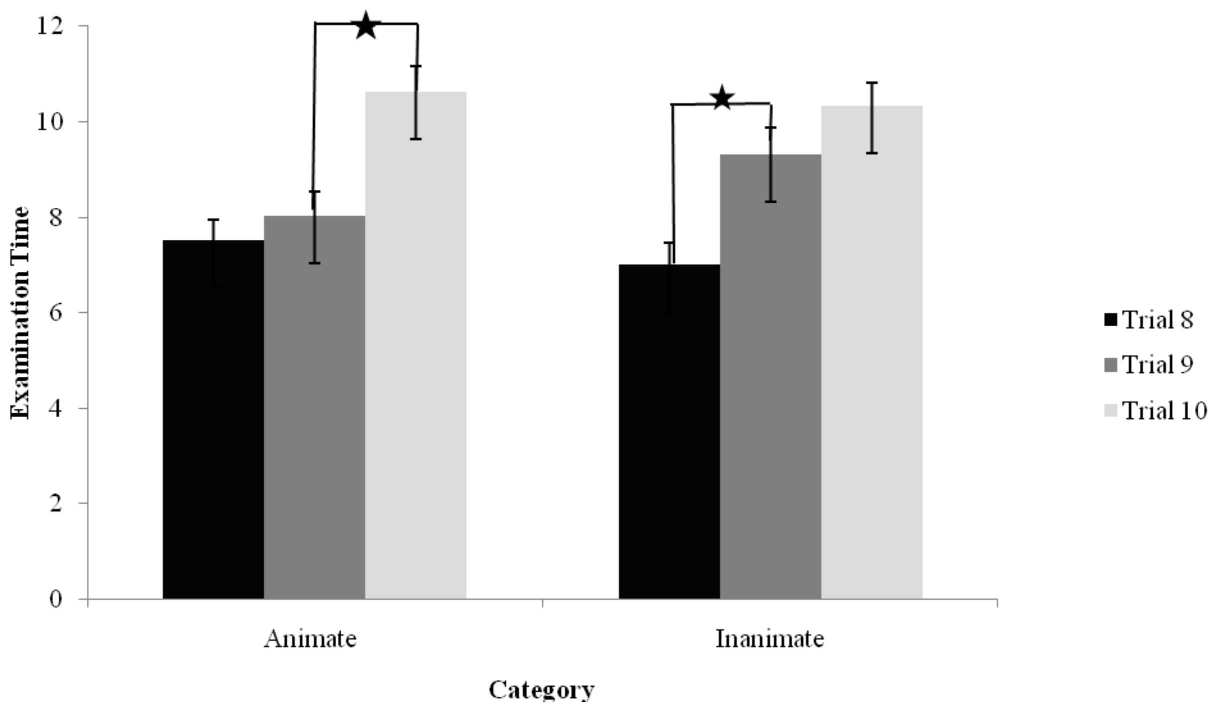

Figure 6: Total examination time on each trial as a function of category

★ *p <0.05*

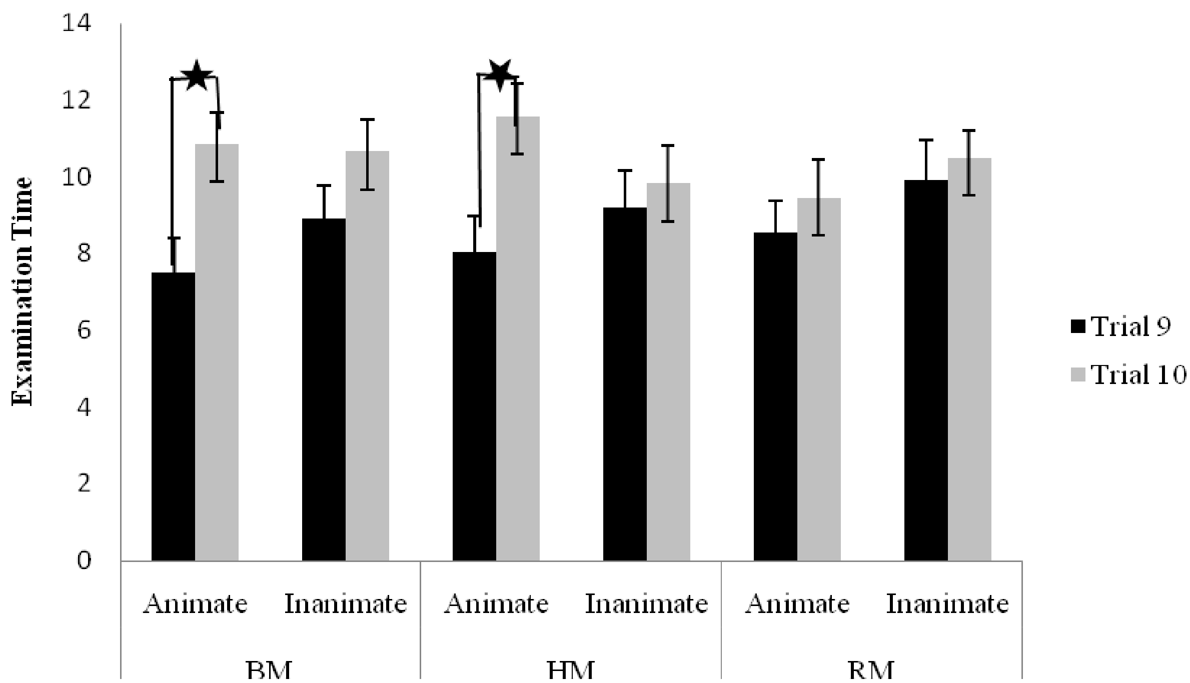

Figure 7: Total examination time on test trials as a function of category and condition

Note: BM= Biological Motion, HM= Human Morphology, RM= Random Motion

★ *p* <0.01

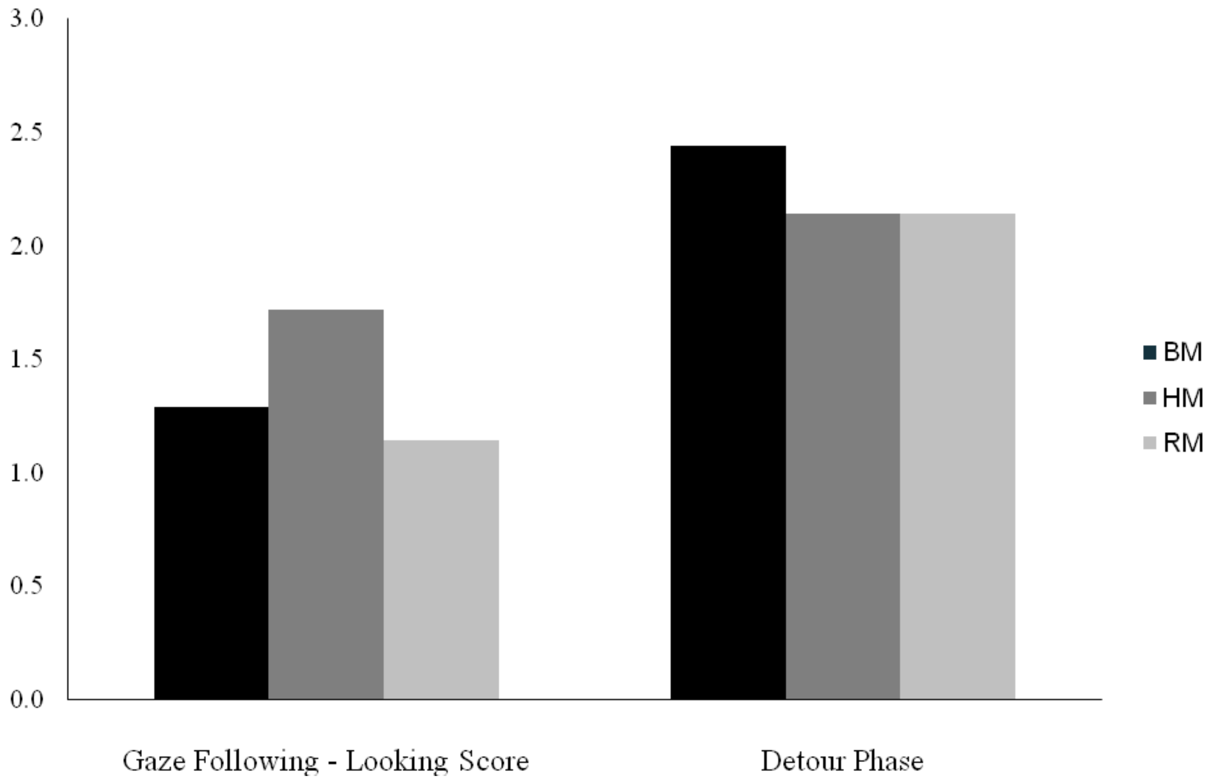

Figure 8: Infants' performance on control tasks

Note: BM= Biological Motion, HM= Human Morphology, RM= Random Motion

Tables

	Condition	Category	Trial	M difference	Standard Error of Mean Difference	*p*
Trial [a]			8 to 9	1.42	0.37	<0.01
			9 to 10	1.80	0.47	<0.01
Trial x Category [b]		Animate	8 to 9	0.51	0.49	*ns*
			9 to 10	3.11	0.59	<0.05
			8 to 10	3.11	0.59	<0.05
		Inanimate	8 to 9	2.33	0.56	<0.05
			9 to 10	1.00	0.67	*ns*
			8 to 10	3.33	0.53	<0.05

Table 1: Results of the mixed factorial ANOVA

[a] Main effect for Trial: F (2, 122)= 30.49, p<0.01
[b] Trial x Category Interaction: F (2, 122)= 3.11, p< 0.05

Appendices

Appendix A: Parental Consent Form

Parental Consent Form

This is to state that I agree to allow my child to participate in a research project being conducted by Dr. Diane Poulin-Dubois, in collaboration with graduate student Kristyn Wright of Concordia University.

A. PURPOSE

I have been informed that the purpose of the research is to examine the development of concept formation during infancy and its relation to cognitive development.

B. PROCEDURES

The present investigation involves the presentation of two short animated videos and play-based tasks. In the first video, your child will watch animated objects (e.g. caterpillar, truck) moving on the screen. In the second video, moving objects will be depicted as dots. Following the video presentation, your child will have an opportunity to play with a variety of toys. What we would like to know is whether the video demonstration will influence your child's interest in different categories of toys. Your child will also participate in two other activities with the experimenter. The first activity examines your child's ability to follow the experimenter's gaze to an object. The second activity examines problem solving and flexible thinking styles using a task that requires your child to obtain a desirable toy.

The whole session should last approximately 45 minutes. During all tasks, your child will be sitting either on your lap or in a child seat and you will be seated directly behind. We will videotape your child's responses and all tapes will be treated in the strictest of confidentiality.

C. RISKS AND BENEFITS

Your child will be given a certificate of merit at the end of the session as a thank-you for his/her participation. Also, you will be offered 20$ for your participation.

There is one condition which may result in the researchers being required to break the confidentiality of your child's participation. There are no procedures in this investigation that inquire about child maltreatment directly. However, by the laws of Québec and Canada, if the researchers discover information that indicates the possibility of child maltreatment, or that your child is at risk for imminent harm, they are required to disclose this information to the appropriate agencies. If this concern emerges, the lead researcher, Dr. Diane Poulin-Dubois, will discuss the reasons for this concern with you and will advise you of what steps will have to be taken.

D. CONDITIONS OF PARTICIPATION

I understand that I am free to withdraw my consent and discontinue my participation at any time without negative consequences, and that the experimenter will gladly answer any questions that might arise during the course of the research.

I understand that my participation in this study is confidential (i.e. the researchers will know, but will not disclose my identity).

I understand that the data from this study may be published, though no individual scores will be reported.

I HAVE CAREFULLY STUDIED THE ABOVE AND UNDERSTAND THIS AGREEMENT. I FREELY CONSENT AND VOLUNTARILY AGREE TO HAVE MY CHILD PARTICIPATE IN THIS STUDY.

MY CHILD'S NAME (please print) ___________________________________

MY NAME (please print) ____

SIGNATURE __________________________ DATE ___________________

WITNESSED BY _______________________ DATE ___________________

I would be interested in participating in other studies with my child in the future (yes/ no): _______

If at any time you have questions about your rights as a research participant, you are free to contact Adela Reid, Research Ethics and Compliance Officer, Concordia University, at (514) 848-2424 ext 7481 or by email at areid@alcor.concordia.ca

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Participant # ____________ Researcher: __________________

Participated in other studies during the same visit:

Name of study	Subject #	Tested by

Appendix B: Demographics

Participant Information

Infant's first name: Date of Birth: ________________________

Infant's last name: Gender: ___________

Language(s) spoken at home (and other places):____

Mother's first name: ______________________ Father's first name: ________________

Mother's maiden name: _____________________ Father's last name:____________

Address: ________________________________ City: ______________________________

Postal Code:______________________________ E-mail: ______________________________

Telephone #:______________home _________________work

_________________mom _________________work dad

Mother's occupation:______________________ Father's occupation:_________________

Mother's education (highest level attained):____

Father's education (highest level attained):____

Mother's marital status:___________________ Father's marital status:_________________

Please answer the following general information questions about your child:

Birth weight:_____________ Length of pregnancy:_______weeks

Birth order:______________(e.g., 1 = 1st child)

Number of children in family:____________

Were there any complications during the pregnancy?______________________________

Has your child had any major medical problems?___________________________________

Does your child have any hearing or vision problems?_______________________________

** Have you ever been contacted by another university to participate in one of their studies?
(Yes/No): _____________________________________

** If you answered yes, please name the university: ____________________________________

Participant # :_____________ Researcher:______________

Appendix C: Coding Sheets

Biological Motion Task

Subject number: __________
Date Tested: ____________________
Language: ______________________

Sex: F M
Date of birth: ________________

Tested by: ________________
Coder: ____________________

Comments:____
____

Habituation Trials

Order : _________
Condition:______________

Habituated: Y N
Number of Trials to Habituate: ____________

Criterion: ___________s
Criterion reached at: __________s

Hab Trials	Looking time (s)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	

Object Examination Task

Subject number: __________ Sex: F M Tested by: ________________

Date Tested: ____________________ Date of birth: ________________ Coder: ____________________

Language: ______________________

Comments:____
____

Test Trials

Order : _________

Habituation Categories : Animate ____ or Inanimate ____

Target Toy : _________

Habituation Categories : Animate ____ or Inanimate ____

Target Toy : _________

OE 1:

Hab Trials	Toy	Examining Duration
1		
2		
3		
4		
5		
6		
7		
8		
Test Trials		
1		
2		

OE 2:

Hab Trials	Toy	Examining Duration
1		
2		
3		
4		
5		
6		
7		
8		
Test Trials		
1		
2		

Gaze Following Task

Subject number: __________Sex: F M Tested by: ________________

Date Tested: ____________________ Date of birth: ________________ Coder: ____________________

Language: ______________________

Comments:____

____

Order : _________

(Trials where infants look down during the onset of head turning are marked N/A)

Makes eye contact w/experimenter after name called:	Y	N	
T1: Follows gaze to toy	Y	N	Duration:__________
Makes eye contact w/experimenter after name called:	Y	N	
T2: Follows gaze to toy	Y	N	Duration:__________
Makes eye contact w/experimenter after name called:	Y	N	
T3: Follows gaze to toy	Y	N	Duration:__________
Makes eye contact w/experimenter after name called:	Y	N	
T4: Follows gaze to toy	Y	N	Duration:__________

Total Looking Score: ______________ (target looks= +1, non-target looks = -1, looking away= 0)

Average Duration of correct looks:________________

Average number of correct looks: _______/4

Detour Task

Subject number: __________Sex: F M Tested by: ________________
Date Tested: ____________________ Date of birth: ________________ Coder: ____________________
Language: ______________________

Comments:____
____

Order : _________

Warm-ups

T1: Opening at front Y N (only go to T2 if unsuccessful at T1)
T2: Opening at front Y N

T3: Opening at front (after teaching) Y N
(if no on **all** of T1 - T3 do not continue; If correct on one or more trials go to T4)

Test Trials	**(Indep)**		**(teaching)**		**Phase (Indep)**				**(teaching)**			
T4: Opening at Right	Y	N	Y	N	1	2	3	4	1	2	3	4
T5: Opening at Left	Y	N	Y	N	1	2	3	4	1	2	3	4

(if unsuccessful with teaching, discontinue; if successful with teaching, continue)

	(Indep)		**(teaching)**		**Phase (Indep)**				**(teaching)**			
T6: Opening at Right	Y	N	Y	N	1	2	3	4	1	2	3	4
T7: Opening at Left	Y	N	Y	N	1	2	3	4	1	2	3	4

Highest Phase Attained (without teaching): ______________________________

Highest Phase Attained (with teaching):_________________________________

Phase 1: only able to reach in their direct line of sight, includes persistent hitting or scratching the closed side. May include taking active steps such as shifting body position or the box, but still reached exclusively in the direct line of sight. Code as a **NO** for left/right orientations. Success may be achieved in **front-open** trials only.

Phase 2: bend and look at the toy through the front opening before sitting up and retrieving the toy while looking through the closed top of the box. Manipulated the box so that the opening could be seen. Leaning forward and retrieving the toy with the **"awkward hand" (opposite hand).**

Phase 3: leaned over and looking in the open side, straightened up, then use the **same-side hand** to retrieve the toy. The initial look through the opening at the beginning was enough to retrieve the toy.

Phase 4: determined the location of the opening by feeling the sides of the box, then inserting the hand in the open side to grab the toy. Retrieved the object without viewing it through the opening.