Biological motion perception and the animate-inanimate distinction in typically-developing children and children with Autism Spectrum Disorder

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Abstract

Biological motion perception and the animate-inanimate distinction in typically-developing children and children with Autism Spectrum Disorder

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The present dissertation had two main objectives. The first objective was to investigate the development of naïve biological reasoning among typically-developing (TD) children and children with high-functioning Autism Spectrum Disorder (HF-ASD). Secondly, the potential link between biological motion understanding and the ability to form the animate-inanimate (A-I) distinction in both TD and HF-ASD children was evaluated. The first study examined the development of the A-I distinction among typically-developing 4- and 5- year-old children, and established that around 5 years of age children are able to form taxonomic A-I categories. Interestingly, when given the opportunity to form categories based on either taxonomic or thematic rules many children switched to categorizing thematically.

The second study examined another aspect of naïve biology, namely the ability to identify biological motion among TD children and children with HF-ASD. This study was the first to compare point-light and schematic presentations of biological motion. The point-light biological motion task required children to identify degraded motion of a human, a cat, a bicycle, and a truck. The schematic biological motion task tested whether children associate expansion-contraction motion with the animate category. Across both motion identification tasks children with HF-ASD were unimpaired in identifying biological motion.

The final study investigated the development of naïve biology among children with HF-ASD and also sought to determine whether motion perception is linked to the formation of A-I concepts. Children with HF-ASD were unimpaired in their ability to form broad A-I categories. In contrast to what has been found during the infancy period, TD preschool children did not prioritize motion cues when forming A-I categories. Rather, it is hypothesized that pre-school children rely on more global representations of naïve biology that include other non-obvious attributes of animates. Similarly, among children with HF-ASD no relationship between prioritization of attention to biological motion and children's ability to form the A-I distinction was found. However, children with HF-ASD who engaged more in the active process of visually comparing biological and non-biological motion were better at forming A-I categories. Taken together, the results of these studies indicate that children with HF-ASD were unimpaired on multiple aspects of naïve biological reasoning, specifically, A-I taxonomic category formation and the identification of biological motion. Additionally, the results of this research also suggest that while TD infants rely on motion cues to guide the formation of A-I categories, school-aged children use more global representations of naïve biology that include other perceptual cues and features.

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I thank Diane Poulin-Dubois, my research supervisor, who has been a source of guidance throughout the process of completing this dissertation. Diane's dedication and enthusiasm for research is unparalleled. I also wish to thank the Autism Research Training (ART) program, a Canadian Institutes of Health Research strategic initiative in autism research. Through the ART program I was fortunate to meet with many experts in the field and learn about a variety of current directions in the field of autism research. In particular, this program facilitated a unique mentorship with Elizabeth Kelley, who co-advised me on many aspects of conducting research with an ASD population. Tackling the challenge of conducting research in cognitive development with both typically-developing children and children with Autism Spectrum Disorder was made possible with the expertise of both Diane and Elizabeth. I have come away with the critical thinking abilities required to conduct research across both areas of development. Each of their unique perspectives has shaped the way I view the importance of research, and the process of scientific inquiry. Thank you!

The love and support of my friends, family, and partner are greatly appreciated. I thank my fiancé, Ariella Kleiman who has been incredibly patient, understanding, and encouraging throughout this process. I thank my fellow graduate students, Elizabeth Hebert, Levi Riven, Jessica Senn, Danit Nitka, Shawanna Barrett, and Hilary Duncan for their sage words, spontaneity, and adventures. The wisdom and support of fellow lab members, Ivy Brooker, Sabrina Chiarella, Jessica Yott, Cristina Crivello, and Jackie Legacy has been wonderful and will not be forgotten.

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Contribution of Authors

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Relative Contributions

I proposed the overall research topic to my thesis supervisor Dr. Diane Poulin-Dubois, and suggested the collaboration with Dr. Elizabeth Kelley at Queen's University. This collaboration was facilitated by my participation in the Autism Research Training (ART) Program, a Canadian Institutes of Health Research strategic initiative in autism research. Through this program, Dr. Kelley was selected as a research mentor and the ART program provided funding for me to travel to her lab to collect a portion of my dissertation data. I worked closely with Diane and Elizabeth in conceptualizing the study methods and design, as well as selecting the experimental stimuli. Prior to testing, I completed the process of ethical approval for this research at the institutional review boards of Concordia University, Queen's University, and the Montreal Children's Hospital. Next, recruitment letters were sent out, and follow-up phone calls were completed with the assistance of Monyka Rodriguez, laboratory coordinator. Monyka contacted French-speaking participants, while I contacted English-speaking participants. I completed all testing of English participants as the primary experimenter. The primary experimenter for French participants with ASD was Jenny Coutu for experimental tasks and Sabrina Chiarella, Ph.D., for the cognitive battery. I completed the testing of participants onsite in the ASD Studies Lab at Queen's University with the assistance of laboratory volunteers. I coded 100% of the samples for each manuscript and Jenny Coutu coded the reliability sample for all three manuscripts. I was responsible for data entry, statistical analysis, interpretation, and preparation and revisions to the three manuscripts for publication. For each manuscript, I wrote the first draft, and both Drs. Diane Poulin-Dubois and Elizabeth Kelley provided feedback. As a part of knowledge translation efforts in the Cognitive and Language Development Laboratory, a summary of the results of each study was sent to the participating families via the biannual newsletter.

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CHAPTER 1

General Introduction

Within the field of cognitive sciences decades of debate have surrounded the question of whether the mind can be parsed into different domains of knowledge (for review, see Barrett & Kurzban, 2006). In a Fodorian sense, a domain of knowledge is "modular," which implies both specificity and encapsulation of information from other psychological systems (Fodor, 1983). This is, however, not what is meant when referring to naïve theories as domains of knowledge. Although there exists a number of different accounts for the development of foundational knowledge (i.e. naïve theories), in the present thesis the *theory* theory perspective is adopted, rather than a modular approach. The *theory* theory is a constructivist approach that suggests that children acquire knowledge by observing the world around them and continuously updating and revising their internal models, similar to the way a scientist proposes and revises theories (Wellman & Gelman, 1992, 1998). Within this framework, the development of naïve theories is untaught and emerges early on in development as infants and children accumulate experiences with the world around them. These theories include both domain-specific information (e.g., psychology, biology, physics), as well as domain-general knowledge such as the ability to make similarity judgments. Naïve theories provide an organizational framework for knowledge that encompasses the realms of biology (e.g., living things; Carey, 1985), psychology (e.g., the psychological world; Wellman, 1990), and physics (e.g., the physical world; Hayes, 1979). Wellman and Gelman (1992) suggest that acquiring knowledge of people, plants, animals, and artifacts is one of the most fundamental tasks of child development. The focus of the present dissertation is to explore and compare the development of a naïve biological theory in both typically-developing (TD) children as well as children with Autism Spectrum Disorder (ASD).

Naïve theories of biology encompass every-day understandings of phenomena such as life, death, growth, reproduction, and inheritance (Carey, 1985; Inagaki & Hatano, 2006). Inagaki and Hatano (2006) suggested that a naïve theory of biology must contain two components: 1) the animate-inanimate (A-I) distinction, and 2) an understanding of the properties of living things or mechanisms for biological events. In the extant literature, a host of studies have investigated how young children reason about various biological properties (Gottfried & Gelman, 2005; Inagaki & Hatano, 1996; Jipson & Gelman, 2007; Rhodes & Gelman, 2009), however, the development of children's ability to explicitly form the A-I distinction has yet to be investigated. The A-I distinction involves the ability to form both animate and inanimate categories. The animate category consists of both people and animals, while the inanimate category consists of furniture, vehicles, clothing, and tools.

The developmental precursors for the A-I distinction have been shown to be in place early on in infancy, within the first year of life (Opfer & Gelman, 2011). Infants are hypothesized to learn the A-I distinction by attending to various correlated attributes, including both static (e.g. featural information) and dynamic (self-initiated, goal-directed movement) animacy cues (Opfer & Gelman, 2011; Rakison & Poulin-Dubois, 2001). A rich body of research has examined the role of various motion cues in infants' development of the animate concept (Arterberry & Bornstien, 2002; Mandler 1992; 2000, Premack, 1990; Poulin-Dubois, Crivello, & Wright, 2015; Rakison & Poulin-Dubois, 2001; Trauble, Pauen, & Poulin-Dubois, 2014). By 6 months of age, infants have been shown to form expectations about objects based on their movement and expect that people, but not objects, will move in a goal-directed manner (Woodward, 1998). Seven-month-olds also have been shown to attend to whether something is capable of changing speed or direction, and use this information to form expectations about the animate or inanimate identity of an ambiguous stimuli (Trauble, Pauen, & Poulin-Dubois, 2014).

The processing of biological motion has been hypothesized to relate to the development of the ability to differentiate animate and inanimate entities (Gelman & Opfer, 2002; Mandler, 1992; Opfer & Gelman, 2011; Rakison & Poulin-Dubois, 2001). In support of this hypothesis, it has also been shown that exposing 12-month-olds to the biological motion of a human walking, depicted in point-light display, improves their ability to categorize contrasts that span the animate-inanimate distinction (e.g., animals and vehicles), but not category contrasts containing only inanimates (Poulin-Dubois, Crivello, & Wright, 2015). Thus, infants' use of information conveyed by animate motion may be considered the beginnings of the development of an implicit form of naïve biological understanding. The introduction to the present thesis discusses the development of naïve biology beginning with a review of the literature examining the perception of animate motion, followed by the animate-inanimate categorical distinction. Each section discusses what is known about the development of each of these capacities in both typically-developing (TD) children and children with Autism Spectrum Disorder (ASD).

Biological motion perception in typical development

Biological motion is defined as the movement patterns of living things. The predisposition to visually orient toward biological motion and prefer this type of motion, compared to non-biological motion, has been demonstrated among 2-day-old newborns (Simion, Regolin, & Bulf, 2008). Among TD children the special status biological motion holds has been replicated using a variety of methodologies including, point-light display (Klin, Lin, Gorrindo, Ramsay, & Jones, 2009; Morita et al., 2012; Simion et al., 2008), schematic biological motion (e.g., the Michotte "caterpillar" stimulus; Michotte, 1963; Schlottmann & Ray, 2010), as well as the motion of a single animated dot (Rutherford, Pennington, & Rogers, 2006; Schultz & Bulthoff, 2013).

Point-light biological motion displays are composed of dots that represent the different joints of biological entities in motion (Johansson, 1973). This motion is typically rendered as white dots on a black background, which move contingently with one another, according to the principles of gravity. Many experimental paradigms assessing the perception of point-light biological motion have measured the ability to identify biological motion under a variety of conditions such as short presentation intervals (e.g., 200ms), manipulating thresholds for detecting biological motion (Annaz et al., 2010; Blake, Turner, Smoski, Pozdol, & Stone, 2003), identifying a biological form among noise (Bertenthal & Pinto, 1994), or identifying the direction of the point-light walker within different gradients of noise (Cutting, Moore, & Morrison, 1988).

Point-light biological motion stimuli contain a perceptable form, which also provide cues relating to the animate or inanimate status of the stimulus. Although this may be seen as confounding motion and form cues, Troje and colleagues (Chang & Troje, 2009; Troje & Westhoff, 2006; Troje, 2013) have shown that displays containing just the dots representing the feet are enough to induce the perception of animacy, without the presence of the human form. It has also been shown that although TD 5-year-olds accurately identify the point-light biological motion of humans, dogs, and birds, they fail to accurately identify these entities when presented with still frames of just the form contained in each motion scene (Pavlova, Krägeloh-Mann, Sokolov, & Birbaumer, 2001). Thus, it seems that motion, rather than form, is the critical cue driving the perception of animacy.

While early studies of point-light biological motion (Johansson, 1973) were primarily focused on mechanisms of perceptual organization (e.g., how the visual system integrates the movement of each individual dot into the percept of a coherent whole), more recent research has shifted to examining the social significance of biological motion perception. Human point-light displays have been shown to not only provide a rich source for information about personal attributes such as gender (Mather & Murdoch, 1994; Troje, 2002), age (Montepare & Zebrowitz-McArthur, 1988), emotions (Atkinson, Dittrich, Gemmell, & Young, 2004; Clarke, Bradshaw, Field, Hampson, & Rose, 2005), and personality traits (Troje, 2008), but these displays have also been shown to provide socially relevant information including the perception of deception (Ruenson & Frykholm, 1983; Sebanz & Shiffrar, 2009) and intentions (Hohmann, Troje, Olmos, & Munzert, 2011).

Although the use of point-light displays has largely dominated research on biological motion perception, other methodologies exist and stand to add complementarity to these investigations. Classic studies by Michotte (1963), Heider and Simmel (1944), Premack (1990), and Tremoulet and Feldman (2000) demonstrate how the motion of simple geometric forms is sufficient to give rise to the impression of animacy. The Michotte (1963) schematic 'caterpillar' stimulus consists of a rectangle that moves in a manner similar to a caterpillar, by extending on one end (i.e. the front), while contracting at the other end (i.e. the back). This non-rigid, expansion-contraction movement has been shown to elicit the perception of goal-directedness in infants as young as 6 months of age (Schlottmann & Ray, 2010); by 3 years of age this motion is judged as 'animal-like' by TD children (Schlottmann, Allen, Linderoth, & Hesketh, 2002); and by 9 years of age it is described as looking like a caterpillar, snake, or slug (Congiu, Schlottmann, & Ray, 2010). One advantage of using schematic biological motion over point-light displays is that schematic motion stimuli do not provide information about the morphology or form of the entity, and therefore the attribution of animacy is based exclusively on motion cues. However, the majority of studies testing biological motion perception in children with ASD have primarily used point-light displays. Thus, one aim of the present dissertation was to compare and contrast performance across these two methodologies in both TD children and children with ASD (Study 2).

Biological motion perception in children with Autism Spectrum Disorder

In contrast to TD toddlers, 2- and 3-year olds with ASD fail to visually orient toward biological motion displays (Falck-Ytter, Rehnberg, & Bölte, 2013; Klin et al., 2009). These deficits in biological motion perception, or visual orienting to social stimuli, may be critical in explaining the myriad of social-cognitive symptoms characteristic of individuals with ASD (Dakin & Frith, 2005; Kaiser & Shiffrar, 2013; Klin, Jones, Schultz, Volkmar, & Cohen, 2002;

Pavlova, 2011; Swettenham et al., 1998). Among children with ASD, a relationship between biological motion perception and measures of social competence has been demonstrated (Klin et al., 2002). Klin and colleagues (2002) showed that children's visual fixation patterns while viewing social and non-social stimuli were related to their scores on standardized measures of social competence. Additionally, severity of autism-spectrum related symptoms on the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000) has also been shown to correlate with children's ability to detect human point-light biological motion (Blake et al., 2003).

Much of the research now suggests that early deficits in the perception of biological motion among young children with ASD are remediated, or compensated for, by adolescence or early adulthood (Cleary, Looney, Brady, & Fitzgerald, 2013; Freitag et al., 2008; Hubert et al., 2007; Moore, Hobson, & Lee, 1997; Murphy, Brady, Fitzgerald, & Troje, 2009; Rutherford & Troje, 2012; Saygin, Cook, & Blakemore, 2010). However, adults with ASD who no longer show impairments in sensitivity to biological motion continue to demonstrate significant deficits in social-cognitive skills. Further, Rutherford and Troje (2012) did not find a relationship between individual differences in sensitivity to biological motion and adults' score on the ADOS. However, the sample in this study was relatively small and may have been underpowered to detect an effect. In an analog sample of adult undergraduates, individual differences in sensitivity to biological motion were shown to relate to social-cognitive abilities (Kaiser & Shiffrar, 2013).

At present, investigations of biological motion perception in ASD have been primarily limited to designs using point-light displays and have seldom been conducted using other methods such as animated schematic biological motion. To our knowledge, only two studies have been conducted using schematic biological motion with children with ASD (Congiu et al., 2010; Ray & Schlottmann, 2007). Ray and Schlottmann (2007) investigated the perception of launch (physical cause) and reaction (psychological cause) events using schematic animations that moved either biologically (non-rigidly) or inanimately (rigidly) among children with ASD. Simple instructions were given using 1-and 2-word utterances to facilitate comprehension. Children with ASD were shown to appropriately attribute psychological causality to events where the agent moved non-rigidly, but demonstrated deficits in interpreting launch events when the agent moved rigidly (i.e., children with ASD did not attribute physical causation). In this study, the Sally-Anne task (Baron-Cohen, Leslie, & Frith, 1985) was also used to evaluate children's theory-of-mind. In this task children meet two puppets – Sally and Anne. Sally takes a marble, places it in her basket, and then walks away. While Sally is gone, Anne takes the marble out of Sally's basket and places it in her own box. When Sally returns, the child is asked where will Sally look for her marble? To pass the test, children must indicate that Sally will look where she left it, rather than its current location. In this study, performance on the Sally-Anne task was not related to performance on launch or reaction tasks in TD children, children with learning disabilities (LD), or children with ASD. In a follow-up study, Congiu and colleagues (2010) presented older high-functioning children with different variations of the same launch stimuli used by Ray and Schlottmann (2007). Although 13-year-old children with high-functioning ASD (HF-ASD) did not show difficulty understanding physical and psychological causality based on animate-inanimate motion cues, they performed more poorly when asked to describe the non-rigid, biological motion, stimulus and were less likely to provide animate descriptions (e.g. caterpillar, snake). Among children with ASD, only 37% of children described the stimulus as animate (compared to 77% of TD children), while 42% of ASD children described it incorrectly as inanimate (e.g. rectangles). In this study, the use of an open-response format may have underestimated children's animacy understanding as it allowed children with ASD to provide literal descriptions (e.g. rectangles) instead of more abstract descriptions of what the rectangle looks like (e.g., a caterpillar).

The animate-inanimate distinction in typical development

Theories of infant cognitive development have suggested that the A-I distinction is formed on the basis of observable biological information, the most salient of which are motion cues. Within the first two years of life, infants discriminate animate from inanimate motion characteristics, and begin to associate these characteristics with particular objects or classes of objects (Rakison & Poulin-Dubois, 2001). Evidence using the sequential touching categorization procedure suggests that an implicit form of the A-I distinction emerges between 14 and 18 months of age (Rostad, Yott, & Poulin-Dubois, 2012). Rakison and Poulin-Dubois (2001) synthesized the literature concerning the various motion cues involved in the formation of the A-I distinction: animate motion is self-propelled (Premack, 1990), has an irregular line of trajectory (Mandler, 1992), can involve action at a distance, moves contingently with other entities, is an agent of action (Gelman & Spelke, 1981), is goal-directed, and intentional. Notably, missing from this description of characteristics is biological motion cues.

To investigate the hypothesis that biological motion is an additional motion cue involved in the development of the A-I distinction, Poulin-Dubois, Crivello and Wright (2015) primed 12-month-old infants with either biological or random motion and measured their subsequent categorization abilities. In this study, biological motion was shown to facilitate infants' categorization of contrasts that crossed the animate-inanimate divide (e.g., animals vs. vehicles), but not contrasts that were uniformly inanimate (e.g., furniture vs. vehicles). Although an implicit understanding of the A-I distinction in infancy has been shown to involve the perception of biological motion, whether these cues continue to be important to children's ability to form explicit concepts of animate and inanimate has not been investigated. Thus, one goal of the present dissertation was to investigate whether motion cues continue to be important to the development of the A-I distinction in childhood (Study 3).

While infants' ability to form taxonomic categories relies on the fact that exemplars of the same category possess correlated perceptual information (e.g., legs are correlated with walking) (Quinn, 2000; Quinn, Eimas, & Rosenkrantz, 1993; Quinn & Eimas, 1997; Rakison & Butterworth, 1998; Rakison, 2003), the formation of A-I categories in childhood has been hypothesized to rely on biological properties such as independent motion, growth, possession of internal parts, and internal thoughts (Gelman & Markman, 1986; Massey & Gelman, 1988; Opfer & Gelman, 2011; Rhodes & Gelman, 2009; Rosengren, Gelman, Kalish, & McCormick, 1991). The body of research investigating the development of children's ability to form explicit A-I concepts has shown that between 4 and 6 years of age, children's categories are more conceptually based and include the ability to make categorical inferences based on properties such as the ability to eat, grow, think, and feel (Gottfried & Gelman, 2005; Inagaki & Hatano, 1996; Jipson & Gelman, 2007; Margett & Witherington, 2011; Massey & Gelman, 1988; Rhodes & Gelman, 2009). Much of the research addressing the development of the A-I distinction in pre-school children focuses on children's ability to attribute various properties to animates, however, few studies have investigated the A-I distinction in terms of children's categorization abilities. In one study investigating children's understanding of animate-inanimate taxonomy, Sigel (1953) presented 7- 9- and 11-year-olds with pre-formed A-I categories and asked children to name the category. While 7-year-olds were unable to label A-I categories, 40% of 9-year olds identified the category "living things" while only 15% were able to identify the category "non-living things." Rather curiously, no additional improvement in children's ability to label A-I categories occurred between 9 and 11 years of age. This study relied heavily on children's verbal abstraction abilities, general language ability, and development, and therefore may have masked children's knowledge of the A-I distinction. The use of tasks that require children to actively form A-I categories, rather than label pre-formed categories, may be more appropriate in measuring children's knowledge of the A-I distinction. However, a thorough investigation of the development of A-I taxonomic categories among pre-school children has yet to be conducted, and thus, formed the rationale for Study 1 of the present dissertation.

The animate-inanimate distinction in children with Autism Spectrum Disorder

Whether children with ASD form the A-I distinction by attending to the same information as TD children, or do so on the same developmental timetable, has also not been investigated. In the extant literature, there has yet to be an investigation of how children with ASD form the broadest, animate-inanimate level category. However, results from previous research examining lower level basic (e.g., dog, truck) and superordinate (e.g., furniture, vehicle) level categories suggest that children with ASD organize semantic categories in fundamentally the same way as TD children. In one of the first studies to examine categorization skills in ASD, Tager-Flusberg (1985a) showed that children with ASD were able to categorize images of basic and superordinate-level categories as accurately as TD children, matched on verbal mental age. However, other research showed that children with ASD (mental age of 9 years) were impaired in categorizing representational objects from basic and superordinate level categories compared to both individuals with intellectual disability and TD children (Shulman, Yirmiya, & Greenbaum, 1995). Furthermore, another study showed that although children with ASD (mental age of 10 years) were as accurate as TD children in categorizing basic and superordinate level categories, their speed of lexical access was slower, particularly when exemplars were less typical instances of a particular category (e.g., peacock is a less typical member of the bird category) (Gastgeb, Strauss, & Minshew, 2006). Among adolescents with a history of ASD who have achieved optimal outcome (i.e., few, if any, symptoms present) residual deficits in categorical induction have been shown to persist (Naigles, Kelley, Troyb, & Fein, 2013).

Although A-I category formation has yet to be investigated in children with ASD, there is reason to hypothesize that this would be particularly challenging in comparison to categorization at lower levels of inclusiveness. Importantly, A-I categories possess fewer shared perceptual features and therefore cannot be easily formed using a rule-based strategy, unlike lower level categories such as dogs, or vehicles. Children with ASD have been shown to rely on a rule-based approach to categorization (Klinger & Dawson, 2001). Furthermore, the detail-focused cognitive style characteristic of ASD (Happé & Frith, 2006) may make it difficult for these children to identify broader categories such as animates and inanimates. The potential link between motion perception and the development of categorization abilities has also yet to be investigated in this group.

Rationale

Taken together, the literature examining the development of naïve biological reasoning in childhood is missing some key components identified by Inagaki and Hatano (2006), namely, an investigation of the development of the A-I taxonomic categories. Thus, the first goal of the present dissertation was to investigate the development of A-I taxonomic categories among TD preschool aged children (**Goal 1)**. The review of the literature on biological motion perception also revealed a disproportionate number of studies that used point-light displays as a measure of biological motion perception. However, biological motion can also be presented using an animated schematic representation. The second goal of the present research was, therefore, to compare children's ability to identify biological motion using these two complementary methodologies within a population of TD children and children with ASD **(Goal 2).** Previous research has also shown a link between biological motion perception and social-cognitive abilities. Thus, an additional exploratory aim of the present research was to add to this growing literature by investigating the relation between biological motion identification and social cognitive skills in younger children with ASD than this body of research has previously tested **(Goal 3)**. Furthermore, the body of evidence suggesting a disruption in motion perception in young children with ASD begets the question of whether motion perception might also relate to the development of A-I concepts. In the present dissertation, motion perception was measured both in terms of verbal identification, as well as visual exploration. Thus, an examination of both whether children with ASD were impaired in forming A-I taxonomic categories, as well as whether such categorization abilities relate to the perception of biological motion was conducted **(Goal 4).** Additionally, given the important role motion plays in the development of A-I concepts in TD infants, an investigation of whether motion continues to be influential to the development of TD children’s explicit animate and inanimate concepts comprised the fifth and final goal of this research (**Goal 5)**.

Study 1 addressed the first goal by testing the acquisition of the A-I distinction among TD 4- and 5-year-old children and compared their performance to that of adults (*n* = 20 4-year-olds; *n* = 23 5-year-olds; *n*=21 adults). In this study, children completed two A-I categorization tasks. The first task used a matching-to-sample procedure, wherein children matched pictures that were the same kind of thing by touching images on a touch-screen computer. The second task used a modified object sorting procedure, wherein children sorted object replicas into categories, then provided verbal explanations of the categories they created. Thus, in this study children's ability to verbally reason about A-I categories was also measured.

Study 2 addressed the second and third goals by investigating another aspect of naïve biology – the ability to identify animate and inanimate motion patterns. In this study, two methodologies used to present biological motion, namely, point-light display and animated schematic biological motion were compared and contrasted for a group of TD children and group of children with high-functioning ASD (HF-ASD). In this study, HF-ASD (n = 22) and TD (n = 21) children were matched on gender, verbal mental abilities, and non-verbal mental abilities, which were measured using the Differential Abilities Scale, Second Edition (DAS-II; Elliott, 2007). An additional goal of this study **(Goal 3)** was to investigate whether the ability to identify biological and non-biological motion relates to the social-cognitive abilities of children with ASD, as measured by parental report.

Study 3 addressed the fourth and fifth goals whereby the potential link between individual differences in the perception of biological motion and the ability to form the A-I distinction was investigated in both children with ASD and a matched group of TD children. Children with HF-ASD (n = 18) were matched with TD children (n =18) on gender and verbal mental abilities, which were measured using the Differential Abilities Scale, Second Edition (DAS-II; Elliott, 2007). Children completed a task measuring visual exploration and attention to biological versus mechanical motion. Visual attention, orienting, and visual exploration variables were all examined in relation to A-I categorization abilities among TD children and children with HF-ASD. The categorization tasks used in this study were the same as those reported in Study 1 and therefore provide a measure of A-I categorization using both pictures and object replicas.

CHAPTER 2

The animate-inanimate distinction in preschool children.

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The animate-inanimate distinction in preschool children

Categorization involves the ability to group objects together on the basis of similarity in kind, or a given attribute. Categories may be organized according to a taxonomic structure, which involves a hierarchical system of rules that govern inclusion, (e.g., a taxonomy of species), or they may be formed on the basis of thematic relation (e.g., all things in the house), or perceptual similarity (all things of the same shape) (see Markman, 1989 for a review). Taxonomic categories are organized hierarchically by increasing level of abstraction, or inclusiveness. At the most inclusive level, animate-inanimate (A-I) level categories involve the distinction between living and non-living things. The animate category includes humans, plants, and animals, while the inanimate category includes non-living things (or artefacts), such as furniture and vehicles. Superordinate level categories are narrower and may include a subset of the animate or inanimate category (e.g., people, animals, furniture, or vehicles). Basic level categories are narrower still, and comprise a subset of the superordinate level category. To illustrate this hierarchical category structure, basic level exemplars such as birds, fish, or dogs are all subsumed under the animal superordinate level category, which is further subsumed under the animate category.

The developmental acquisition of different category levels has been investigated using a number of implicit and explicit measures throughout the infancy and childhood periods. During infancy, a superordinate-to-basic-level shift in category development has reliably been observed across experimental paradigms: between 2 and 4 months of age with paradigms based on visual fixation (Arterberry & Bornstein, 2002; Quinn & Johnson, 2000), between 6 to 12 months with object examination tasks (Pauen, 2002), and between 18 and 30 months with sequential touching tasks (Bornstein & Arterberry, 2010; Mandler, Bauer, & McDonough, 1991). Although few studies have investigated the development of animate-inanimate categorization within this developmental timetable, some evidence using the sequential touching procedure suggests that A-I categorization emerges between 14 and 18 months of age (Rostad, Yott, & Poulin-Dubois, 2012); that is, around the same time superordinate level categories have also been shown to emerge with this procedure (18 months: Mandler et al., 1991; between 12 and 18 months: Bornstein & Arterberry, 2010).

In childhood, the development of taxonomic categories has been typically measured using object sorting, matching-to-sample, or labelling tasks. The object sorting procedure measures children's grouping of objects into spatially distinct categories (Starkey, 1981). In this procedure, children are given an array of objects and are instructed to group objects that are 'the same kind of thing.' Unlike the implicit categorization procedures used in infancy, when children spontaneously group objects according to taxonomic relatedness, it is thought to reflect a more conceptual understanding that objects placed in the same group share common properties or functions. In contrast to the free-response format used in the object sorting task, the matching-to-sample task is more structured and allows various constraints to be placed on the types of associations that are possible. In the matching-to-sample procedure one sample image is presented alongside two possible matches, whereby one may share a taxonomic relation, and the other may share a thematic relation with the sample. While the matching-to-sample task has been used to investigate children's preference to form either taxonomic or thematic categories, it has also served to document children's ability to form taxonomic categories by presenting a taxonomic match and an unrelated, rather than thematic, match. By contrasting children's performance on matching-to-sample and object sorting procedures, both the ability to form taxonomic associations (i.e. matching-to-sample), as well as children's relative preference to form taxonomic over thematic associations (i.e. object sorting) can be assessed. In the present study, we sought to examine whether children possess knowledge about taxonomic categories at different levels of inclusiveness, and also consider the impact of salient thematic cues in potentially disrupting children's ability to demonstrate their knowledge of taxonomic associations.

In contrast to research examining the development of categorization abilities in infancy, a reverse pattern has been observed in the development of categories in childhood. Specifically, basic level categories are mastered before broader superordinate level categories (Mervis & Crisafi, 1982; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976; Tager-Flusberg, 1985a). As early as 2 years of age, children have been shown to match objects belonging to the same basic level category, more proficiently than objects belonging to the broader superordinate level category (Daehler, Lonardo, & Bukatko, 1979). Mervis and Crisafi (1982) investigated the acquisition of 2.5-, 4- and 5.5- year-old children's superordinate, basic, and subordinate level categories using a matching-to-sample task. Using simple geometric stimuli, mastery of basic level categories was demonstrated as early as 2.5 years, while mastery of superordinate level categories was acquired by 4 years of age, and mastery of subordinate level categories was acquired by 5.5 years of age. Children's ability to form animate-inanimate level categories, however, was not tested in this study. Using natural and artefact categories in the matching-to-sample procedure Tager-Flusberg (1985a) found that 4- and 5- year-olds categorized proficiently across a range of basic level exemplars, obtaining nearly 100% accuracy. However, children's categorization at the superordinate level was less accurate (82%) and much more variable across the various superordinate level exemplars (66% for vegetables; 92% for animals; 95% for vehicles, 68% for furniture). Other evidence for a basic-to-superordinate level shift in children's category development has been reported across a number of studies using the object sorting procedure (Daehler et al., 1979; Waxman & Gelman, 1986). In one of such studies, Rosch and colleagues (Rosch et al., 1976) showed that 3-year-olds' basic level categorization was superior to their performance at the superordinate level.

Some theorists have suggested that the discrepancy in findings between the infant and early childhood literatures may be explained by differences in the mechanisms children use to form categories. It has been hypothesized that infants' ability to form taxonomic categories relies on the fact that members of the same category have correlated perceptual information (e.g., eyes, limbs, wheels, or wings) (Quinn, 2000; Quinn, Eimas, & Rosenkrantz, 1993; Quinn & Eimas, 1997; Rakison & Butterworth, 1998; Rakison & Poulin-Dubois, 2001; Rakison, 2003), as well as the fact that infants associate other information such as spatial structure and motion path with the kind of thing an object or entity is (Mandler, 2012, 1991, 1992). Although perceptual features continue to play a role in older children's categorization, the formation of categories, in particular, at the animate-inanimate level, also relies on children's ability to understand abstract biological properties such as independent motion, growth, possession of internal parts, and internal thoughts, which are not readily perceptable (Gelman & Markman, 1986; Massey & Gelman, 1988; Opfer & Gelman, 2011; Rhodes & Gelman, 2009; Rosengren, Gelman, Kalish, & McCormick, 1991). Thus, older children's categories are arguably more conceptually based. The different pattern of acquisition of category levels may also reflect a difference between pre-linguistic categories, and categories children form once language is acquired (Gelman & Koenig, 2003). For instance, studies examining maternal input demonstrate that mothers are more likely to label objects at the basic level (e.g., car), rather than use broader, superordinate level, or narrower, subordinate level, terms (e.g., vehicle or Mustang) (Callanan, 1985; Gelman, Coley, Rosengren, Hartman, & Pappas, 1998). Thus, it is not surprising that the basic level category is both the first to develop and the first to be represented in children's expressive language. In the present study, children's verbal abilities were measured in order to determine whether children's relative mastery of language was correlated with performance on the categorization tasks.

In one of the few studies to compare children's animate-inanimate categorization with other levels of category inclusiveness, Sigel (1953) presented 7-, 9-, and 11-year-old children with pre-formed categories (e.g. animals, vehicles, animates, inanimates) and asked children to name the category. Children demonstrated mastery of superordinate level categories between 7 and 9 years of age. Identification of animate and inanimate categories, however, was unsuccessful at 7 years of age (0%), but improved by 9 years of age, wherein 40% of children identified the category 'living things', while only 15% identified the category 'non-living things'. Interestingly, no additional improvement in the identification of animate and inanimate categories was reported by 11 years of age. These results suggest that the animate and inanimate categories are the last to emerge in childhood and are not completely mastered by 11 years of age. Notably, children's ability to form animate and inanimate categories was not directly tested in this study. Instead, children were tested on their identification of A-I concepts using a task that heavily relied on children's verbal abstraction ability. Thus, the use of less verbally demanding tasks may provide a better measure of the development of animate and inanimate categories.

Other studies investigating how pre-schoolers reason about ontological kinds have asked children to generate questions about different animate-inanimate classes or determine whether various properties should be extended to animates or inanimates (i.e., an inferential categorization task). Margett and Witherington (2011) found that 4-year-old children asked more biological questions about plants and animals, compared with immobile artefacts. However, for the class of mobile artefacts, fewer functional questions and more biological questions were asked, suggesting that 4-year-olds overgeneralize the ability to move to be consistent with the category of living things. When asked to classify each exemplar as living or non-living, 4-year-olds classified animals and immobile artefacts correctly. However, when the non-living class engaged in movement (e.g., mobile artefacts such as vehicles), or the living class lacked observable movement (e.g., plants), 4-year-olds were less accurate in their A-I classifications. These results suggest that children's early concepts of living and non-living are biased by the ability to move, or lack thereof. In another study examining pre-schoolers understanding of naïve biology, Massey and Gelman (1988) showed that 3-year-olds extended the biological property of self-propulsion to animates and not animal-like statues or wheeled vehicles on 78% of trials, while 4-year-olds responded correctly on 90% of trials. When asked explicitly whether each item was alive, 3-year-olds responded correctly on 61% of trials, while 4-year-olds were more accurate and responded correctly on 85% of trials. Children's spontaneous verbal responses justifying their categorical inferences were also coded. Animate-inanimate category membership comprised 25% of children's responses (e.g., animal, toy), while explanations relating to enabling parts (15%), general appearance (15%), agency (10%), real vs. pretend (8%), capacity for independent motion (8%), and material composition (5%) comprised the last category of responses children provided.

In a series of experiments comparing how children reason about biology and psychology, Jipson & Gelman (2007) tested whether children extend a number of other properties to animate and inanimate categories. Specifically, they tested whether 3-, 4-, and 5-year-olds extend biological properties (e.g., eat, grow), psychological properties (e.g., think, feel), perceptual properties (e.g., see things, feel ticklish), and artefact properties (e.g., man-made, breakable) to various animate and inanimate objects. By 5 years of age, children were found to extend biological and perceptual properties to animates, but not inanimates. Other research testing the depth of children's understanding of biological properties has explored the nature of internal parts (Gottfried & Gelman, 2005), ability to self-start (Rhodes & Gelman, 2009), and the capacity for growth (Inagaki & Hatano, 1996). Between 3 and 4 years of age children have been shown to develop knowledge of the internal parts of animates and inanimates (Gottfried & Gelman, 2005). However, by 4 years of age children were not able to make the link between internal parts and external events such as movement, or growth. By 5 years of age, children have been shown to understand that animals, but not artefacts, are able to self-start, or move on their own (Rhodes & Gelman, 2009). Five-year-olds also have been shown to differentiate natural kinds from non-living things based on a capacity for growth and have an emerging understanding that natural kinds are also characterized by the need to take in food and water, as well as the possibility of falling ill (Inagaki & Hatano, 1996). Between 5 and 6 years of age, children have also been shown to attribute properties such the ability to grow or die to animals and plants, but not artefacts. Thus, while it is apparent that children 4- to 6- years of age possess knowledge of animate and inanimate kinds, this research has focused primarily on how children generalize specific properties (e.g., kind of movement) to animates or inanimates, and does not address whether children spontaneously group objects according to animate-inanimate taxonomy.

While the body of research using inductive reasoning paradigms has shown that pre-school children possess knowledge about various properties, which are consistent with different ontological kinds, children's ability to form animate and inanimate taxonomic categories has not been thoroughly investigated. That is, while previous studies have shown that children treat animates and inanimates differently when extending various properties to each, few studies have examined how children perform when asked to form, and verbally explain, animate and inanimate taxonomic categories. In the current study, we asked children to group objects taxonomically, but did not provide inductive cues concerning which properties (e.g., biological, psychological, featural) children should attend to when making category decisions. Children's ability to form A-I taxonomic categories was tested using both 2-dimensional and 3-dimensional stimuli, and provided both implicit and explicit measures of children's category knowledge. Children's acquisition of taxonomic categories was measured implicitly using the matching-to-sample task. An object sorting task was also used to examine whether children prefer to conceive of category relations in a taxonomic, as opposed to thematic, manner. Specifically, the extent to which children's animate-inanimate level categorization is influenced by the presence of thematically related stimuli could help to explain why it has been difficult to document the early development of A-I categories in younger children. During the object sorting procedure, children were also explicitly asked to explain why they believe objects in each grouping were the same kind of thing. Thus, the aims of the present research were to: (a) provide an implicit test of children's ability to form animate-inanimate taxonomic categories using matching-to-sample and object sorting tasks, (b) explore how children verbally reason about their categorization choices, specifically which properties they use to justify their decisions, and (c) examine the impact of different task demands on children's performance across categorization tasks.

Method

Participants

Two groups of 4- and 5-year-old children participated (N = 46). An additional group of 21 adults also participated to provide a validation of the matching-to-sample task. Of the 46 children tested, 3 were excluded due to language delay (n = 1) or neurodevelopmental disorder (n = 2). The 4-year-olds had a mean age of 4.65 years (n = 20; 12 males; SD = 0.51 years), while the 5-year-olds had a mean age of 5.87 years (n = 23; 12 males; SD = 0.33 years). One 5-year-old did not complete the matching-to-sample task due to technical difficulties, but was included on the object sorting task. All children were English-speaking and had normal or corrected to normal vision. General cognitive ability was assessed using the Differential Abilities Scale, Second Edition (DAS-II; Elliott, 2007). The verbal comprehension index provided an estimate of children's verbal mental age, which will henceforth be referred to as the child's verbal ability. Thirty-three of the 43 children included in the analyses completed the test.

Materials and Procedure

Children completed the tasks in a fixed order, wherein the matching-to-sample task was administered first, the object sorting task second, and the test of cognitive ability administered last. Such an ordering of tasks was desirable in order to obtain reaction times on the matching-to-sample task that were not influenced by fatigue or practice. Parents either sat behind the child as they completed the tasks, or in an adjacent room.

Matching-to-Sample Categorization Task. The matching-to-sample task was administered using a 30-inch touch-screen computer. Each trial involved presenting children with three detailed colour drawings. To ensure that children's accuracy was not influenced by the presence of atypical members of a category, stimuli were selected based on typicality ratings described in previous research (Rosch & Mervis, 1975; Uyeda & Mandler, 1980; Van Overschelde, Rawson, & Dunlosky, 2004). That is, the most common instances of vehicles, furniture, and animals were selected as stimuli. The majority of images used were gathered from children's picture dictionaries. Exceptionally, photographs of adults in an up-right position were used as stimuli. Careful attention was paid in pairing each sample image with two response options that could not be matched based on size, directional orientation, color, or thematic association.

The matching-to-sample task is a forced-choice test of categorical associations wherein a sample category exemplar is presented and the participant must decide which of two options is the same kind of thing. Each trial began with one centrally located sample picture and two comparison pictures, which were located below, inside a rectangular box. Children completed 5 training trials to become familiar with the task, followed by 24 test trials. Test trials presented three different levels of categorization (each with 8 trials): animate-inanimate, superordinate, and basic level.

The training phase consisted of five subordinate level trials (e.g., breeds of dogs, types of chairs). Children were instructed to "touch the picture here [pointing to both response options] that is the same kind of thing as this [pointing to the sample picture above]." If no response was made after 5 seconds the experimenter prompted the child by asking, "is an [name picture 1] or a [name picture 2] the same kind of thing as this [pointing to the sample picture]?" Feedback about the accuracy of the responses was provided on training trials only, whereby a green "check mark" appeared over correct responses and a red "X" appeared over incorrect responses. If a child responded incorrectly on training trials, the experimenter explained which picture was the correct response. Before the test trials began, children were told that "the computer would not help them find the right picture, but to keep finding the picture they thought was the same kind of thing."

Children were not given feedback on test trials but were simply encouraged to keep going. The presentation of test trials was fixed and pseudo-randomized so that trials of the same categorization level never occurred on more than two consecutive trials. For each categorization level, half of the trials showed an animate exemplar as the sample and half of the trials had an inanimate exemplar. To ensure that children did not develop a response bias, placement of the correct response option was pseudo-randomized so that the correct response never occurred on the same side for more than two consecutive trials; across trials, the correct response occurred equally often on the left and right side.

On animate-inanimate trials, sample images such as cow, chicken, airplane, or couch were presented with comparison images of animates (e.g., people) and inanimates (e.g., car, table, chair, truck, train). On superordinate level trials, images of animals (e.g., bear, horse, donkey, pig) vehicles (e.g., jeep, bus, motorcycle, boat), and furniture (e.g., bed, desk, book case, chair) were presented as samples; one within-category image and one out-of-category image were used as comparison pictures. Basic level trials presented different images of types of birds (e.g. cardinal, hawk), dogs (German Shepard, Golden Retriever), fish (goldfish, bass), chairs (rocking chair, living room chair), tables (night stand, coffee table), cars (sports car, sedan), and trucks (dump truck, pick-up truck). On basic level trials, all three images belonged to the same superordinate class.

Coding. Presentation of trials and recording of responses was programmed using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) so that both accuracy and reaction time (RT) were recorded. Children received a score (proportion correct out of 8 trials) for each categorization level.

Content Validation. How well each trial measures taxonomic associations at each category level was assessed by administering the procedure to a group of adults (n = 21). The percentage of adults who responded correctly was 85% or above on all but one trial, wherein only 10% of adults responded correctly. Thus, this trial was removed from the analyses.

Object Sorting Categorization Task. The object sorting task was adapted from Markman, Cox, and Machida (1981). Children were provided with spatial cues using two transparent plastic bowls into which 8 novel objects were sorted. Whereas other versions of this task (Vygotsky, 1962) measured children's category knowledge by analysing spatial grouping of objects on a table (e.g., distance of objects). Similar to the matching-to-sample task, typical exemplars of each category were selected. Figurines of people included children and adults of different ethnicities wearing different coloured clothing. Animal replicas included a horse, dog, cow, elephant, bird, and fish. Furniture replicas included a bed, desk, table, cabinet, chair, ottoman, and couch. Vehicle replicas included a car, pick-up truck, motorcycle, bus, helicopter, and train.

Children first participated in a brief training phase to become familiar with the task. During this phase the experimenter demonstrated how to complete the task using simple objects. The experimenter began the demonstration by drawing the child's attention to two anchor objects, each placed in transparent bowls (e.g., ice-cream and grapes). The experimenter then demonstrated using a third object, while saying, "if I gave you this one [ice-cream], you would put it here [with ice-cream anchor] because it is the same kind of thing." Following the demonstration, children were given the remaining objects to categorize. Corrective feedback was provided if children made sorting errors. Following each training trial, the experimenter drew the child's attention to the toys placed in each bowl, "we put all the [ice-cream] in this bowl because they are the same kind of thing, and we put all the [grapes] in this bowl because they are the same kind of thing."

Two test trials were administered for each of the three categorization levels (animate-inanimate, superordinate, basic). A total of six test trials were administered, with the presentation order of each level counterbalanced. On test trials, children's attention was directed toward the placement of the anchor objects and children were subsequently handed objects to categorize, one by one. Children were instructed to place each object in the bowl with 'the same kind of thing'. Each trial consisted of 6 objects to be sorted, 3 objects from each category. Following each sorting trial, children's attention was drawn to each bowl and children were asked, "What makes these the same kind of thing?"

At the animate-inanimate level, four possible trial pairings (labelled according to the object anchors) were person-vehicle, person-furniture, animal-vehicle, and animal-furniture. Each child completed one trial with a person as the anchor and one trial with an animal as the anchor, (paired with either a vehicle or furniture as the other anchor). At the animate-inanimate level, an additional superordinate level object (matching the animate anchor) was included, but not scored, to ensure the A-I category contained at least two people and three animals, or vice versa. At the superordinate level, all children completed a vehicle-furniture trial, as well as either an animal-vehicle, or an animal-furniture trial. At the basic level, all children completed one basic level animate trial (dog-bird or cat-fish) and one basic level inanimate trial (chair-table or car-plane).

Coding. The object sorting task was coded for two types of analysis, based on: accuracy of taxonomic sorting and verbal explanation why each group of toys was 'the same kind of thing.' The coding scheme for taxonomic accuracy was developed based on previous object classification studies (Sugarman, 1983). A total score of 2 was given if the child sorted both categories taxonomically without errors. A score of 1 was given if the child made one sorting error (one incorrect category), but sorted the other five objects correctly. A zero score was given if the child made two or more sorting errors. Notably, children who sorted objects according to a thematic, rather than taxonomic, association received a score of 0, having made more than two taxonomic errors. These children, however, were differentiated from children whose sorting did not demonstrate any clear strategy by analysing children's verbal responses about why the objects they grouped, belong together. Each category level was tested with two trials (possible score of 2), therefore, children's performance at each level was computed as a score out of 4.

Children's verbal responses were coded based on a scoring system described in previous research (Kagan, Moss, & Sigel, 1963; Sigel, Anderson, & Shapiro, 1966). Children's explanation of the relationship among objects was coded as taxonomic, thematic, perceptual, or no response. A taxonomic response was any reference to the kind of things the objects are (e.g., living things, animals, vehicles, dogs). A thematic response was any response that employed thematic associations to describe the objects' relationship (e.g., people and their pets [describing the relationship between people and animals], things people use [describing the relationship between furniture and vehicles], things in the house). A perceptual response was coded as any response that focused on common observable features of the objects (e.g., all have eyes, tails, legs, wheels, move on their own). Finally, no response was recorded for children who did not provide a verbal explanation for why they thought each group of objects were alike. Children's verbal responses on all six trials were coded. If children described the relation among objects within the same category level in more than one way, both responses were recorded. See Table 1 for examples of how children's responses were coded. A second experimenter coded 26.6% of the sample and inter-rater reliability was calculated as Kappa = .97 (with 99% agreement) for children's sorting accuracy score. Inter-rater agreement for the classification of children's verbal responses for each category was calculated as Kappa = .92 (with 93% agreement).

Results

Matching-to-Sample Task. On the matching-to-sample task, a 3 (Age) x 3 (Level) ANOVA revealed a significant main effect for Age, $F(2, 60) = 37.67$, $p < .01$, $\eta^2 = .56$, a main effect for Level, $F(2, 120) = 20.92$, $p < .01$, $\eta^2 = .26$, and a significant Age x Level interaction, $F(4, 120) = 5.54$, $p < .01$, $\eta^2 = .16$. Pairwise comparisons were adjusted with Bonferroni correction for multiple comparisons. Comparisons for the effect of Level revealed that performance followed the same pattern, whereby basic level performance ($M = .87$) was similar to superordinate level performance ($M = .89$), which were both superior to animate-inanimate performance ($M = .74$). The main effect of Age showed significant improvement in categorization between 4 ($M = .73$) and 5 ($M = .80$) years of age, M difference = .07, $p = .04$, as well as significant improvement in categorization between 5 years of age ($M = .80$) and adulthood ($M = .97$), M difference = .17, $p < .01$. Pairwise comparisons for the Age x Level interaction are summarized in Figure 1. At the basic level, improvement in performance between 4 and 5 years of age was observed, M difference = 0.11, $p = .01$, while no additional improvements were found between 5 years and adulthood ($p = .17$). Thus, by 5 years of age, basic level categorization was found to be mastered. At the superordinate level, a trend for improvement in performance between 4 and 5 years of age was found, *M* difference = .08, p = .08, and significant improvement in performance between 5 years of age and adulthood was also found, *M* difference = .10, $p = .02$. Thus, although superordinate level categorization by 5 years of age is adequately mastered (> 85% correct) these abilities continue to develop into adulthood. At the animate-inanimate level, performance between 4 and 5 years of age showed little improvement ($M = .61$ to $M = .64$, $p = 1.0$), however, significant improvement in animate-inanimate categorization abilities was demonstrated between 5 years ($M = .64$) of age and adulthood ($M = .97$), $p < .01$.

Further analyses were conducted to determine if children and adults' categorization abilities differed significantly from chance (chance = .5). At the basic and superordinate levels, both 4- and 5-year-old children categorized significantly above chance ($p < .01$). While 4-year-olds' animate-inanimate level categorization was above chance at the trend level, ($M = .61$, SD = .26), $t(19) = 1.89$, $p = .08$, 5-year-olds A-I categorization was significantly greater than chance ($M = .64$, $SD = .21$), $t(21) = 3.14$, $p < .01$. As expected, in adulthood, animate-inanimate categorization performance was also significantly greater than chance ($M = .97$, $SD = .08$), $t(20) = 27.16$, $p <.01$.

A second 3 (Age) x 3 (Level) mixed-model ANOVA examining reaction time on correct trials revealed a significant main effect for Level, $F(2, 98) = 15.89$, $p < .01$, $\eta^2 = .25$, a main effect for Age, $F(2, 49) = 16.18$, $p < .01$, $\eta^2 = .40$, and a significant Age x Level interaction, $F(4, 98) = 2.66$, $p = .04$, $\eta^2 = .10$. Pairwise comparisons for the effect of Level revealed that children's performance followed the same pattern as their response accuracy. That is, reaction time for basic level responses (3.22 sec) was equivalent to superordinate level responses (3.47 sec), p = 1.0, which were both faster than the animate-inanimate level responses (5.14 sec), $p < .01$. Pairwise comparisons for the effect of Age revealed similar reaction times in 4- and 5-year-old children (*M* of 4-year-olds = 5.14 sec, *M* of 5-year-olds = 4.39 sec, $p = .58$), but significantly faster reaction times in adulthood ($M = 2.31$ sec), $p < .01$. Pairwise comparisons for the Age x Level interaction are shown in Figure 2.

To examine developmental changes in the acquisition of category levels between 4 and 5 years of age, children's performance and reaction time (RT) for each level was correlated with age (adults were not included in these analyses). At basic and superordinate levels, categorization performance was positively correlated with age, (basic level: $r(42) = .47$, $p < .01$, superordinate level: $r(42) = .31$, $p < .01$) and negatively correlated with reaction time (basic level RT: $r(42) = -0.43$, $p < .01$, superordinate level RT: $r(42) = -.39$, $p < .01$). However, at the animate-inanimate level, no relationship between age and accuracy $r(42) = .12$, $p = .44$, or reaction time, $r(42) = -.05$, $p = .78$, was observed. In order to determine whether children's verbal abilities were related to performance on the matching-to-sample task, a correlational analysis was conducted. Performance across all levels of the matching-to-sample task was not found to relate to children's verbal abilities, $r(31) = .12$, $p = .52$, nor was reaction time across categorization levels, $r(31) = -.09$, $p = .62$.

Object Sorting Task. To examine children's taxonomic accuracy on the object sorting task a 2 (Age) x 3 (Level) ANOVA was conducted. A significant main effect for Level $F(2, 86) = 67.68$, $p < .01$, $\eta^2 = .62$, but no significant main effect for Age, $F(1,41) = 2.05$, $p = .16$, $\eta^2 = .05$, or Age x Level interaction, $F(2, 82) = .29$, $p = .75$, $\eta^2 = .01$, was found. Pairwise comparisons for the effect of Level revealed that children's performance followed the same pattern as the matching-to-sample categorization task, wherein basic (3.67) and superordinate (3.95) level categorization abilities were equal, yet superior to animate-inanimate (1.53) level abilities. Pairwise comparisons for categorization performance as a function of Level and Age are shown in Figure 3.

To examine developmental changes in performance, age was correlated with performance on the animate – inanimate categorization only, as performance on the basic and superordinate level trials was at ceiling. The relation between age and animate-inanimate object sorting score was not statistically significant, $r(44) = .23$, $p = .14$. Correlational analyses were conducted to determine whether children's verbal abilities were related to performance on the object sorting task. Performance across all levels of the object sorting task tended to relate to children's verbal abilities, $r(32) = .30$, $p = .09$.

How children reasoned about each category was investigated using the content of children's verbal explanations (e.g. taxonomic, thematic, perceptual) across categorization levels. Since children were able to provide more than one verbal response on each trial, the total number of responses for each level was used. The null hypothesis that the total number of verbal responses for each category level would be equally distributed among the different types of explanations was tested using a series of binomial chi square tests. For each categorization level chance responding was calculated as 33.3% of responses, as there were three possible response options. Since the same pattern of verbal responses was observed in both 4- and 5-year-old children, the reported analyses were collapsed across age. Figure 4 shows the percentage of each response type for each category level.

A total of 47 responses were provided at the animate-inanimate level. Although it was expected that children would be more likely to provide taxonomic responses as rationale for their categorization choices, children were not more likely to describe the animate-inanimate relationship taxonomically (17% of responses), χ^2 (2, n = 43) = 3.75, $p > .10$. In fact, 45% of the responses children provided as rationale for their categories were based on thematic associations, while 38% of responses were based on perceptual associations. It is important to consider these results when interpreting children's relatively low A-I taxonomic categorization accuracy scores, as this data suggest that some children were indeed using a thematic categorization strategy when sorting animate and inanimate objects. At the superordinate level, children successfully formed categories of animals, vehicles and furniture, however, their preference for providing taxonomic explanations (46% of responses) did not reach statistical significance, χ^2 (2, n = 43) = 3.22, $.10 < p < .20$. At the superordinate level, thematic responses were provided 21% of the time (not significantly different from chance), while perceptual responses occurred the remaining 33% of the time. At the basic level, however, children were significantly more likely to describe the relationship as taxonomic (63% of responses), χ^2 (2, n = 43) =15.29, $p < 0.01$. Thematic responses were provided 20% of the time, while perceptual responses were provided the remaining 17% of the time.

Additional analyses were conducted to determine whether children's verbal abilities were related to the number of verbal responses children provided. At the animate-inanimate level, verbal abilities were correlated with the number of verbal responses children provided, $r(33) = .41$, $p < .01$. However, at the superordinate, $r(33) = -.06$, $p = .73$, and basic levels, $r(33) = -.05$, $p = .79$ verbal abilities were not related, presumably due to the fact that both 4- and 5-year old children mastered object sorting at the basic and superordinate levels.

Inter-task correlations. Inter-task correlations between the matching-to sample (accuracy and RT) and object sorting (accuracy) tasks were examined for the animate-inanimate category level only, as children performed at ceiling on both the basic and superordinate level trials of the object sorting task. Among 4-year-olds neither accuracy, nor reaction time on the matching-to-sample task were found to correlate with accuracy on the object sorting task, *r*(18) = -.15, *p* = .55, *r*(18) = -.19, *p* = .47, respectively. Similarly, among 5-year-olds, the relation between animate-inanimate categorization accuracy and object sorting performance was not statistically significant, *r*(21) = .31, *p* = .16, nor was the relationship with reaction time, *r*(21) = .17, *p* = .52. Whether or not a child adopted a taxonomic or thematic object sorting strategy was analysed to determine whether adopting either sorting strategy would generate corresponding differences in performance on the A-I taxonomic categorization trials of the matching-to-sample task. Across 4- and 5-year-old age groups, preference for adopting either a taxonomic (n = 21) or thematic (n = 22) sorting strategy was not found to relate to performance on A-I trials of the matching-to-sample task, [taxonomic sorting preference *M* = .63; thematic sorting preference (n = 22), *M* = .65], *t*(41) = .28, *p* = .78. This suggests that children who adopted a thematic sorting strategy on the object sorting task simply preferred thematic associations (as in pretend play), despite possessing the relevant taxonomic knowledge of animate-inanimate categories, as demonstrated by their performance on the matching-to-sample task.

Discussion

The primary goal of the current research was to investigate the development of children's taxonomic categorization abilities, particularly at the animate-inanimate level. While most previous research investigating the animate-inanimate distinction in childhood has employed inductive inference procedures (e.g., whether animates or inanimates possess various biological properties), the current study tested children's ability to make spontaneous categorical judgments about which objects are the same kind of thing. That is, unlike the inductive inference procedure children were not told which properties to attend to when making decisions about category membership. Converging evidence from the matching-to-sample and object sorting categorization tasks revealed a similar sequence of development in category levels, although individual children did not perform similarly on both tasks. The results of this experiment provide support for the hypothesis that children's categories are acquired in a sequence from least to most inclusive (e.g. from basic to superordinate to animate-inanimate level).

Consistent with previous research using the matching-to-sample task (Mervis & Crisafi, 1982; Tager-Flusberg, 1985a) basic and superordinate level categories were found to be mastered by 4 years of age. The present study attempted to replicate and extend this research by testing children's matching-to-sample performance at these levels, as well as at the animate-inanimate level (e.g., categorizing people with animals, and furniture with vehicles). At the animate-inanimate level, 5-year-olds' performance was above chance, but not as well developed as adults. Our results are consistent with the body of literature showing that children as young as 5 years of age possess an emerging conceptual understanding of ontological kinds (Erickson, Keil, & Lockhart, 2010; Gottfried & Gelman, 2005; Jipson & Gelman, 2007; Margett & Witherington, 2011; Rhodes & Gelman, 2010).

The results of the object sorting task also suggest that by 4 years of age children reliably create basic and superordinate level taxonomic associations. However, at the animate-inanimate level, children demonstrated fewer A-I taxonomic associations in comparison to less inclusive category levels. Verbal explanations for the associations children created among objects in each category were found to vary as a function of category level. Specifically, while taxonomic responses were most frequently provided on basic (e.g., dogs, airplanes) and superordinate level (e.g., animals, vehicles) trials, thematic explanations were most frequently provided on animate-inanimate level (e.g., people in their cars) trials. That children did not prefer taxonomic explanations for the animate-inanimate level is consistent with the results of Massey and Gelman's (1988) study where children's spontaneous verbal explanations for their decisions about which kinds of things could travel up a hill independently were analysed. Although Massey and Gelman (1988) concluded that taxonomic category membership was most frequently described (25%), their enabling parts (15%) and appearance (15%) categories would both be considered perceptual explanations using our coding scheme and therefore, would comprise the majority (30%) of responses. Thus, a similar proportion of taxonomic (17% current study) and perceptual (38% current study) explanations were provided across both studies. Interestingly, this same pattern of verbal responses was also found when examining only those children who sorted objects taxonomically. That is, children who correctly sorted A-I objects according to taxonomy, still provided thematic (40%) and perceptual (44%) descriptions, rather than taxonomic (16%) descriptions. This suggests that 4- and 5- year-old children who are able to create animate-inanimate categories are still developing their ability to verbally reason about these relations.

Results of the current study extend those of Margett and Witherington (2011) who found that 4-year-olds had an emerging, yet incomplete, understanding of living and non-living things, which was based on whether or not an object was able to move. In the present study, all animate and inanimate stimuli were presented as unable to move (e.g., as static images). Notwithstanding, 5-year-olds were still able to categorize at the animate-inanimate level above chance on the matching-to-sample task. This suggests that by 5 years of age children have developed a more nuanced understanding of the animate-inanimate distinction, whereby humans and animals were still considered animate despite being presented as static images, and vehicles were still categorized as inanimate despite previous experiences where these objects were capable of movement. That 5-year-olds in the current study were found to perform above chance, but not as proficiently as adults is also consistent with the results of Erickson and colleagues (2010) who demonstrated a similar emerging knowledge of biological and psychological causation.

The hypothesis that children's categorization ability may be related to the development of their verbal abilities was investigated using correlational analyses. These analyses showed that verbal ability was not related to performance accuracy or reaction time on the matching-to-sample task, but tended to correlate with accuracy scores on the object sorting task and was significantly related to the number of verbal responses children provided. Overall, the correlational analyses suggest that verbal abilities were not strongly related to performance on non-verbal aspects of the categorization tasks, however, when verbal explanations were required, children with a larger vocabulary were shown to provide more verbal responses.

Interestingly, children's animate-inanimate categorization performance was not correlated among the matching-to-sample and object sorting tasks. These results, however, are not surprising due to the fact that the two tasks differed in a number of important ways. In the matching-to-sample task, object anchors remained present on the screen throughout the trial, and thus were more noticeable in children's decision making. In contrast, in the object sorting task, the distinctiveness of category anchors diminished as more objects were added to each bowl. That is, if children made categorization errors early on in the procedure (e.g., after sorting 2 of 6 total objects), the cohesiveness of the category decreased, making it more likely that additional errors would be made. The two tasks differed, more importantly, in terms of whether or not children were able to create both taxonomic and thematic object associations. In the matching-to-sample procedure, image triads were selected to prevent children from making thematic associations (e.g. matching a person with furniture or vehicles), therefore, providing a 'cleaner' test of children's animate-inanimate understanding. Since we were also interested in whether the saliency of thematically relevant associations would influence children's ability to demonstrate taxonomic object associations, children were given the opportunity to sort objects according to thematic associations on the object sorting task.

The comparison of results across categorization tasks is relevant to the broader theoretical debate concerning the flexibility and nature of children's categorization development (Blaye & Bonthoux, 2001; Denney and Ziobrowski, 1972; Waxman & Namy, 1997). Specifically, the matching-to-sample task provided a "pure" assessment of the development of children's taxonomic categories, while the object sorting task allowed children to flexibly group objects according to either taxonomic or thematic associations. Given the differences in task demands, it is important to consider the question of whether it is children's abilities, or merely their preference, which is being reflected by their performance. Our results indicated that 5-year-olds were able to categorize at the A-I level on the matching-to-sample task, but did not form taxonomic categories as readily on the object sorting task. This suggest that 5-year-olds indeed possess the animate-inanimate distinction, however, their taxonomic knowledge could be masked when given the opportunity to form thematic associations. The fact that children who sorted thematically on A-I trials of the object sorting task were also able to categorize taxonomically on the matching-to-sample task suggests that the object sorting task provided a measure of taxonomic vs. thematic preference, rather than a 'pure' measure of taxonomic knowledge. Thus, on the object sorting task the salience of thematic associations interfered with children's ability to demonstrate their knowledge of animate-inanimate taxonomy.

A number of explanations can be proposed to explain why the animate-inanimate level is the last to emerge in children's conceptual development. First, animate-inanimate categories are the broadest and can only be formed by attending to common abstract features among category members. Second, the terms "animate" and "inanimate," or "living" and "non-living" are not frequently used as descriptors when teaching children the names of different objects and entities, so, unlike basic level categories, a common label cannot facilitate categorization. Finally, the complete development of the animate-inanimate distinction in childhood may take longer due to a qualitative restructuring of the animate-inanimate concept (Carey, 1985). Although an implicit form of the animate-inanimate distinction has been documented in infants during the second year of life, such categories are largely based on static and dynamic perceptual cues. In childhood, the development of animate-inanimate distinction has been shown to be affected by children's tendency to make similarity judgments in comparing other animate exemplars to humans as an ‘animate standard’, rather than considering other aspects of an exemplars’ biological relatedness (Carey, 1985; Inagaki & Hanato, 1987). That is, children seem to find challenging the idea that humans are another type of animal.

The research presented here contributes to a more complete understanding of the development of the animacy concept in childhood. It is one of the few studies to provide a detailed account of the emergence of the animate-inanimate distinction using tasks that measure children’s ability to form taxonomic categories. The matching-to-sample and object sorting tasks provide unique measures of children’s spontaneous categorical decisions. Thus, this research provides a complement to the body of research investigating whether children extend various properties to animates or inanimates (Inagaki & Hatano, 1996; Jipson & Gelman, 2007; Massey & Gelman, 1988). The present research adds to our current understanding of children’s conceptual development by presenting additional evidence that animate-inanimate level categorization is the last to develop in childhood. These results therefore, support the hypothesis that the development of older children’s categorization abilities follows a bottom-up developmental trajectory. Taken together, results of the matching-to-sample and object sorting tasks provide further support for the emerging development of the animate-inanimate distinction in the early childhood years.

Taxonomic Response	Thematic Response	Perceptual Response
Animate-Inanimate Level		
living, non-living	people and their things/ cars	with eyes, no eyes; with face, no face
alive, not alive	they [people] take care of these [animals], in the house, not in the house	moves, move by itself, walk, needs someone to push it, these stay
Superordinate Level		
animals	at the zoo (animals)	has feet (animals)
furniture	for the house, dolly stuff (furniture)	comfy, flat (furniture)
vehicles, cars	drive them, travel (vehicles)	drive, have seats, has wheels, no wheels, go fast (vehicles)
Basic Level		
dogs, cats, birds	live on land, live in the sea, water	crawl, has feet (cat), has fins (fish), has wings, beak (birds)
chairs, tables	in the house, not inside	Sit on (chairs), put things on (tables)
Cars, planes	on the road, in the air	have wings, flying things (planes), cannot fly (cars)

Table 1. *Coding Scheme for Verbal Responses on the Object Sorting Task*

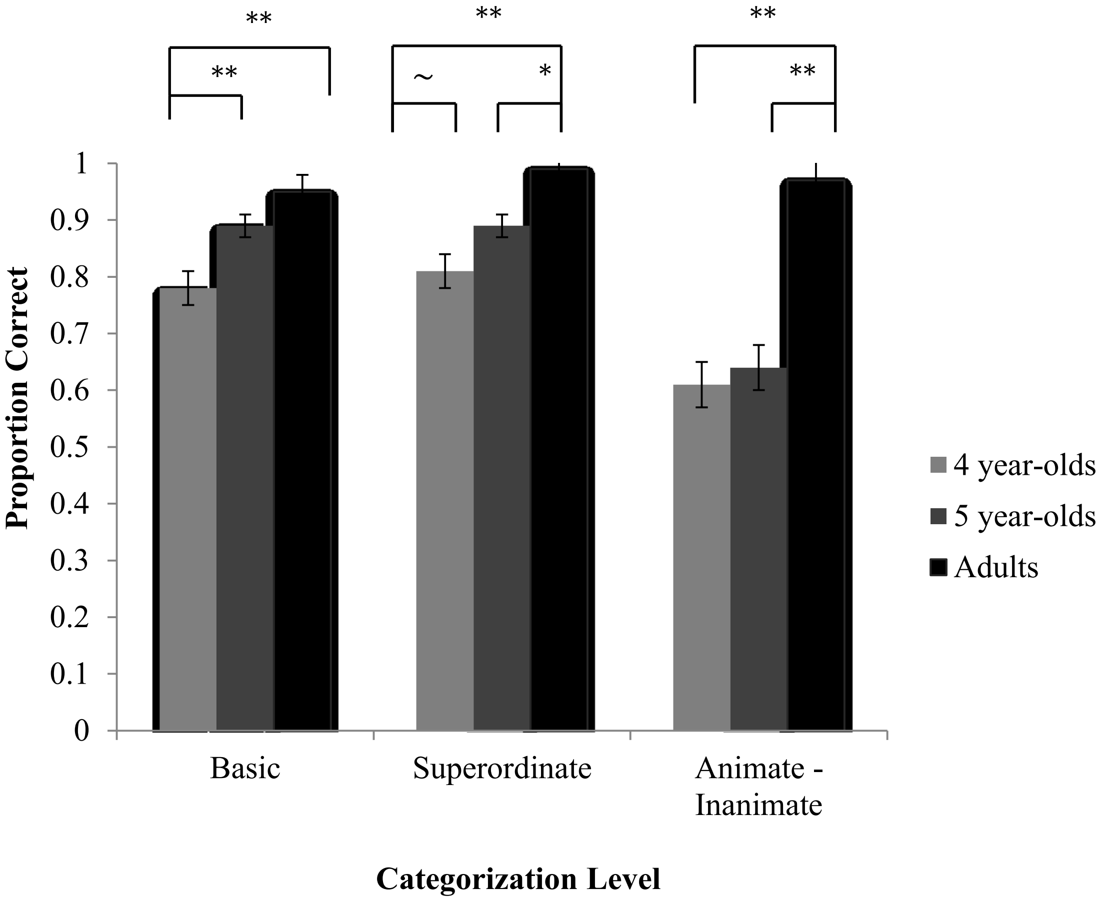

Figure 1. Proportion of correct responses as a function of taxonomic level for the matching-to-sample task. Note. ~ indicates $p < .10$, * $p <.05$, and ** $p <.01$.

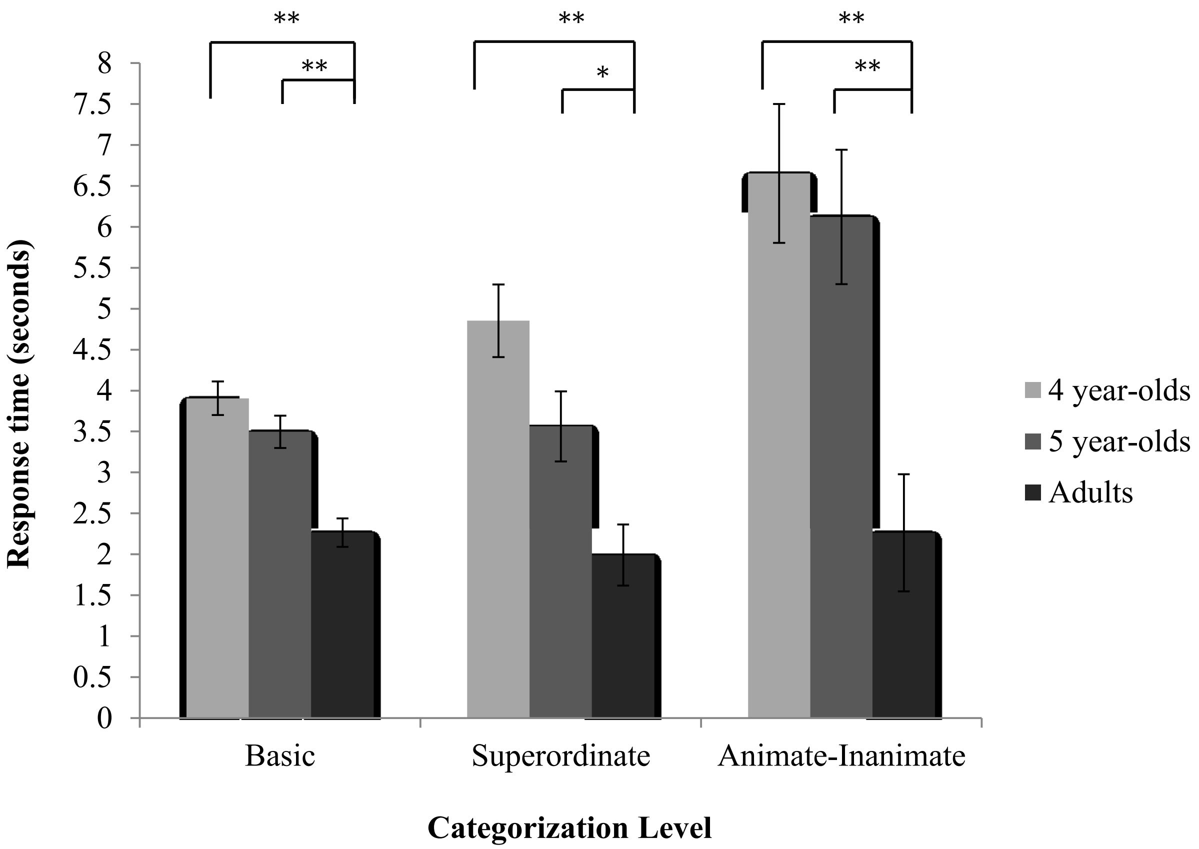

Figure 2. Mean reaction time (in seconds) as a function of taxonomic level for the matching-to-sample task. Note: ~ indicates $p < .10$, * $p < 0.05$, ** $p < 0.01$

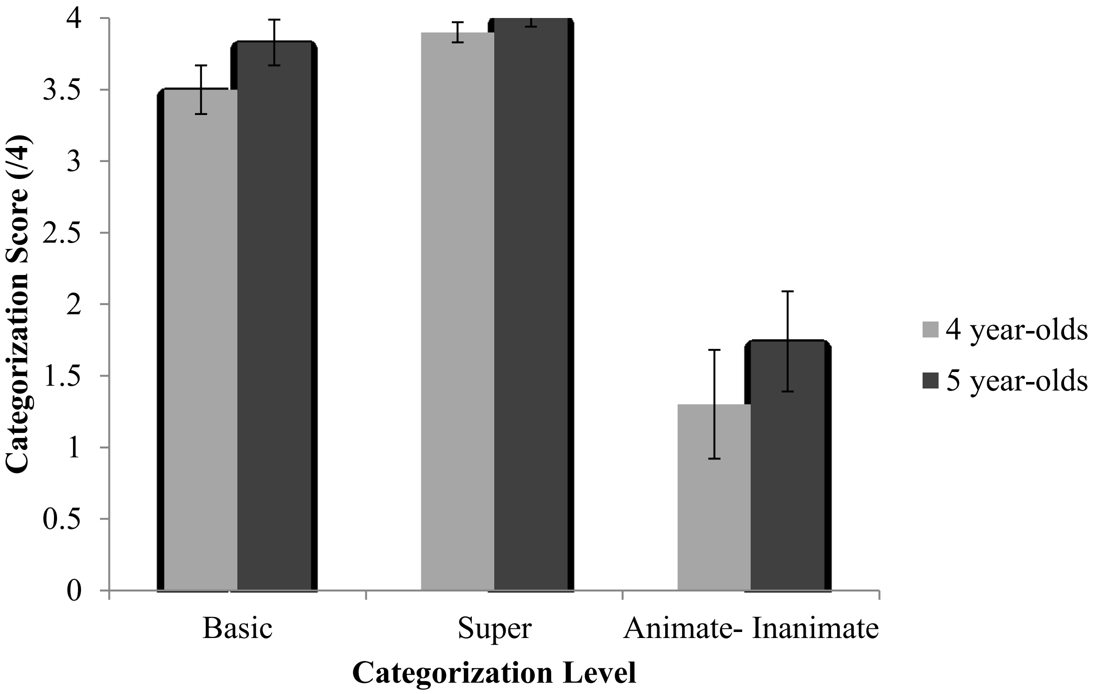

Figure 3. Mean scores as a function of taxonomic level for the object sorting task. Note: ~ indicates $p < .10$, * $p < 0.05$, ** $p < 0.01$

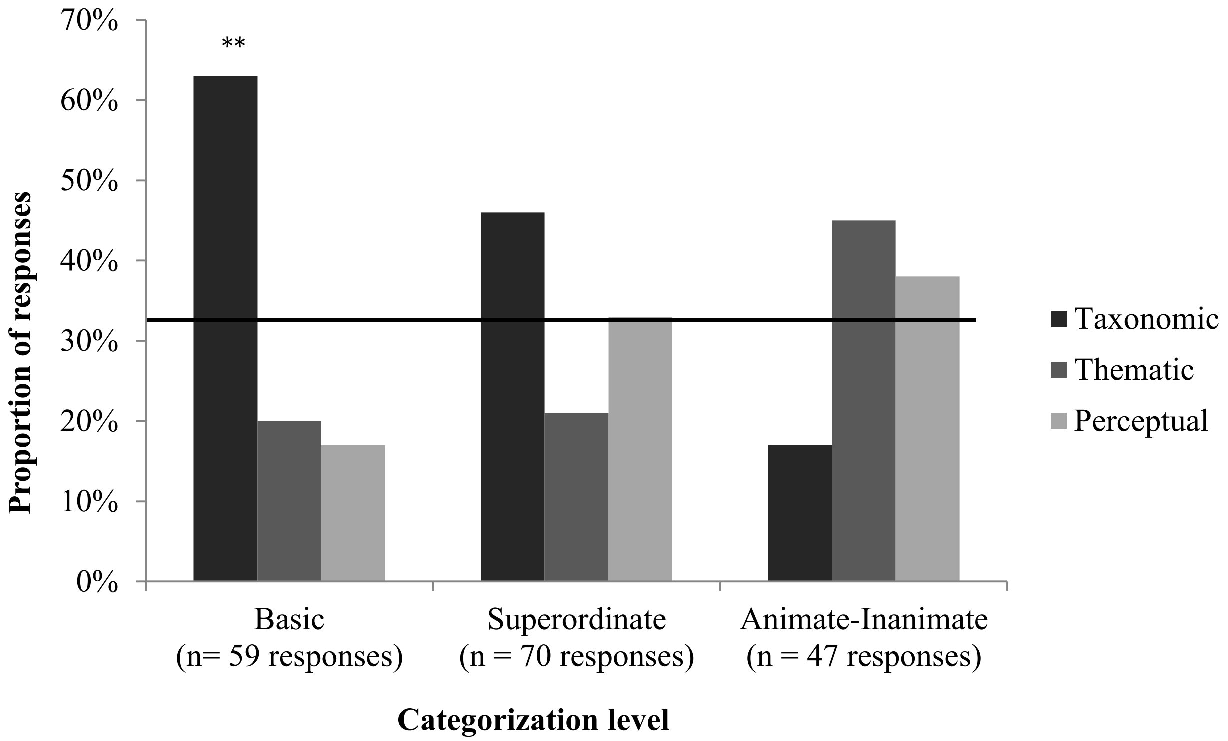

Figure 4. Percentage of verbal explanations at each category level. Solid line denotes chance responding (33%). Note: ~ indicates $p < .10$, * $p < 0.05$, ** $p < 0.01$

CHAPTER 3

Schematic and realistic biological motion identification in children with high-functioning Autism Spectrum Disorder

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Schematic and realistic biological motion identification in children with high-functioning Autism Spectrum Disorder

One of the most robust and replicable findings in psychology is that the visual system is exquisitely tuned to detect point-light biological motion (Blake & Shiffrar, 2007). In typical development, newborn infants and toddlers have been shown to prefer biological motion over non-biological motion (Simion et al., 2008) or inverted motion (Klin et al., 2009). The predisposition to attend to biological motion has been shown in typical development using multiple methods including, point-light display (Klin et al., 2009; Morita et al., 2012; Simion et al., 2008), schematic motion such as the Michotte "caterpillar" stimulus (Michotte, 1963; Schlottmann & Ray, 2010), or the motion of a single animated dot (Rutherford et al., 2006; Schultz & Bulthoff, 2013). This early sensitivity and preference for animate motion has been difficult to reconcile with some research suggesting that individuals with Autism Spectrum Disorder (ASD) have deficits in biological motion perception (Annaz et al., 2010; Annaz, Campbell, Coleman, Milne, & Swettenham, 2012; Blake et al., 2003; Centelles, Assaiante, Etchegoyhen, Bouvard, & Schmitz, 2013; Congiu et al., 2010; David et al., 2013; Herrington et al., 2007; Kaiser, Delmolino, Tanaka, & Shiffrar, 2010; Klin et al., 2009; Koldewyn, Whitney, & Rivera, 2011, 2010). However, a number of other studies do not support the contention that biological motion processing deficits are characteristic of ASD, particularly among high-functioning, older individuals with ASD (Cleary et al., 2013; Freitag et al., 2008; Hubert et al., 2007; Moore et al., 1997; Murphy et al., 2009; Parron et al., 2008; Rutherford & Troje, 2012; Saygin et al., 2010).

The processing of biological motion has been hypothesized to relate to the development of core cognitive abilities such as the ability to differentiate animate and inanimate categories (Gelman & Opfer, 2002; Mandler, 1992; Opfer & Gelman, 2011; Rakison & Poulin-Dubois, 2001), as well as social-cognitive abilities, commonly affected in individuals with ASD. The aims of the current research were to a) investigate whether children with high-functioning ASD (HF-ASD) identify animate (biological) and inanimate (mechanical) motion and b) explore whether children's performance on biological motion identification tasks relate to parental report of ASD symptoms.

Animate motion cues such as an entity's ability to cause motion at a distance, change direction or speed, and engage in self-propulsion are important for the development of the concept of living and non-living things in infancy (Csibra, Gergely, Bíró, Koós, & Brockbank, 1999; Csibra, 2008; Premack, 1990; Mandler, 1992; Rakison & Poulin-Dubois, 2001; Schlottmann, Surian, & Ray, 2009; Tremoulet & Feldman, 2000). Similarly, typically-developing (TD) preschool and school-aged children use motion information to guide their animacy judgements (Gelman & Coley, 1990; Mak & Vera, 1999). However, this research has not specifically evaluated whether biological motion, as a single animacy cue, is sufficient for TD children and children with HF-ASD to accurately differentiate animate-inanimate categories. The current research aimed to investigate this question using a novel schematic motion categorization task.

Research regarding the perception of biological motion has generally used point-light displays (Johansson, 1973), or schematic, non-rigid "caterpillar" motion (Michotte, 1963). Different aspects of biological motion are emphasized with each method and existing research has yet to compare performance across methodologies. Whereas point-light biological motion emphasizes the "gravity-defined trajectory" of the limbs of living organisms (Troje, 2013), schematic motion depicts non-rigid, expansion-contraction movement, which only animate beings are capable of. One advantage of using schematic biological motion over point-light displays is that schematic motion stimuli do not provide information about the general form of the organism (e.g., limbs), and therefore the attribution of animacy is based on the object's motion alone. While schematic biological motion is an advantageous method to study the perception of animacy, the majority of studies testing biological motion understanding in children with ASD have primarily used point-light display.

Point-Light Biological Motion

Point-light displays depict the movement of an animate being by placing point-light dots on all the major joints of the body and rendering the rest of the body invisible. Although the resulting motion is considerably degraded, the point-light markers have been shown to convey important information about both the structure of the body and the dynamic movements of each of the parts (Chang & Troje, 2008; Troje, 2002). In one of the few studies to examine the development of children's ability to identify biological motion, Pavlova and colleagues (2001) found that 5-year-old children could accurately identify animate point-light displays of humans, dogs, and birds with the presentation of a single motion trial (Pavlova et al., 2001). However, children were not tested on their ability to identify non-biological, or mechanical motion, as a comparison. Other research has investigated how well human and mechanical motion are visually detected in TD children, adults, and young adults with ASD. Kaiser, Delmolino, Tanaka, and Shiffrar (2010) presented coherent and scrambled motion point-light displays of a human and a tractor, which were either masked (among noise) or unmasked. Scrambled motion displays contain the same dots as coherent motion, but are displaced to remove the form cues in coherent motion displays. While both TD groups showed greater visual sensitivity to human motion (both masked and unmasked), compared to the motion of a tractor, young adults with ASD (*M* age = 20) showed equal sensitivity to the motion of a human or a tractor.

The large majority of investigations concerning how children with ASD perceive biological and mechanical motion have been confined to studies of visual preference and discrimination, while few studies provide a direct test of how children identify the form represented in point-light displays. Of the studies that have asked children with ASD to verbally identify biological motion displays, most have involved identifying complex physical actions (Swettenham et al., 2013), subjective states, or emotions (Hubert et al., 2007; Moore et al., 1997; Parron et al., 2008). While children's ability to identify an agent's emotions and internal states when presented using point-light display has been investigated, how accurately children with ASD identify animate vs. inanimate motion exemplars has yet to be examined. In the current study, we compared children with HF-ASD with TD children on their ability to identify biological and mechanical motion point-light displays. Additionally, we wanted to explore whether children are equally able to identify schematic, compared to point-light, biological motion.

Schematic Biological Motion

Classic studies by Michotte (1963), Heider and Simmel (1944), Premack (1990), and Tremoulet and Feldman (2000) demonstrate how the motion of simple geometric forms is sufficient to give rise to the impression of animacy. This perception of animacy has been described as a rapid, automatic, and largely stimulus-driven process (Heider & Simmel, 1944; Schlottmann & Ray, 2010). Schematic presentations of biological motion such as the Michotte "caterpillar" depict a rectangular-shaped stimulus that moves by elongating from one side, then contracting on the opposite side. These stimuli have been shown to elicit the perception of goal-directedness in infants as young as 6 months of age (Schlottmann & Ray, 2010) and are judged as 'animal-like' in TD children as young as 3 years of age (Schlottmann et al., 2002).

Although schematic biological motion has been widely used to research animacy perception in TD children, this methodology has seldom been used to study animacy understanding in children with ASD. To our knowledge, only two studies have been conducted using schematic biological motion with children with ASD (Congiu, Schlottmann & Ray, 2010; Ray & Schlottmann, 2007). Ray and Schlottmann (2007) investigated ASD children's perception of launch and reaction events presented as schematic animations that moved either biologically (non-rigidly) or inanimately (rigidly). Children with ASD (*M* age = 8.4 years) were shown to have difficulty perceiving launch events. In particular, when launch events were presented using rigid (inanimate) motion children with ASD did not prefer to attribute physical causality. In a similar study, Congiu and colleagues (2010) presented older high-functioning children with ASD with schematic stimuli that either moved rigidly, or non-rigidly. Children were tested on their understanding of physical and psychological causality using different variations of the launch event. Although 13-year-old children with HF-ASD did not show difficulty understanding the principles of physical and psychological causality, they had difficulty identifying and describing the non-rigid, biological motion stimulus as animate (Congiu et al., 2010). Only 37% of children with HF-ASD described the stimulus as "caterpillars," "snakes," or "slugs" compared to 77% of typically-developing children. Interestingly, 42% of children with ASD provided inanimate responses such as "rectangles," while only 23% of control children provided inanimate responses. It is, however, possible that asking children to identify the schematic stimulus as animate using an open-response format may have underestimated children's animacy understanding as it allows children to provide literal descriptions (e.g. rectangles) instead of more abstract descriptions of what the rectangle looks like (e.g., a caterpillar).

Biological Motion and Social Functioning

The hypothesis that the development of social functioning is dependent upon, or at least, related to, the perception of biological motion has received recent support in a number of studies (see Kaiser & Shiffrar, 2013 for a review). Among children with ASD, a relationship between biological motion perception and measures of social competence has been demonstrated, whereby children's visual fixation patterns while viewing social and non-social stimuli were found to relate to standardized measures of social competence (Klin et al., 2002). Additionally, ASD severity on the ADOS has also been shown to correlate with children's ability to detect human point-light biological motion (Blake et al., 2003). Using an analog population of adult undergraduates, traits of ASD as measured by the Autism Quotient (AQ: Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) were found to relate to sensitivity in detecting human biological motion, but not object motion (Kaiser & Shiffrar, 2013). Thus, deficits in biological motion perception, or visual orienting to social stimuli, may be critical in explaining the myriad of social-cognitive symptoms characteristic of individuals with ASD (Dakin & Frith, 2005; Kaiser & Shiffrar, 2013; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pavlova, 2011; Swettenham et al., 1998). To date, these investigations have correlated visual preference, and ability to discriminate, biological motion, but have not evaluated whether a relation exists between the ability to identify biological motion stimuli and aspects of social functioning. In the present study it was expected that better performance on animate trials of the biological motion identification tasks would be associated with lower scores on the Social Communication Questionnaire (Rutter, Bailey, & Lord, 2003), a screening instrument for ASD, and symptoms of the broader autism phenotype as measured by the Social Responsiveness Scale (SRS; Constantino & Gruber, 2005). In contrast, we would not expect identification of inanimate, mechanical, motion to be related to scores on the SCQ or SRS.

Study Aims

The main goal of the present research was to compare the performance of children with high-functioning ASD to TD children on tasks requiring the identification of biological motion across two methodologies: point-light motion and schematic motion. Our knowledge of how children with ASD perceive biological and mechanical motion has been largely confined to studies assessing visual preference and discrimination, while less is known about what young children with ASD recognize when viewing the degraded movements of humans, animals, and vehicles shown in point-light displays. A novel task was developed to test whether TD children and children with HF-ASD identify schematic biological motion as consistent with animate entities. Additionally, given that this is the first study to present children with both point-light and schematic biological motion displays, performance across tasks was compared to shed light on the empirical question of whether the same over-arching animacy concept is assessed for both types of biological motion. Given that the perception of biological motion has been hypothesized to be important for the development of cognitive and social abilities (Kaiser & Shiffrar, 2013;

Pavlova, 2011, 2013), an additional exploratory aim of the present study was to investigate whether performance of children with HF-ASD across biological motion identification tasks correlates with cognitive ability and scores on two measures of ASD symptomatology.

Method

Participants

The ASD group consisted of 22 children (16 males) diagnosed with a diagnosis on the autism spectrum and a control group of 21 TD children (13 males) matched on gender, chronological age, and nonverbal mental age. Three participants in each group were tested but not included in the final analysis for the point-light motion identification task due to missing data (technical difficulties). Thus, analyses for the schematic motion identification task included 22 children with HF-ASD, while 19 children with HF-ASD were included in the analysis of point-light biological motion identification. Participants in the ASD group were recruited from a University database, a hospital with specialized autism diagnostic services, as well as referrals from specialized centers treating children with ASD. Participants were not included if their full scale IQ on a standardized IQ test was below 70. All participants in the ASD group had previously received a clinical diagnosis of Autistic Disorder or Asperger's Syndrome by satisfying diagnostic criteria on the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000). Children recruited from specialized diagnostic and treatment centres also satisfied diagnostic thresholds on the Autism Diagnostic Interview (ADI-R; Lord, Rutter, & Le Couteur, 1994). The Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003)[1]and Social Responsiveness Scale (SRS; Constantino & Gruber, 2005) were used to provide additional information about symptomatology and autism severity. Participants with HF-ASD all had a primary diagnosis of Autistic Disorder (n=11), Pervasive Developmental Disorder – Not

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[1] Although all children in our sample of HF-ASD carried a valid clinical diagnosis on the autism spectrum, a number of children did not meet the accepted cut-off of 15 on the Social Communication Questionnaire. However, recent research suggests that lowering the cut-off to 13 or 11 improves sensitivity and specificity, especially among high-functioning children with ASD (Corsello et al., 2007; Oosterling, Swinkels, Jan van der Gaag, Visser, Dietz, & Buitelaar, 2009). Of the 22 children with HF-ASD in our sample, 9 failed to meet the cut-off of 15 or above. However, it was not the case that children who failed to meet SCQ thresholds were less impaired, or more likely to be identified by a diagnosis on the broader Autism Spectrum (e.g. PDD-NOS, Asperger's Syndrome), compared with children who did meet cut-off, χ^2 (n = 22) = .24, p = .89.

Otherwise Specified (PDD-NOS) (n=4), or Asperger's Syndrome (n=7). Five participants with HF-ASD also had a secondary diagnosis of Attention Deficit Hyperactivity Disorder (ADHD), two participants had epilepsy, and three participants were born prematurely (less than 37 weeks gestation). Participants from the control group were recruited from a University database. TD participants had no other neuropsychological or developmental disorders (e.g. epilepsy, language delay) and did not have any (known) first-degree relative with an Autism Spectrum Disorder. All TD and HF-ASD participants had normal, or corrected to normal vision. All participants completed the Differential Abilities Scale, Second Edition (DAS-II; Elliott, 2007). ASD and TD groups were subsequently matched on nonverbal mental age and chronological age. Table 2 shows the mean nonverbal mental age and chronological age for each group.

Materials and Procedure

The point-light motion identification task and schematic motion categorization task were administered using a 30-inch computer monitor. The schematic motion categorization task was always administered before the point-light motion identification task. Since children also completed other cognitive tasks not related to biological motion, only four trials of each task were administered to ensure attentiveness and avoid fatigue. As such, measures were taken to ensure the reliability of data, namely, the presentation of inter-trial fixation points with an attractive sound to orient children's attention to the screen. Children's performance was recorded using a camcorder. Parents either sat behind the child as they completed the tasks, or in an adjacent room.

Schematic Motion Categorization Task. A novel forced-choice biological motion identification task was developed to test whether schematic biological motion (e.g. non-rigid expansion-contraction) is sufficient for children to infer the animate-inanimate category membership of an ambiguous geometric entity (Träuble, Pauen & Poulin-Dubois, 2014). In this task, all other static and dynamic animacy cues were removed in order to determine whether biological motion is understood as an animacy cue among children with HF-ASD. The biological motion stimulus was adapted from the Michotte (1963) "caterpillar" stimuli, which consisted of a rectangle that moved non-rigidly by elongating and contracting. The novel stimulus had an organic-like, curvilinear form that was consistent with the overall shape of either an animate, or an animate, category exemplar. The general idea of this paradigm was to present children with an animate and an inanimate category exemplar (e.g. realistic images of a dog and truck), which became masked by a semi-translucent curtain, producing two identical “shadows.” Children observed one shadow moving across the screen (either biologically or non-biologically) and were subsequently asked to identify which of the two objects had moved as the shadow. The animation was divided into three phases: a familiarization phase, a motion phase, and a test phase. The main elements of the animation are shown in Figure 5.

During the familiarization phase, children viewed static images of an animal and a vehicle on the left-hand portion of the screen. Children were asked to label the objects, then a semi-translucent curtain covered both objects so that they appeared as identical “shadows.” Children’s attention was drawn to the objects hiding behind the curtain, “look they’re hiding.” The curtain was lifted and both objects were revealed again, then a completely opaque curtain covered both objects so they were no longer visible. During the motion phase, children were told, “one of them is going to move.” One shadow moved across the middle portion of the screen and disappeared behind a second opaque curtain. At test, children were asked, “which one moved?” If children did not provide a verbal response, a prompt (“was it the [dog] or the [truck]?”) was provided. Following the child’s verbal response the opaque curtain was lifted and the identity of the moving shadow was revealed. Identification of the moving stimulus as either animate (e.g., dog) or inanimate (e.g., truck) could be made only by attending to the movement of the shadow, as no other animacy cues (e.g., change in speed or direction, self-propulsion) were provided. Children were not told that the manner of motion was the relevant feature they should attend to when making this decision. Two motion conditions were presented: biological motion (non-rigid expansion and contraction), or non-biological (rigid sliding across the screen).

Prior to completing test trials children were familiarized with the task by completing two warm-up trials. These trials used the same basic set-up and the same verbal explanations as test trials. However, warm-up trials differed in that the familiarization images were a caterpillar and a bicycle, and more importantly, the task could be successfully completed without attending to the motion, but to the shape of the shadow. In the warm-up phase, each familiarization image cast an appropriately shaped “shadow,” thus, children could respond correctly by simply matching the moving shadow that looked like a bicycle to the image of the bicycle. In contrast, on test trials an ambiguously shaped blob was used to represent both animate and inanimate familiarization images. In order to continue on to the test trials, children were required to demonstrate an understanding of the task by responding correctly on two consecutive trials. Thus, if an error was made on one of the warm-up trials, both warm-up trials were repeated.

Children completed a total of four test trials, whereby two sets of familiarization objects (cow-motorcycle pairing, dog-truck pairing) were presented with two types of moving shadows (biological and non-biological). The presentation of trials was counterbalanced for the type of motion presented on the first trial (biological, non-biological) and trials were pseudo-randomized so that the first two trials contained one of each set of familiarization stimuli and presented one biological and one non-biological motion scene.

Coding. Children's verbal responses were coded as either correct or incorrect on each trial; therefore, children could receive a maximum score of 4. Performance on animate (biological motion) and inanimate (non-biological motion) trials was scored separately and a percentage correct (out of 2) was calculated. Performance on the first and second presentation of each type of motion was also scored as a percentage correct (out of 2), to investigate whether the provision of feedback would produce improvement across trials.

Point-Light Motion Identification Task. To test whether children with high-functioning ASD identify biological and non-biological motion patterns, children were presented with point-light videos of a human, a cat, a truck, and a bicycle (Troje, 2002, provided the human point-light video stimuli; all other stimuli were adapted from Arterberry & Bornstein, 2001). The human point-light display was shown in front view, while all other stimuli were shown at a visual angle of 60 degrees to allow all four limbs of the cat and two wheels of each vehicle to be visible. Each video contained 11 point-light dots, which were placed on major parts of the human and cat (e.g. head, neck, shoulders [2], elbows [2], pelvis, knees [2], feet [2]) and major areas of the truck (e.g., wheels [3 per wheel], front bumper [2], back bumper [2], roof [1]) and bicycle's frame (e.g., wheels [3 per wheel], seat [2], frame [1], handle bars [2]. In each video, the stimulus was shown to be moving rightward, but remained stationary with no horizontal translation. Each trial was 6 seconds in duration and depicted either 3 complete gait cycles (animates) or 3 complete wheel rotations (vehicles) [0.5 seconds per cycle]. Videos were presented in random order. Prior to the presentation of each trial, a central fixation cross appeared accompanied with an attractive sound in order to orient children's attention to the screen.

Children were instructed to "watch" each video and were subsequently asked, "What is that?" If children did not provide a verbal response within 30 seconds, the experimenter encouraged them by saying, “What does it look like?” If children still did not provide a response the experimenter proceeded to the next trial “Let’s try another one.” Children’s verbal responses on each trial were recorded.

Coding. Verbal responses for each trial were recorded verbatim and scored as either correct or incorrect. Acceptable responses were coded as follows: human point-light display [man/woman, someone walking, person, or human], cat point-light display [cat, dog], bicycle point-light display [bicycle, motorcycle, truck], truck point-light display [truck, car, sedan, bicycle]. Since the point-light display of the bicycle and truck were both presented in side view, each depicting only two wheels, children who labeled the truck as a bicycle, and vice versa, were still considered correct. However, labeling the truck or bicycle as a morphologically different vehicle (e.g. train, airplane) was not considered a correct response. Thus, on each of four trials children’s responses were scored as correct or incorrect and a total score was calculated as a percentage correct (out of 4). Children also received a score for their identification of animate, biological motion trials (out of 2), and a score for their identification of inanimate, mechanical motion trials (out of 2).

Results

Schematic Motion Categorization Task. Preliminary analyses revealed no significant main effect of Order, or Group x Order interaction. Additionally, no significant main effect of Trial (first or second), or Group x Trial interaction was found. Thus, all subsequent analyses were collapse across these factors. To examine whether performance of children with HF-ASD differed from TD children on animate and inanimate motion trials a 2 (Group) x 2 (Motion) mixed-model ANOVA was computed with Bonferroni corrections for multiple comparisons. Results revealed no main effect of Group, $F(1, 41) = 0.0$, $p = .99$, partial $\eta^2 = .00$, that is, overall, children with HF-ASD performed as well as TD children matched on gender, age, and non-verbal cognitive ability (*M* of HF-ASD = 77.28%, *M* of TD = 77.38%). No significant main effect for Motion was found, $F(1, 41) = 2.34$, $p = .13$, partial $\eta^2 = .05$, indicating that children generally performed equally well on animate (*M* = 81.40%) as opposed to inanimate (*M* = 73.26%) motion trials. The Group x Motion interaction was also not significant, $F(1, 41) = .03$, $p = .86$, partial $\eta^2 = .00$ (see Table 3 for scores).

A group of 21 adults were also tested to provide validation of the task. Adults' overall performance on animate trials was 95.24% correct, while performance on inanimate trials was 83.33% correct.

Point-Light Motion Identification Task. To examine whether the accuracy of children's identification of point-light motion differed as a function of Motion Type (animate vs. inanimate) or Group (HF-ASD vs. TD) a 2 (Group) x 2 (Motion Type) mixed-model ANOVA was computed. A main effect of Motion Type was found, $F(1,35) = 5.64$, $p = .02$, partial $\eta^2 = .14$, wherein children from both groups were better able to identify animate ($M = 82.43\%$), compared to inanimate ($M = 63.51\%$), point-light displays. No difference in performance between children with HF-ASD ($M= 76.32\%$) and TD controls ($M = 69.45\%$) was found, $F(1,35) = .72$, $p = .40$, partial $\eta^2 = .02$. The Group x Motion Type interaction was also not significant, $F(1,35) = .08$, $p = .78$, partial $\eta^2 = .00$.

Given that no group differences in accuracy of point-light identification were found, we also provide a qualitative description of the types of errors children made. Of particular interest was whether children in either group incorrectly labeled an animate as an inanimate, and vice versa. When asked to identify animate point-light displays, all children in the TD group either labeled the animate stimuli as another animate (e.g., seal), or did not provide a response. On the inanimate point-light displays, one TD child labeled an inanimate (e.g., bicycle) as an animate (e.g. human), while all other children either labeled stimuli incorrectly, but as inanimates (e.g., airplane), or provided no response. Children with HF-ASD also largely followed this pattern, whereby errors on animate point-light trials consisted of incorrect, animate responses (e.g., cow), or no response. However, one child with HF-ASD incorrectly labeled an animate (e.g., cat) as an inanimate (e.g., car). Errors HF-ASD children made on inanimate point-light trials consisted of other inanimate responses (e.g. train), no response, or, in the case of two children, providing an incorrect animate label (e.g. kids, turtle).

A group of 21 adults were also tested to provide validation of the stimuli. Adults' accuracy in identifying the agent in each animate display was 97%, while adults' accuracy in identifying each object in the inanimate displays was 91%.

Inter-task and correlational analyses. Children's scores on both tasks were compared to determine whether children were equally successful at identifying schematic and realistic point-light biological motion. A 2 (Group) x 2 (Task) x 2 (Motion Type) mixed-design ANOVA with Bonferroni correction for multiple comparisons was computed. This analysis revealed a significant main effect of Motion Type, $F(1,35) = 7.99$, $p < .01$, partial $\eta^2 = .19$, indicating that across tasks, HF-ASD and TD children performed better when identifying animate (M = 82.30%), as opposed to inanimate (M = 68.90%), motion. The main effect of Task was not significant, $F(1,35) = 1.70$, $p = .20$, partial $\eta^2 = .05$, indicating that children performed similarly on the schematic (M = 78.30%) and point-light (M = 72.90%) biological motion identification tasks. No significant main effect of Group, $F(1,35) = .60$, $p = .45$, partial $\eta^2 = .02$ (M HF-ASD = 78.30%, M TD = 72.9%), Group x Task interaction, $F(1,35) = .13$, $p = .72$, partial $\eta^2 = .00$, or Group x Motion Type interaction, $F(1,35) = .04$, $p = .84$, partial $\eta^2 = .00$, was found. Non-parametric correlations (Kendall Tau rank coefficients) between tasks were also performed, whereby scores on each task (out of 4) were compared. Kendall's Tau was selected since scores on the motion identification tasks were not continuous and performance tended to cluster toward the upper range of values. Interestingly, among children with HF-ASD performance on the point-light motion identification and schematic motion identification tasks was significantly correlated, $\tau(17) = .55$, $p < .01$, however, this was not the case for TD children, $\tau(16) = .16$, $p = .45$.

Correlational analyses (Kendall Tau rank coefficients) were also conducted to investigate whether developmental variables such as cognitive ability or chronological age were related to biological motion identification performance. For the HF-ASD group, it was expected that developmental age, rather than chronological age, would relate to performance on motion identification measures, whereas among TD children chronological age was hypothesized to relate to performance. Among children with HF-ASD, performance on the schematic motion identification task was correlated with non-verbal cognitive ability, $\tau(20) = .39$, $p = .02$, but not with chronological age, $\tau(20) = .24$, $p = .16$. For the TD group, performance on the schematic motion identification task only tended to relate to chronological age, $\tau(19) = .33$, $p = .07$, and non-verbal cognitive ability, $\tau(19) = .31$, $p = .09$. On the point-light motion identification task, performance in the HF-ASD group was significantly correlated with non-verbal cognitive ability, $\tau(17) = .37$, $p = .05$, but not chronological age, $\tau(17) = .22$, $p = .23$. While in the TD group, both non-verbal cognitive ability, $\tau(16) = .60$, $p < .01$, and chronological age, $\tau(16) = .40$, $p = .05$, was correlated with performance on the point-light motion identification task.

Biological motion and ASD Symptoms. Non-parametric correlations were computed to examine the relation between task performance and social-cognitive difficulties as measured by the Social Communication Questionnaire (SCQ) and the Social Responsiveness Scale (SRS). To test the hypothesis that identification of biological motion relates to children's social-cognitive abilities, children's performance on biological motion trials of each procedure were collapsed to create an animate motion identification score (out of 4). Similarly, children's performance across inanimate motion trials of the point-light motion identification task and schematic motion trials were collapsed to create an inanimate motion identification score (out of 4). Based on previous research, one would expect that performance on animate motion identification trials would negatively correlate with parental report of ASD symptoms on the SRS, and screening scores on the SCQ, whereas performance on inanimate motion identification trials would not be expected to relate to either parent report measure. As expected, performance of children with HF-ASD on animate motion identification trials tended to negatively relate to parental reports on the Social Communication Questionnaire, $\tau(17) = -.36$, $p = .07$, while performance on inanimate motion trials was not related to SCQ scores, $\tau(17) = -.21$, $p = .28$. However, performance on neither animate, nor inanimate, motion identification trials were significantly related to ASD symptomatology on the Social Responsiveness Scale, $\tau(17) = -.27$, $p = .16$, $\tau(17) = .11$, $p = .57$, respectively.

Discussion

Whether deficits in biological motion perception are one of the hallmarks of Autism Spectrum Disorder has been a topic of much debate. The primary goal of the current research was to compare the performance of children with HF-ASD on two tasks of biological motion identification: a point-light motion identification task and a novel schematic motion identification task. Although schematic biological motion is frequently used to study animacy perception in typical development, few studies have used this methodology to study motion perception in ASD. The observed performance across tasks suggests that insofar as biological motion is used as a cue for animacy judgments, school-aged children with HF-ASD perform as well as TD controls, matched on chronological age, nonverbal cognitive ability, and gender. Consistent with the results of Rutherford, Pennington and Rogers (2006), no reliable autism-specific deficit in animacy perception was found. Furthermore, children with HF-ASD were able to process biological motion cues to make accurate animacy judgments even when presented with a single trial.

While much of the literature on biological motion perception has focused on the psychophysical aspects of point-light stimuli (e.g., visual preference, discrimination of masked stimuli) the current study sought to determine whether children with high-functioning ASD identify simple point-light presentations of animate and inanimate stimuli. Children were asked to identify point-light displays of a person, a cat, a truck, and a bicycle. Overall, children with high-functioning ASD performed similarly to TD children. Across HF-ASD and TD groups, children were better able to identify animate point-light displays (human and cat), compared to inanimate displays (truck and bicycle). Although it is not surprising that TD children were better able to identify animate, compared to inanimate motion, that children with high-functioning ASD also showed the same pattern was somewhat unexpected. Given the body of evidence suggesting that, unlike TD children, children with ASD do not preferentially attend to social stimuli (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009; Kaiser et al., 2010; Klin et al., 2002, 2009; Maestro et al., 2002), it might be hypothesized that this lack of attentional preference might lead to a reduced ability to identify point-light displays of people or animals.

A novel schematic biological motion categorization task (the “shadow” paradigm) was designed to examine whether children identify an ambiguous “shadow” as animate or inanimate based its movement. Consistent with the biological motion point-light display identification task, children with HF-ASD performed similarly to TD controls. That children with HF-ASD readily associated non-rigid, expansion-contraction movement with other living things that do not move in this specific way (e.g. dog, cow) suggests that children with HF-ASD are able to make abstract inferences across the animate domain. The results of this study can be contrasted with Congiu and colleagues (2010) who asked 13-year-old children with HF-ASD to describe the ‘Michotte’ stimulus using an open-response format. While 77% of TD children described the stimulus as animate (e.g., “caterpillar,” “slug,” “snake”) only 37% of children with ASD provided animate descriptions. While the results of Congiu and colleagues (2010) study suggest that children with ASD experience difficulty with the perception of animacy, it is possible that lower cognitive ability (Mean FSIQ = 75, range 40 to 110), or children’s preference to provide literal responses (e.g., rectangles, squares) could account for these differences. In the present study, younger children *(M* = 6.49 years) with HF-ASD were shown to associate the ‘Michotte’ expansion-contraction motion with mammals when presented as a forced-choice task.

The present study is the first to compare children with HF-ASD's performance on schematic and point-light biological motion identification tasks. Among children with HF-ASD, performance was significantly correlated across the two tasks. That is, those children who performed well on the point-light motion task generally performed well on the schematic biological motion task, and those who performed poorly on the point-light motion task generally performed poorly on the schematic motion task. Interestingly, performance of TD children was not correlated across point-light and schematic biological motion tasks. This absence of relationship may suggest that the TD children and children with ASD approached the two tasks differently or that different cognitive resources were required to successfully complete each task. However, it is possible to rule out the hypothesis that children could have been selecting their responses based on idiosyncratic features of the stimuli, such as a general preference for animate or inanimate stimuli, as this strategy would have resulted in chance level performance.

Results of the present study replicate and extend previous studies that reported a significant relation between cognitive ability and biological motion processing in individuals with ASD (Atkinson, 2009; Koldewyn et al., 2010; Rutherford & Troje, 2012). As expected across both biological motion identification tasks, nonverbal mental age was found to correlate with performance among children with HF-ASD. A number of different explanations are possible for these results. The stronger relation between cognitive ability and performance in HF-ASD, but not in TD children, may be explained by the fact that children with HF-ASD generally had a larger range of scores on the standardized measure of nonverbal mental abilities. Within the ASD group, relatively poorer performance on the biological motion tasks may be related to below-average cognitive ability whereas above-average cognitive ability may not necessarily provide children an additional advantage. That performance among children with HF-ASD was not impaired overall, but was significantly related to nonverbal cognitive ability suggest that deficits in biological motion processing may not be specific to a high-functioning ASD population, but instead may be a correlate of cognitive delay. Since the current study only included children with HF-ASD it is possible that performance on biological motion identification tasks is impaired among younger, or lower-functioning, children.

A secondary aim of this study was to investigate the relation between children's ability to identify biological motion and measures of social-cognitive functioning, namely those used to screen for ASD (e.g., SCQ) and assess the severity of symptomatology (e.g., SRS). Consistent with our hypothesis HF-ASD children who had higher scores on the SCQ tended to perform more poorly when identifying animate point-light and schematic motion, while scores on the SCQ were unrelated to performance on inanimate motion identification trials. However, symptoms of ASD measured by the SRS were not found to relate to children's ability to identify animate or inanimate point-light or schematic motion. One possible explanation for these results is that the SRS was originally designed to assess the broader autism phenotype (Constantino & Gruber, 2005), therefore, SRS scores of children who already had a diagnosis on the autism spectrum were clustered in the severe range of symptom scores and were not variable enough to correlate with our performance measures. Had we also administered the SRS to the TD group a relationship between broader autism spectrum traits and performance on animate biological motion identification trials may have emerged. That the SCQ and SRS were not administered to the TD group is one limitation to the current study.

Results of the current study are not in conflict with the view that early deficits in biological motion perception may be a diagnostic predictor of the development of ASD (Kaiser & Pelphrey, 2012). It is possible that deficits in biological motion processing are present in infancy (Klin et al., 2009), and over the course of development, compensatory strategies are increasingly relied on in order to successfully complete biological motion tasks. Mixed empirical results concerning whether deficits in biological motion processing are enduring into childhood (Annaz et al., 2010; Blake et al., 2003; Centelles et al., 2013; Congiu et al., 2010; Milne et al., 2002; Parron et al., 2008; Rutherford et al., 2006; Swettenham et al., 2013) provide evidence for neuroplasticity in the mechanisms responsible for biological motion perception. Grossman and colleagues (2004) demonstrated that not only can biological motion performance be improved with training, but improvement among TD adults was correlated with changes in activation in brain regions implicated in the processing of biological motion (Grossman, Blake, & Kim, 2004). In another study, adults with Asperger's Syndrome were shown to perform similarly to controls on a task requiring individuals to identify the direction of biological motion, however, the Asperger's Syndrome group demonstrated decreased brain activation in areas typically recruited in biological motion processing (Herrington et al., 2007).

The ability to extract information from biological motion displays has far-reaching implications for children's concept formation and understanding of the social world (Klin & Jones, 2008; Pavlova, 2011; Yoon & Johnson, 2009). In the current study, the perception of animacy in children with high-functioning ASD was assessed with the "shadow" paradigm, a forced-choice task that required children to associate animate stimuli with the ability to move biologically by expanding and contracting. However, modifying the current procedure to test children's ability to discriminate biological motion by manipulating the salience of biological motion cues (e.g., varying the degree of expansion and contraction) may potentially be a more sensitive measure to detect whether differences in performance across groups exist. Additionally, aside from biological motion, a number of other animacy cues exist and remain to be explored in and ASD population. Future research may wish to examine animacy understanding in children with ASD using a wide range of cues, such as the ability to self-start, change speed, or change direction. A developmental adaptation of the schematic biological motion identification task has been used to test nonverbal infants as young as 7 months of age using a violation-of-expectation paradigm (Trauble et al., 2014). This non-verbal adaptation would not only allow for the assessment of animacy understanding in younger, nonverbal children with ASD, but also makes possible the investigation of animacy understanding in a high-risk infant study (i.e., infant siblings of children with ASD). In order to evaluate the hypothesis that biological motion processing impairments are a hallmark of ASD, and affect the development of social-cognitive abilities, an examination of biological motion understanding in infant siblings at risk for ASD would be extremely valuable.

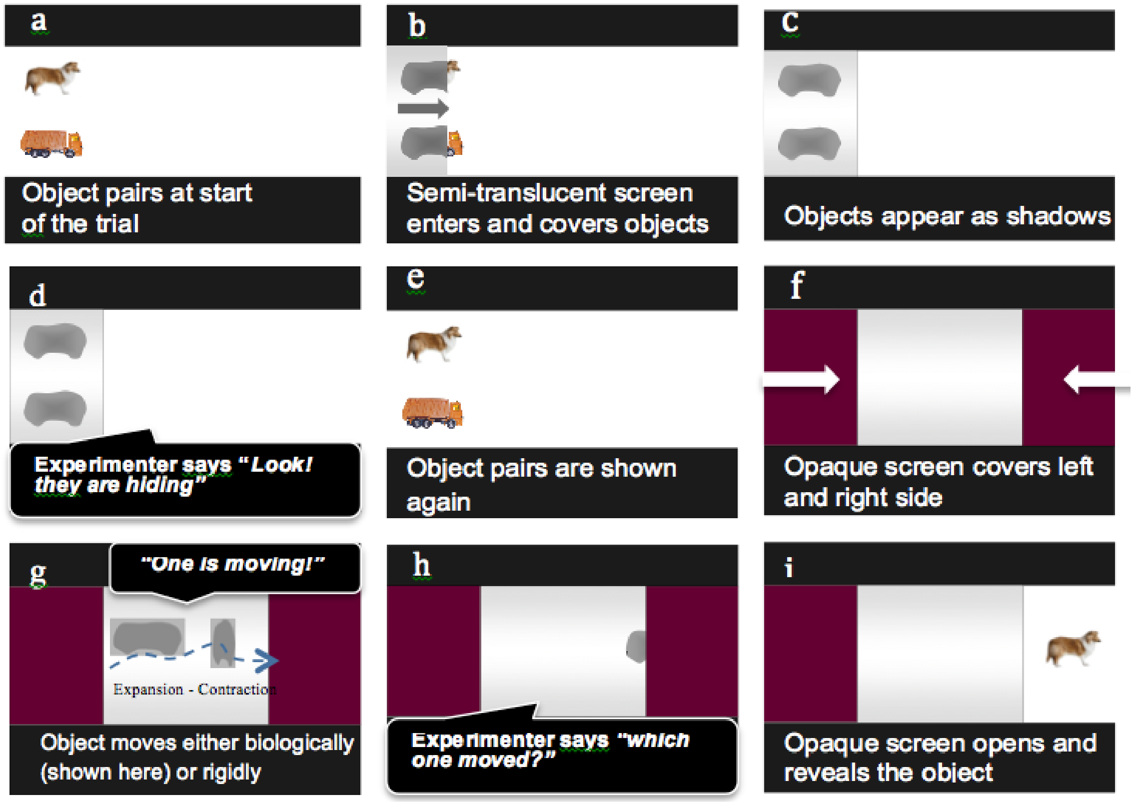

Figure 5. Diagram of the schematic biological motion categorization task

Note: Frames (a) to (f) show the familiarization phase, frame (g) shows the motion phase, frame (h) shows the test phase, and frame (i) provides children with feedback on their response. During the familiarization phase children are introduced to two identical shadows representing each response option. The shadows of each object (shown) were designed to be identical, yet resemble either response option as closely as possible. Children viewed one shadow move across the screen either animately by expanding and contracting (i.e., dog), or inanimately by sliding across the screen (i.e., truck) during the motion phase. At test, children are asked which they thought had moved.

	Gender (m:f)	Chronological age (*SD*)	Nonverbal mental age (*SD*)	Nonverbal IQ (*SD*)	SRS total score	SCQ Total
TD (n = 21)	13:8	6.96 (1.50)	7.31 (2.0)	106.85 (9.44)	--	--
HF-ASD (n = 22)	19:3	6.48 (1.74)	7.29 (2.48)	103.13 (14.59)	79.04 (10.87)	16.73 (6.56)

Table 2. *Participant Characteristics for HF-ASD and TD Groups*

Note. Test of equality of means for chronological age, *t*(41)= .97*, p* = .34, and nonverbal mental age, *t*(41) = .04, *p* = .97. SRS = Social Responsiveness Scale; scores on the SRS are reported as t-scores (*M* = 50, *SD* = 15). SCQ = Social Communication Questionnaire; scores of 15 or above are considered to meet cut-off for ASD on this screening measure.

	Point-Light Motion Identification		Schematic Motion Identification	
	Animate	Inanimate	Animate	Inanimate
HF-ASD	86.84%	65.79%	81.82%	72.73%
TD	77.78%	61.11%	80.95%	73.81%

Table 3. *Percentage of Correct Responses on the Schematic and Point-light Biological Motion Identification Tasks for Each Group*

CHAPTER 4

Wright, K., Kelley, E., & Poulin-Dubois, D. (revise resubmit). Attention to biological motion and the animate-inanimate distinction in children with high-functioning Autism Spectrum Disorder, *Research in Autism Spectrum Disorders*

Attention to biological motion and the animate-inanimate distinction in children with high-functioning Autism Spectrum Disorder

The ability to categorize, or to flexibly group entities together on the basis of a rule, is a fundamental cognitive ability. While some object categories can be formed using simple observable features, more complex categories, such as the animate-inanimate distinction, are formed on the basis of abstract principles. It has been hypothesized that the capacity to move or initiate actions without external force (Gelman & Spelke, 1981) might be key to children's understanding of the animate-inanimate distinction. During the infancy period, the ability to differentiate implicit animate and inanimate concepts has been shown to be facilitated by animate, biological motion cues (Poulin-Dubois, Crivello, & Wright, 2015). Interestingly, young children with Autism Spectrum Disorder have been shown to have deficits in the perception of biological motion (Falck-Ytter, Rehnberg, & Bölte, 2013; Simion, Regolin, & Bulf, 2008). In the present study, we report the first investigation of the potential link between individual differences in the perception of biological motion and the ability to form the animate-inanimate distinction in children with ASD.

The body of research concerning the development of an implicit form of animacy concept among typically developing infants supports the notion that attention to motion plays a key role in cognitive development. Theories of infant cognitive development have identified motion, or path, as an organizational mechanism involved in directing infants' attention to socially relevant information, such as whether an entity is animate or inanimate, is goal directed, or intentional (Gelman & Opfer, 2002; Mandler, 1992; Opfer & Gelman, 2010; Rakison & Poulin-Dubois, 2001). Mandler (1992, 2012) suggested that conceptual knowledge about the "kinds of things" objects are is derived from the perception of motion characteristics. Building on this idea, we hypothesize that attention to animate and inanimate motion cues facilitate the formation of A-I concepts. Among typically-developing (TD) infants, exposure to biological motion has been shown to facilitate 12-month-olds' categorization of contrasts spanning the animate-inanimate distinction (e.g. animal and vehicle contrasts), but not contrasts consisting of only inanimates (e.g., furniture and vehicles) (Poulin-Dubois, Crivello, & Wright, 2015).

Although implicit understanding of the A-I distinction during the infancy period has been shown to involve the perception of motion cues (Gelman & Opfer, 2002; Opfer & Gelman, 2010), whether motion continues to facilitate children's ability to form explicit A-I categories has yet to be investigated. The development of A-I concepts in childhood has primarily been investigated using tasks requiring categorical inferences based on biological properties (Gottfried & Gelman, 2005; Inagaki & Hatano, 1996; Jipson & Gelman, 2007; Margett & Witherington, 2011; Massey & Gelman, 1988; Rhodes & Gelman, 2009). This body of research has shown that knowledge of animate properties such as the ability to eat, grow, think, and feel as well as the internal structure of animates emerges between 4 and 6 years of age. In one of few studies to examine the ability to form animate and inanimate taxonomic categories, Wright, Poulin-Dubois and Kelley (2014) showed that by 5 years of age A-I categorization was above chance, but was not as well developed as adults.

Whether children with Autism Spectrum Disorder (ASD) form animate-inanimate level categories similar to TD peers has not been thoroughly investigated. However, there is reason to hypothesize that the A-I distinction would be particularly challenging for children with ASD. Importantly, A-I categories possess few observable shared features and therefore cannot be easily formed using a rule-based strategy. Children with ASD have been shown to rely on a rule-based approach to categorization (Klinger & Dawson, 2001). Further, the current body of research has yielded inconsistent findings concerning whether deficits in categorization at less inclusive levels are present in ASD. Specifically, Gastgeb, Strauss, and Minshew, (2006) showed that while 10-year-old children with high-functioning ASD (HF-ASD) were unimpaired in categorizing superordinate (e.g., animal) and basic (e.g., dog) level categories, they responded more slowly when exemplars deviated from the most typical instances of a particular category (Gastgeb, Strauss, & Minshew, 2006). Other research using an object sorting procedure, however, showed that mental age matched individuals with ASD (mental age of 9 years) were impaired in categorizing representational objects from basic and superordinate level categories compared to individuals with intellectual disability and TD children (Shulman, Yirmiya, & Greenbaum, 1995).

While the existing research has yet to evaluate whether children with ASD form A-I categories, the related question of whether perception of low-level characteristics of animate motion are affected in children with ASD has been extensively studied (Klin & Jones, 2006; Johnson & Rakison, 2006; Rutherford, Pennington, & Rogers, 2006). Children with ASD have been found to be slower in learning to discriminate animate motion, compared with both TD children and children with other developmental disabilities (Rutherford, Pennington, & Rogers, 2006). Additionally, although children with ASD have been shown to possess knowledge of the motion patterns of animates (e.g., having legs is correlated with walking), knowledge of the broader significance of possessing legs in relation to the animate concept was lacking (e.g., things with legs are living) (Johnson & Rakison, 2006). Children with HF-ASD were also more likely to describe the animate expansion-contraction motion of a geometric stimulus using inanimate descriptions (e.g., rectangles) while TD children preferred to use animate descriptors (e.g., caterpillars) (Congiu, Schlottmann, & Ray, 2010). In sum, the body of research addressing animacy perception in children with ASD largely suggests deficits in the formation of an animacy concept based on motion cues, however, children's ability to form animate and inanimate categories has yet to be empirically investigated.

Visual processing of biological motion produced by living organisms is of immense value for successful social interaction and nonverbal communication (see Pavlova, 2011, 2013, for review). In TD newborns, an early predisposition to attend to, and discriminate, biological motion point-light displays has been reliably demonstrated (Bardi, Regolin, & Simion, 2010; Simion et al., 2008). In contrast, disruptions in visual perception of biological motion have been proposed as a hallmark of ASD (for a review see Kaiser & Pelphrey, 2012). Deficits in social motivation have been hypothesized to underlie this early attentional predisposition to prefer non-social aspects of the environment (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Specifically, toddlers with ASD have been shown to pay less attention to biological motion compared to non-social motion (Falck-Ytter et al., 2013; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009), pay less attention to dynamic social images, compared to dynamic geometric images (Pierce, Conant, Hazin, Stoner, & Desmond, 2011), and spend less time attending to faces during dynamic social interactions (Shic, Bradshaw, Klin, Scassellati, & Chawarska, 2011). However, compensation for these early deficits have been shown to occur, whereby among high-functioning, adolescents and adults with ASD, deficits in biological motion perception were no longer present (Cleary, Looney, Brady, & Fitzgerald, 2013; Freitag et al., 2008; Hubert et al., 2007; Moore, Hobson, & Lee, 1997; Murphy, Brady, Fitzgerald, & Troje, 2009; Rutherford & Troje, 2012; Saygin, Cook, & Blakemore, 2010). Although the general trend in the research points to early deficits in biological motion processing, with compensation happening later in development, some studies have identified more subtle deficits that persist into adolescence and adulthood (Cook et al., 2009; Koldewyn, Whitney, & Rivera, 2010; 2011), in particular, with respect to extracting social and emotional meaning from the motion displays (Hubert et al., 2007; Moore, Hobson, Lee, 1997; Parron et al., 2008).

In the present study, we investigated whether understanding of the animate-inanimate distinction is related to individual differences in attention to animate, as opposed to inanimate, motion in children with HF-ASD. The objectives of the present research were twofold. The first aim was to explore the early understanding of the animacy concept among children with HF-ASD (*Mage* = 6.61 years). Second, we aimed to investigate whether visual attention to biological motion was related to the formation of the animate-inanimate distinction among children with HF-ASD.

In the current study, categorization abilities were tested using both object sorting and matching-to-sample tasks to provide different measures of taxonomic categorization. Traditionally, in the matching-to-sample procedure one sample image is presented with two possible matches - one match is taxonomically related, and the other is thematically related. For the present investigation, we presented children with one taxonomic match and one unrelated match, in order to provide an assessment of whether children possess the given taxonomic category. On the object sorting task, we also presented children with the opportunity to create thematic, as well as taxonomic, associations. The object sorting procedure requires children to group three-dimensional objects into spatially distinct categories (Starkey, 1981). Children were instructed to group together the "same kind of thing" and were free to create either taxonomic or thematic categories. Thus, we contrasted children's performance on both a pure measure of taxonomic knowledge (e.g., matching-to-sample) with a more conservative measure of children's relative preference for taxonomic, compared to thematic, relations (e.g., object sorting). Previous research investigating the animate-inanimate distinction in TD preschoolers has shown that although 5-year-olds possess knowledge of the animate-inanimate distinction, this knowledge was masked when given the opportunity to also form thematic associations (Wright, Poulin-Dubois, & Kelley, 2015). The results of this study were also used as the basis for selecting a group of HF-ASD children who were within a similar developmental timetable.

To measure children’s attention to biological, compared to non-biological, motion, a preferential looking task was developed using point-light displays of animate (e.g., human, cat) and inanimate (e.g., bicycle, truck, randomly moving dots) stimuli, which were presented as split-screen videos. In contrast to previous research using the preferential looking paradigm whereby the same stimuli is paired repeatedly across trials (Annaz, Campbell, Coleman, Milne, & Swettenham, 2012; Bardi et al., 2010; Simion et al., 2008), we presented an array of novel biological and non-biological motion contrasts to avoid habituation and increase ecological validity.

Given the documented deficits in the perception of animate motion in children with ASD (Klin & Jones, 2006; Johnson & Rakison, 2006; Rutherford, Pennington, & Rogers, 2006), we expected that children with HF-ASD would show less preference for biological motion than TD children. With respect to the second aim of this study, we expected that among TD children, higher levels of visual attention toward biological motion would be associated with better performance on animate categorization trials (animals and people). Although we predicted no group-level attentional preference for animate motion among children with HF-ASD, individual differences in attention to animate motion were also predicted to relate to the development of A-I categorization abilities in a similar manner as TD children (Rutter, Bailey, & Lord, 2003).

Method

Participants

The HF-ASD group consisted of 19 children (15 males), *M* age = 6.61 years (range 4.67 to 9.16 years) with a diagnosis on the autism spectrum, while the typically developing (TD) control group consisted of 19 children (16 males), *M* age = 6.41 years (range 4.17 to 10.08 years). All children with HF-ASD tested in this study also participated in Study 2, while the matched comparison group of TD children differed slightly in composition to maximize matching the two groups on cognitive skills (i.e., nonverbal versus verbal mental abilities). Two participants were tested but not included (n = 1 TD; n = 1 HF-ASD) as they demonstrated a clear directional preference to look only to one side of the screen (>80% of total looking time) across trials of the biological motion task.

Participants in the HF-ASD group were recruited from a University database, a hospital with specialized autism diagnostic services, as well as referrals from specialized centers treating children with ASD. Participants were not included if their full scale IQ on a standardized IQ test was below 70. All participants in the HF-ASD group had previously received a clinical diagnosis on the autism spectrum by satisfying the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV-TR) diagnostic criteria, as well as the diagnostic thresholds on the

Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000). Children recruited from specialized diagnostic and treatment centers also satisfied diagnostic thresholds on the Autism Diagnostic Interview – Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994). The Social Communication Questionnaire (Rutter et al., 2003) and Social Responsiveness Scale (Constantino & Gruber, 2005) were administered to provide additional information about current symptoms of ASD. Participants with HF-ASD had a primary diagnosis of Autistic Disorder (n = 8), Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS)(n = 4), or Asperger's Syndrome (n = 6).

Participants from the TD comparison group were recruited from a University database. TD participants had no other neurological or developmental disorders (e.g., epilepsy, language delay) and did not have any known first-degree relative with an Autism Spectrum Disorder. All TD and HF-ASD participants had normal or corrected-to-normal vision. All participants completed the Differential Abilities Scale, Second Edition (DAS-II; Elliott, 2007). HF-ASD and TD groups were matched on gender, chronological age, and verbal IQ. Table 4 shows the mean chronological age, and verbal IQ scores for each group.

Materials and Procedure

Children completed the tasks in a fixed order, wherein the matching-to-sample task was administered first, the object sorting task second, the biological motion task third, and the test of cognitive ability administered last. Tasks were administered in this order to obtain reaction times on the matching-to-sample task that would not be affected by fatigue or practice. The biological motion preference task was administered after the categorization tasks to ensure that exposure to biological motion stimuli did not prime children's ability to differentiate animate-inanimate categories, as has been previously shown to occur in infancy (Poulin-Dubois, Crivello, & Wright, 2015). Children were accompanied by a parent who either sat behind the child as they completed the tasks, or in an adjacent room behind a one-way mirror.

Matching-to-Sample Categorization Task. The matching-to-sample task is a forced-choice test of categorical association, whereby children were asked to decide which of two images are the same kind of thing as a centrally located sample image. In the current study children were tested not only on their ability to categorize at the animate-inanimate level, but trials assessing less inclusive concepts (i.e., basic and superordinate) were interspersed to assess a wider range of categorization abilities. These trials were used to maintain children's motivation toward the task as they provided varying levels of difficulty. Animate-inanimate level trials assessed children's ability to form concepts of animates (including both people and animals) as well as inanimates (including both furniture and vehicles). Superordinate level trials measured children's ability to form animal, furniture and vehicle concepts. While basic level trials measured children's ability to form narrower categories of dogs, birds, fish, chairs, tables, cars, and trucks. Within each superordinate or basic level trial sample images and response options did not cross the animate inanimate divide (e.g. all animates, or all inanimates).

Five training trials were presented, followed by 24 test trials. On test trials three different levels of categorization were presented with 8 trials each: animate-inanimate, superordinate, and basic-level. All images were selected to be the most typical exemplars of each category based on ratings described in previous research (Rosch & Mervis, 1975; Uyeda & Mandler, 1980; Van Overschelde, Rawson, & Dunlosky, 2004). Children provided their responses by touching a 30-inch touch-screen computer. Both accuracy and reaction time were recorded as previous research suggests that reaction time may be a more sensitive indicator of differences in cognitive processing in children with ASD, particularly when no group differences in accuracy are found (Gastgeb, Strauss, & Minshew, 2006; Soulières, Mottron, Giguere, & Larochelle, 2011).

The training phase consisted of five subordinate level trials. On training trials, feedback was provided in the form of a green check-mark appearing over correct responses and a red "x" appearing over incorrect responses. The experimenter also provided an explanation for the correct response if children responded incorrectly.

During the test phase, children were not given feedback on the accuracy of their responses but were simply encouraged to keep going. The presentation of test trials was fixed and pseudo-randomized so that trials of the same categorization level never occurred on more than two consecutive trials. An equal number of test trials contained animate versus inanimate sample images. The correct response option was also counterbalanced to occur equally often on the left and right side, and did not occur on the same side for more than two consecutive trials. Sample images were carefully paired with each response option to ensure that correct responses could not be made on the basis of perceptual features such as size, directional orientation, or color. At the animate-inanimate level, trials were constructed to ensure that children's ability to categorize taxonomically was measured, as opposed to a preference for thematic relatedness. That is, on an animate-inanimate trials sample images were always those of animals, rather than people, to prevent children from matching people with thematically related objects, such as vehicle or furniture. Presentation of trials and recording of responses was programmed using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) so that both accuracy and reaction time (RT) were recorded. A score of 0 was recorded for incorrect trials and a score of 1 for correct trials. Percent correct was our measure of accuracy and children received a score ranging from 0 to 100% for each categorization level: however, only the animate-inanimate level was analyzed for the purposes of the current study. Similarly, children's RT on each trial were recorded as an average for each categorization level, however RT's were analyzed for the animate-inanimate level only.

Content Validation. A group of 21 adults also completed the matching-to-sample task to assess how well each trial measures taxonomic associations. We used a criteria of 85% correct to define trials that measure the intended concept. One animate-inanimate level trial was identified as problematic as only 10% of adults responded correctly. This trial was therefore removed from subsequent analyses.

Object Sorting Categorization Task. The traditional object sorting procedure involves the grouping of three-dimensional objects into spatially distinct categories (Markman, Cox, & Machida, 1981; Starkey, 1981). In the current experiment, we adapted the object sorting task to provide this structure by using transparent plastic bowls to facilitate children's categorization (Wright, Poulin-Dubois, & Kelley, 2015). Children were provided with one category exemplar in each bowl, and were subsequently given 6 novel objects to be sorted. Similar to the matching-to-sample task, typical exemplars of each category were selected. Figurines of people included children and adults of different ethnicities wearing different coloured clothing. Animal replicas included a horse, dog, cow, elephant, bird, and fish. Furniture replicas included a bed, desk, table, cabinet, chair, ottoman, and couch. Vehicle replicas included a car, pick-up truck, motorcycle, bus, helicopter, and train.

Children first participated in a brief training phase to become familiar with the task. During this phase, the experimenter demonstrated how to complete the task using simple object anchors in the bowls (e.g., sorting ice-cream cones vs. grapes). The experimenter then took a third object and demonstrated how to categorize it into the correct bowl. Children were given the remaining objects to categorize and corrective feedback was provided if children made sorting errors.

Two test trials were administered to assess animate-inanimate level categorization. As in the matching-to-sample procedure, additional basic and superordinate level trials were administered to provide an assessment of children's categorization skills at varied levels of difficulty. A total of six test trials were administered, with the presentation order of each level counterbalanced. On test trials, category anchors were provided in each bowl and children were subsequently handed objects to categorize, one by one. Children were instructed to place each object in the bowl with 'the same kind of thing'. Each trial consisted of 6 objects to be sorted, 3 objects from each category. Following each sorting trial children were asked, "What makes these the same kind of thing" to asses explicit knowledge of these categories.

At the animate-inanimate level, two category anchors were drawn from four possible pairings: person-vehicle, person-furniture, animal-vehicle, and animal-furniture. Each child completed one trial with a person as the anchor and one trial with an animal as the anchor. At the A-I level, an additional superordinate level object (matching the animate anchor) was included, but not scored, to ensure the A-I category contained at least two people and three animals, or vice versa.

Coding. The object sorting task was coded for both accuracy of taxonomic sorting and verbal explanation why each group of toys was 'the same kind of thing.' The coding scheme for taxonomic accuracy was developed based on previous object classification studies (Sugarman, 1983). A score of 2 was given if the child sorted both categories without error. A score of 1 was given if the child made one sorting error, but sorted the other five objects correctly. A zero score was given if the child made two or more sorting errors. Children who sorted objects according to a thematic, rather than taxonomic, association received a score of 0. These children, however, are differentiated from children whose sorting did not demonstrate any clear strategy by analyzing children's verbal reasoning about each category. For each categorization level a total possible score of 4 was computed; however, only animate-inanimate categorization was analyzed for the purpose of this study. In order to compare animate-inanimate categorization performance across matching-to-sample and object sorting tasks, scores ranging from 0 to 4 were converted a scale ranging from 0 to 100% correct.

Children's verbal responses were coded based on a scoring system described in previous research (Kagan, Moss, & Sigel, 1963; Sigel, Anderson, & Shapiro, 1966) and reported in detail in Wright, Poulin-Dubois, and Kelley (2014). Children's verbal responses were coded as taxonomic, thematic, perceptual, or no response. A taxonomic response was any reference to the kind of thing the objects are (e.g. living things, non-living). A thematic response was any response that described a thematic association among objects (e.g., people and their pets [describing the relationship between people and animals], things people use [describing the relationship between furniture and vehicles], things in the house). A perceptual response was any response that focused on observable features (e.g. all have eyes, wheels, move on their own). Multiple responses for the association between the same set of objects were possible and were coded according to the above criteria.

A second experimenter coded 27% of the sample and inter-rater reliability was calculated as Kappa = .97 (with 99% agreement) for children's sorting accuracy score. Inter-rater agreement for the classification of children's verbal responses for each category was calculated as Kappa = .92 (with 93% agreement).

Biological motion task. Each trial was composed of two videos of point-light displays placed on either side of the screen, one animate and one inanimate. The directional motion (e.g., leftward or rightward), and placement of the animate stimuli (e.g., left or right side) was counterbalanced across all trials. Each individual point-light video contained 11 dots, which were placed on the key parts of the human and cat (e.g. head, neck, shoulders, elbows, pelvis, hips, legs) and major areas of the truck (e.g., wheels [3 per wheel], front bumper, back bumper, roof) and bicycle's frame (e.g., wheels [3 per wheel], seat, frame, handle bars). The stimulus was shown to be moving at a speed of 0.5 gait cycles or wheel rotations per second, but remained stationary with no horizontal translation. The point-light video of a human was provided by Troje (2002), while the cat, truck and bicycle stimuli were adapted from Arterberry and Bornstein (2001). The human point-light display was shown in front view, while all other stimuli were shown at a visual angle of 60 degrees to allow all four limbs or two wheels to be visible. The random motion video was constructed using VPixx software (VPixx Technologies Inc.,) with the same 11 point-light dots, whereby each dot was assigned a fixed speed and straight line of trajectory. Dots did not possess animate motion cues such as the ability to change speed, direction, or move contingently with any other dot. In the random motion video, directionality was controlled by having equal number of dots move left, right, up and down.

Procedure. Children were seated in front of a 30-inch computer monitor equipped with a centrally-located camera located above the screen. Children's visual fixations to either the left or right side of the screen during the presentation of stimuli were recorded using the camera and coded offline. Stimuli were programmed and presented using E-Prime software (Schneider et al., 2002). Six different video pairings were shown: cat-bicycle, cat-truck, cat-random, human-bicycle, human-truck, and human-random. Trials were presented in a pseudo-randomized order so that the animate motion stimuli never appeared on the same side for more than two consecutive trials and appeared on the left side for half the trials, and on the right side for the other half of the trials.

To begin each trial, a centrally located fixation cross accompanied by the sound of a bell appeared on screen to ensure that children's eye gaze at the start of each trial was equidistant between the social and non-social motion stimuli. Valid trials were considered those in which the child had looked at each of the two stimuli at least once within each 6 s trial. Whether children demonstrated an overall preference for stimuli presented on the left or right side was examined. Children who spent more than 80% of the time looking at one side of the screen were excluded (n = 1 TD; n = 1 HF-ASD).

Coding. Children's attention to either biological or non-biological motion was coded frame-by-frame using Interact 13.0 software (Mangold International, 2014). The coder was blind to the location of the biological or non-biological motion stimuli. The dependent variable was the proportion of looking time to the animate, biological motion stimuli for each 6-second trial. A second experimenter, blind to the location of the animate stimuli coded 48% of the sample for reliability. Across all six trials, Pearson product-moment correlations comparing values between coders averaged *r* = .90 (range = .82 to .98).

Results

Animate-inanimate categorization. To examine group differences in performance on the A-I categorization tasks, a 2 (Group) x 2 (Task) ANOVA was computed. This analysis revealed no main effect for group, *F*(1, 34) = 1.73, *p* = .20, η^2 = .05, indicating HF-ASD children performed as well as TD children on animate-inanimate categorization, *M* HF-ASD = 69% (*SD* = 31%); *M* TD = 57% (*SD* = 36%). No main effect for Task was found, *F*(1,34) = 2.21,*p* = .15, η^2 = .06. Finally, a significant Group x Task interaction was found (see Figure 6), *F*(1,34) = 4.03, *p* =.05, η^2 = .11, whereby follow-up pairwise comparisons (with Bonferroni correction) revealed that on the object sorting task children with HF-ASD, *M* = 71% (*SD* = 39%) tended to perform better than TD children, *M* = 44% (*SD* = 48%), *p* = .08. Within the HF-ASD group, children performed similarly well on the matching-to-sample, *M* = 67% (*SD* = 24%) and object sorting task, *M* = 71% (*SD* = 39%), indicating that across both tasks a taxonomic categorization strategy was adopted. Among TD children, taxonomic categorization was demonstrated on the matching-to-sample task, *M* = 69% (*SD* = 24%), but not maintained when given the opportunity to switch to a thematic sorting strategy in the object sorting task, *M* = 44% (*SD* = 48%), *p* = .02.

An analysis of the reaction times (RT) obtained on the animate-inanimate trials of the matching-to-sample task indicating that TD and HF-ASD groups responded equally fast (HF-ASD *M*= 5,042 ms, *SD* = 4,571ms; TD *M*= 5,945ms, *SD* = 4,016 ms, *t*(34) = -.63, *p* = .53).

Finally, the quantity and quality of verbal responses describing the categories children created in the object sorting task were analyzed for both HF-ASD and TD groups. The number of children who did not provide a verbal response was equivalent across HF-ASD (n = 5) and TD (n = 4) groups, X^2 = .24, *p* = .63. Chi square analyses for the proportion of children who provided each type of response (e.g., taxonomic, thematic, perceptual) on at least one occasion are shown in Table 5.

Biological motion task. An independent samples test of equality of means revealed group differences in proportion of time spent looking at the animate motion between HF-ASD (*M* = .51, *SD* = .10) and TD groups (*M* = .43, *SD* =.10), *t*(34) = 2.55, *p* = .02, d = .80. Chance analyses were conducted to determine whether children's attention to animate, biological, motion significantly differed from .50. The HF-ASD group did not demonstrate preferential attention to the animate stimulus, *M* = .51, *t*(17) = .63, *p* = .54. In contrast, the TD group demonstrated a below-chance looking time, *M* = .43, *t*(17) = -3.50, *p* < .01, indicating greater visual attention to the inanimate motion. Children with HF-ASD tended to look longer at the animate motion when paired with an identifiable inanimate (e.g., truck, bicycle) (*M* = .54), compared to trials where animate motion was contrasted with random motion (*M* = .45), *t*(17) = 1.80, *p* =.09. In contrast, TD children performed similarly on motion trials where animate motion was contrasted with an identifiable inanimate (e.g., truck, bicycle) (*M* = .44), compared to trials where animate motion was contrasted with random motion (*M* = .49), *t*(17) = .80, *p* = .43. We investigated the possibility that visual interest in the inanimate motion among TD children might be related to the fact that children were trying to identify the inanimate stimuli. Thus, we analyzed whether the ability to correctly identify animate or inanimate motion (proportion correct) differed between HF-ASD and TD groups. A 2 (Group) x 2 (Category) ANOVA was conducted. This analysis revealed no group differences in the ability to identify the point-light stimuli (*M* HF-ASD = 75%, *SD* = 23%; *M* TD = 66%, *SD* = 30%). A trend-level main effect for Category was found, *F*(1,27) = 3.76, *p* =.06, η^2 = .12, whereby across HF-ASD and TD groups children were better able to identify the animate (*M* = 79%) compared to inanimate (*M* = 62%) point-light motion. No significant Group x Category interaction was found, *F*(1, 27) = .52,*p* = .48, η^2 = .02.

An additional group of (n = 11) adults were also tested on the biological motion visual attention procedure to determine whether lessened attention toward animate motion in the TD group should be considered developmentally appropriate. Consistent with the performance of TD children, adults also did not demonstrate visual preference for animate motion (*M* = .54, *SD* = .09) at a level significantly greater than chance, *t*(10) = 1.39, *p* = .20. When we compared trials where animate motion was contrasted with identifiable inanimate (e.g., truck, bicycle) vs. random motion, adult responders tended to prefer biological motion when paired with vehicle motion, *M* = .55, *t*(10) = 2.00, *p* = .07, while their performance did not significantly differ from chance when animate motion was paired with random motion, *M* = .51, *t*(10) = .30, *p* = .77.

The number of saccades (i.e., gaze switches) children made between the animate and the inanimate motion displays during each 6 sec trial was also analyzed. Given that the number of saccades did not significantly differ by trial type, we analyzed the average number of saccades across all trials. No group differences in number of saccades was found for HF-ASD (*M* = 3.38, *SD* = .84) and TD (*M* = 3.38, *SD* = .64), *t*(34) = -.02, *p* = .99.

Attention to biological motion and the animate-inanimate distinction. Pearson product-moment correlation coefficients were computed to examine the link between time HF-ASD and TD children spent attending to biological (vs. inanimate) motion and their concurrent categorization abilities. For both HF-ASD and TD groups, we expected a positive correlation between the proportion of time spent looking at biological motion and the ability to categorize animate stimuli, whereas children who spent more time looking at inanimate motion were expected to perform better on inanimate categorization. Among children with HF-ASD, increased attention to animate motion was not significantly correlated with animate categorization abilities, *r*(16) = -.21, *p* = .42; however, greater attention to inanimate motion was found to relate to children's ability to categorize inanimate stimuli, *r*(16) = .56, *p* = .02. On the object sorting task, the ability to categorize at the animate-inanimate level was not related to increased visual attention to biological motion in children with HF-ASD, *r*(16) = -.25, *p* = .33.

Similarly, among TD children, visual attention toward biological motion was unrelated to animate categorization and attention toward inanimate motion was also not related to inanimate categorization on the matching-to-sample task, *p*'s > .50. Similarly, on the object sorting task visual attention toward biological motion in the TD group was also not related to A-I categorization performance, *p* > .40.

To investigate whether individual differences in the number of times children switched between looking at animate or inanimate motion when presented simultaneously (i.e., number of saccades) was related to performance on the A-I categorization tasks Pearson product-moment correlations were computed for each group. Interestingly, among children with HF-ASD, an increased number of saccades was positively correlated with A-I categorization abilities on the matching-to-sample task, *r*(16) = .51, *p* = .03, and tended to relate to performance on the object sorting task, *r*(16) = .43, *p* = .08. Thus the active process of comparing animate and inanimate motion was related to concurrent ability to differentiate animate and inanimate images and 3-dimensional objects. However, among TD children, the number of saccades was not related to A-I categorization performance on either matching-to-sample or object sorting task, *r*(16) = -.05, *p* = .84, *r*(16) = .20, *p* = .42.

Discussion

Although perception of low-level characteristics of animate motion have been investigated in children with ASD (Klin & Jones, 2006; Johnson & Rakison, 2006; Rutherford, Pennington, & Rogers, 2006) this study is the first to investigate how children with HF-ASD understand animate (people and animals) and inanimate (furniture and vehicles) taxonomic categories. Results of this study support the previous research that concepts related to biological knowledge may be intact among children with ASD (Peterson & Siegel, 1997), even when concepts other than growth or inheritance are tested.

In the current study, a matching-to-sample task was administered to obtain a pure measure of animate-inanimate taxonomy, while an object sorting task allowed children to more flexibly form associations based on either taxonomic or thematic associations. Among children with HF-ASD, no deficits in the formation of animate (people and animals) or inanimate (furniture and vehicles) concepts were found. Furthermore, reaction time measures on the matching-to-sample task showed that children with HF-ASD were as fast as TD children in processing animate and inanimate conceptual relationships. In fact, on the object sorting task children with HF-ASD tended to outperform TD children in their ability to spontaneously sort animate and inanimate objects. This result is interpreted to be most likely an artifact due to the fact that TD children were more likely to switch to a thematic categorization strategy (e.g., placing humans in vehicles or on furniture) when given the opportunity, while children with HF-ASD preferred to maintain a taxonomic strategy. It is possible that the performance of children with HF-ASD reflects a greater preference for rule-based categorical decisions, or further, that difficulty with cognitive flexibility or perseveration proved to be beneficial to their performance on the object sorting task. We also reasoned that TD children's interest in pretend play may have motivated the switch to a thematic categorization strategy. It is also possible that children with ASD tended to outperform TD children on this task because they have received additional practice sorting and categorizing objects within their early intervention therapies. However, if this were the case, children with ASD would be expected to outperform TD children across all other categorization levels, which we did not observe.

A secondary aim of this study was to examine whether deficits in attention to biological motion, if found, were related to a broader deficits in the formation of the animacy concept. Among both HF-ASD and TD groups, the hypothesis that increased attention to biological motion would relate to children's ability to categorize animates was not supported. A number of possible factors might account for these null results. First, in contrast to evidence that biological motion facilitates categorization abilities in infancy (Poulin-Dubois, Crivello, & Wright, 2014), school-aged children's concept of animate and inanimate also includes other principles of naïve biology (e.g., capacity for growth, internal parts and thoughts: Gelman & Markman, 1986; Massey & Gelman, 1988; Opfer & Gelman, 2010; Rhodes & Gelman, 2009; Rosengren, Gelman, Kalish, & McCormick, 1991). Understanding of more advanced biological concepts, for example, the concept of inheritance, has also been shown in older children with ASD (Peterson & Siegal, 1992). Therefore, unlike infants, young school-aged children, both with and without ASD, may no longer prioritize biological motion as a cue to animate class membership. Further, the analysis of children's gaze patterns suggests that at least among children with HF-ASD, the number of times children switch between looking at animate and inanimate motion is more strongly related to categorization performance than measures of overall visual attention. That is, children with HF-ASD who engaged in a more explicit comparative process when looking at a simultaneous presentation of animate and inanimate motion were better at categorizing animate and inanimate images and objects. One possible explanation for these findings relates to the evidence that children with ASD have difficulty with gaze shifting, or disengaging their attention (Elsabbagh et al., 2013; Landry & Bryson, 2004; Zwaigenbaum et al., 2005). Thus, it is possible that a more general propensity toward, or conversely away from, switching or set-shifting in a sub-group of the children with HF-ASD drove the correlation between how frequently children compare animate and inanimate motion and their concurrent categorization abilities. However, it is unlikely that a 'sticky attention' hypothesis could entirely explain these results given that no group differences were found in the average number of saccades used by HF-ASD and TD children. Future research in this area should adopt a developmental perspective to examine the relation between biological motion perception and the development of A-I categorization skills in both TD infants, infants at-risk for developing an ASD, as well as younger preschool children with a more limited understanding of naïve biology (e.g., animate- inanimate distinction, notion of growth, death, insides).

Second, while the finding that children with HF-ASD failed to pay more attention to biological motion stimuli is consistent with previous research (Falck-Ytter et al., 2013; Klin et al., 2009), the performance of the TD children was unexpected. Specifically, TD children attended to inanimate motion more than to animate motion. These results may, however, be explained by the fact that our methodology did not involve habituation or prolonged exposure to the same-stimuli pairings, but rather presented novel pairings on each trial. Previous research showing a preference for animate motion in typical development has used designs where the participant was habituated to animate stimuli that was paired with scrambled, rigid, or inverted versions of the same stimuli (Bardi et al., 2010; Simion et al., 2008). Other research investigating visual preference in children with ASD has also contrasted animate motion stimuli with inverted displays of the same stimuli played backwards (Falck-Ytter et al., 2013; Klin et al., 2009). The motion contrasts used in the current experiment were selected to represent a naturalistic contrast between the motion of animate entities and non-living things. Thus, the inanimate stimuli were not simply an inverted, or modified, display of the animate stimuli. To clarify whether the performance of the TD group was developmentally appropriate, an additional group of adults were tested. Results revealed that adults also did not demonstrate a preference for biological motion, suggesting that their response style was not atypical. That the performance of TD children and adults did not replicate previous research when the biological motion preference task was modified suggests that the visual preference paradigm may not be a robust measure of the reported bias toward socially relevant motion. The assumption or notion that TD children and adults show a preference for socially-relevant aspects of the environment has important implications for hypotheses relating to social motivation deficits as an explanatory model of the development of ASD.

The social motivation hypothesis (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Webb et al., 2010; Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012) asserts that the early developmental trajectory of ASD in infancy involves a disruption of the social brain pathways responsible for directing attention to social aspects of the environment. Following from this view, one would hypothesize potential downstream effects in the development of social-cognitive abilities characteristic of ASD. In the present study, children’s relative preference for biological over mechanical or random motion was a measure of social motivation. We tested whether visual attention to animate motion was related to children’s knowledge of the animacy concept, a putative precursor to social cognition. The results of the current study indicate that the animate-inanimate distinction was not related to attention to animate motion in both the TD and HF-ASD groups. However, we acknowledge that visual preference for biological motion provides an indirect low-level assessment of social motivation, which may not parallel results of more naturalistic measures of social motivation such as coding home videos, or using pictures of objects that include children's circumscribed interests (e.g., Sasson, Ellison, Turner-Brown, Ditcher, Bodfish, 2011; Sasson & Touchstone, 2013).

An interesting future direction to this line of work would be to compare a range of laboratory-based measures of social orienting (e.g., speech vs. non speech, faces vs. objects, etc.) with multiple measures of social cognition (e.g., implicit and explicit false belief). This would allow us to determine the consistency across social orienting measures, as well as which type of social orienting deficits might best predict later social-cognitive skills. Although it has been suggested that ASD can be construed as an extreme case of diminished social motivation (Chevallier et al., 2012), a similar link might also be expected among TD children. Given that interindividual differences have also been reported in the processing of social stimuli and the development of social cognitive skills, this interesting issue is currently being pursued in ongoing studies.

	HF-ASD	TD		
	M (SD)	*M* (*SD*)	*t*	*p*
Chronological Age	6.61 (1.29)	6.41 (1.75)	.40	.70
Verbal IQ	102 (19.03)	105.22 (11.44)	.62	.54
Verbal Mental Age	6.75 (2.06)	7.11 (2.35)	.48	.63
Social Communication Questionnaire (SCQ)	17.00 (6.89)	--		
Social Responsiveness Scale (SRS)	78.44 (10.31)	--		

Table 4. *Participant Characteristics for HF-ASD and TD groups*

Note. On the SCQ scores of 15 or above are considered to meet cut-off for ASD. However, a lower cut-off score (e.g., 13 or 11) has been suggested to improve the sensitivity and specificity of the SCQ, in particular among high-functioning children (Corsello et al., 2007; Snow & Lecavalier, 2008). Although some children with HF-ASD no longer screened above the established cut-off, significant ASD symptomatology was reported on the SRS. n = 18 per group.

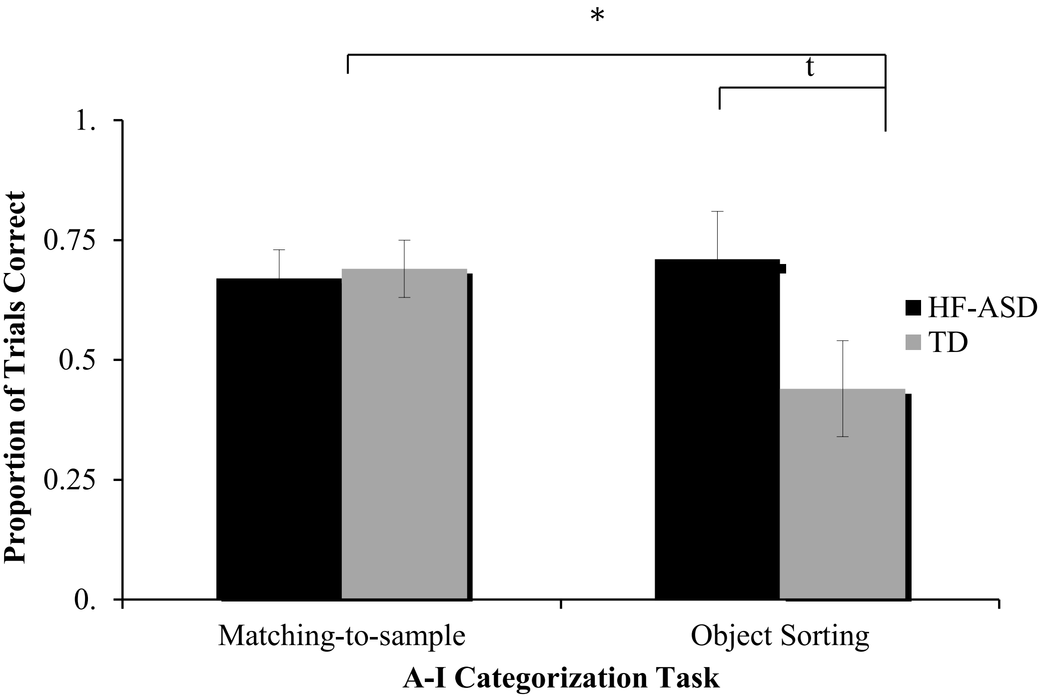

Figure 6. Categorization performance as a function of group and task

Note: * denotes $p < .05$, *t* denotes $p < .10$

	HF-ASD	TD		
	M %	*M* %	$X^2(1,35)$	*p*
Taxonomic	35%	33%	.02	.90
Thematic	41%	39%	.02	.89
Perceptual	24%	39%	.96	.33

Table 5. *Mean Percentage of Children who Provided Each Type of Verbal Response*

Note: Percentage of children providing each type of response does not add up to 100% because children were permitted to provide more than one verbal response describing the category. n= 18 per group.

Chapter 5

General Discussion

Motion has been hypothesized to lay the foundation for the development of the animate-inanimate (A/I) categorical distinction (Gelman & Opfer, 2002; Mandler, 1992, 2012; Opfer & Gelman, 2011; Rakison & Poulin-Dubois, 2001), a foundational cognitive ability. In the extant literature, the emergence of an implicit A-I concept in infancy has been documented (Poulin-Dubois, Frenkiel-Fishman, Nayer, & Johnson, 2006; Rostad, Yott, & Poulin-Dubois, 2012). This line of research has also documented a link between exposure to biological motion and categorization abilities, wherein priming infants with human biological motion has been shown to specifically impact 12-month-olds ability to categorize contrasts that include other animals (Poulin-Dubois, Crivello, & Wright, 2015). However, beyond the infancy period, little is known about the development of an explicit, conceptual understanding of the A-I categories in childhood, or whether biological motion continues to be influential to older children's category judgments. Additionally, among children with ASD there is evidence for an early emerging disruption in attention to biological motion (Falck-Ytter, Rehnberg, & Bölte, 2013; Klin & Jones, 2008; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Therefore, it may be expected that if children with ASD pay less attention to motion cues shown to relate to the development of A-I categories, they may also display deficits in the ability to form the A-I distinction. The present dissertation is the first to examine these aspects of naïve biology, namely, the potential relation between biological motion perception and the A-I distinction among both TD children and children with HF-ASD.

The present dissertation consisted of three studies that were conducted with the overarching goal of investigating the development of naïve biological reasoning among TD children and children with HF-ASD. One primary goal of this research was to examine the development of the taxonomic categorization at the most inclusive level (animate-inanimate) among TD preschool children, as well as children with HF-ASD. A second main goal was to investigate another aspect of naïve biology, knowledge of biological motion, among TD children and children with HF-ASD children. The first study (Wright, Poulin-Dubois, & Kelley, 2015) provided an assessment of children's taxonomic categorization abilities (i.e., matching-to-sample), as well as their relative preference for forming taxonomic categories (i.e., object sorting). Study 2 (Wright, Kelley, & Poulin-Dubois, 2014) examined children's explicit identification of biological motion by comparing the performance of TD children and children with HF-ASD on two identification tasks: point-light display and animated schematic motion. Finally, Study 3 (Wright et al., 2015) aimed to tie together the first two studies by investigating whether biological motion perception was related to the development of the ability to form A-I categories among both TD children and children with HF-ASD.

The first study contributes to the literature by establishing that by 5 years of age, TD children possess explicit knowledge of the A-I distinction, although the development of these abilities continues to improve into adulthood. The results this study confirmed that the A-I categorization level is the last category level to emerge in children's conceptual development. Further, the comparison of children's performance on the matching-to-sample and object sorting task in this study is informative to the broader debate concerning the nature and flexibility of children's categories. Using a within-subjects design, this research documented children's ability to form taxonomic categories (i.e., matching-to-sample), as well as their relative preference for categorizing according to taxonomic or thematic associations (object sorting). In the present study, 4- and 5-year olds were equally likely to switch from a taxonomic to a thematic categorization strategy. Interestingly, those children who switched to a thematic categorization strategy on the object sorting task (51% of the sample) were still shown to possess the relevant A-I taxonomic knowledge when tested using the matching-to-sample procedure. Thus, in typical development 4- and 5-year old children flexibly switch between categorizing using a taxonomic and thematic strategy. The results of this study established a baseline of performance in typical development, and were used to select children with HF-ASD for Study 3 (Wright, Kelley, & Poulin-Dubois, revise resubmit).

The large variability in cognitive ability among individuals with ASD has posed challenges for identifying features or abilities that are uniquely affected in the disorder, and are not simply a correlate of lower cognitive ability. To partial out the impact of cognitive ability, children in Studies 2 and 3 participated in cognitive evaluations and were only included in the sample if they did not have an intellectual disability. The results of Studies 2 and 3 suggest that average-IQ children with ASD are unimpaired in the formation of A-I categories, and additionally, show no deficits in the identification of biological motion. Thus, if deficits in categorization or identification of biological motion are found they should not be considered a universal feature of ASD. Results of Study 3 also suggest that children with HF-ASD are developmentally similar to TD children in that neither group was found to prioritize biological motion as a cue that is relevant to differentiating animate and inanimate concepts. Importantly, this study provided the first investigation of animate and inanimate taxonomic categories among children with ASD.

More broadly, Studies 2 and 3 also indirectly inform the ongoing debate concerning the nature of cognition in ASD. In particular, the question of whether preference for local-level information affects global processing, and if so, the degree in which local-global processing is affected. The weak central coherence theory (WCC; Happé & Frith, 2006) suggests that individuals with ASD prioritize strategies that lead to enhanced ability to focus on local details, at the expense of the global picture. However, the enhanced perceptual functioning account (EPF; Mottron, Dawson, Soulières, Hubert, & Burack, 2006) suggests that while individuals with ASD have enhanced ability to focus on local details, their ability to perceive the global picture is not impaired. Thus, while the WCC and EPF theories agree that individuals with ASD have an enhanced ability to process information at the local level, they disagree concerning whether these abilities come at the expense of being able to perceive the broader picture.

In Study 2 children were shown point-light displays, which depict motion that is degraded and contains only dots that represent the global form and motion of the particular stimuli. Children were asked to identify what the dots represent as a whole. Had children with HF-ASD focused too much on the local motion they would have been more likely to incorrectly label stimuli according to the local motion of the various parts (e.g., legs, wheels) rather than identifying the Gestalt form. Children with HF-ASD, however, did not provide responses of this nature, and moreover labelled the Gestalt form as accurately as TD children. Thus, results of this study suggest that if children with HF-ASD indeed prefer to process information at the local level, consistent with the EPF hypothesis, this processing style does not come at the expense of global processing.

Study 3 tested multiple levels of categorization that allows for an evaluation of the WCC and EPF accounts of local-global information processing abilities among children with HF-ASD. A comparison of performance across categorization levels provides an assessment of children's performance on local versus global categorization tasks. That is, the ability to categorize at the basic level requires an attention to local detail (e.g., features that differentiate cats from dogs), whereas the ability to categorize at the global, A-I level requires the ability to ignore differences in local details and group together perceptually dissimilar objects or entities (e.g., a person and a bird, or a table and a boat). Consistent with the EPF theory, the results of Study 3 suggest that children with HF-ASD are not impaired in forming broad, A-I level categories and did so with similar speed and accuracy as TD children.

Relatedly, the different methodology used in the object sorting task allowed for a comparison of the sorting preferences of HF-ASD and TD children. Overall, children with HF-ASD were slightly less likely to switch from a taxonomic to a thematic sorting strategy, compared with TD children (56% of children with HF-ASD switched on at least one trial, compared with 67% of TD children). Children with HF-ASD, therefore, were more likely to maintain a taxonomic approach to categorizing, and thus, tended to outperform their matched TD peers. The greater propensity to switch from a taxonomic to a thematic categorization strategy in typical development likely reflects children's preference for pretend play, as thematic categorization often involved placing people on furniture or in cars. While some may speculate that children with ASD simply demonstrated diminished cognitive flexibility by maintaining a taxonomic strategy, research investigating cognitive flexibility in ASD suggests that while people with ASD are behaviourally more inflexible in their day-to-day-lives, they do not demonstrate cognitive inflexibility on experimental tasks (Geurts, Corbett, & Solomon, 2009). These results, however, are likely better explained by delays in imaginative or pretend play commonly observed among children with ASD (for a review see Jarrold, 2003).

While the A-I distinction has been commonly considered an important component of naïve biological reasoning (Inagaki & Hatano, 1994), biological motion perception has been less frequently discussed as a component of naïve biology. Although it has been suggested that deficits in biological motion perception, a low-level characteristic of naïve biology, are one of the hallmarks of ASD (Kaiser & Shiffrar, 2013; Pavlova, 2011, 2013), results of Study 2 suggest that these deficits may not be a universal feature of ASD. That is, high-functioning school-aged children with HF-ASD readily identified point-light displays containing both biological and non-biological motion. Children with HF-ASD were also shown to associate non-rigid expansion-contraction motion with the animate class, and rigid motion with the inanimate class. These results are in line with previous research showing no reliable autism-specific deficit in animacy perception among school-aged children with ASD (Rutherford, Pennington, & Rogers, 2006). It is, however, possible that early deficits in processing biological motion may still be a diagnostic predictor of ASD in younger toddlers (Kaiser & Pelphrey, 2012; Klin & Jones, 2008; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). The body of research to date suggests that the development of biological motion processing is delayed in ASD, but does develop over the childhood and adolescent period (Cleary, Looney, Brady, & Fitzgerald, 2013; Freitag et al., 2008; Hubert et al., 2007; Klin & Jones, 2008; Klin et al., 2009; Moore, Hobson, & Lee, 1997; Murphy, Brady, Fitzgerald, &Troje, 2009; Rutherford & Troje, 2012; Saygin, Cook, & Blakemore, 2010). It is also possible that although the children with HF-ASD demonstrated a mature behavioural response in identifying the point-light displays, they may have succeeded by recruiting different brain areas than what has been observed in typical development. Previous neuroimaging studies have shown group differences in brain responses between TD and ASD participants, despite similar behavioural performance on biological motion discrimination tasks (Freitag et al., 2008; Herrington et al., 2007). Among individuals with ASD hypo-activation in the posterior superior temporal sulcus, one area of the social brain network has been documented while viewing biological motion point-light displays (Blake & Shiffrar, 2007). Another potential explanation for the fact that no group differences were found relates to the fact that only children with HF-ASD (i.e., without a comorbid intellectual disability) were included. In this study, high-functioning children were selected to be able to determine whether differences in performance were uniquely related to having an ASD and were not attributable to deficits in general intellectual functioning. Nonetheless, even among a well-matched sub-sample of children with ASD the results of this study support previous research finding a link between cognitive functioning and biological motion perception abilities (Rutherford & Troje, 2012).

This study was the first to compare children's performance using two different methodologies of identification of biological motion: point-light display and animated expansion-contraction motion. Interestingly, while the performance of children with HF-ASD was correlated across tasks, the performance of TD children was not. That performance of TD children was unrelated across two tasks purported to measure biological motion is potentially problematic from the perspective of establishing construct validity. Although 'biological motion' was defined differently in each procedure (i.e., gravity-defined motion versus expansion-contraction motion), one would expect children who identify point-light biological motion to also associate schematic biological motion with the class or animates, and vice versa. One possible explanation for these results is that the differing nature of the stimuli might have implicated the recruitment of different brain pathways. Recent research has shown that biological form and motion are processed by distinct neurological pathways (Miller & Saygin, 2013; Thompson & Baccus, 2012; Vangeneugden, Peelen, Tadin, & Battelli, 2014). The biological motion point-light display stimuli contain both form and motion cues, while the schematic biological motion stimuli held form constant in order to isolate motion cues. Thus, the biological motion point-light display task may have simultaneously recruited form and motion processing pathways of the brain (i.e., ventral and dorsal pathways), while the schematic biological motion task may have recruited only motion pathways (i.e., dorsal pathway). Furthermore, that performance of children with HF-ASD was correlated might suggest that children were using a different cognitive process than TD children to complete these tasks. Future research using functional imaging while TD and HF-ASD children view schematic and point-light biological motion may help identify the differences in how children process animate form versus motion cues.

Emerging evidence suggests that individual differences in biological motion perception predict the severity of symptoms or traits of ASD. In particular, sensitivity in detecting biological motion has been linked to ASD severity scores on the ADOS (Blake, Turner, Smoski, Pozdol, & Stone, 2003), as well as self-reported traits of ASD in an unaffected undergraduate population (Kaiser & Shiffrar, 2013). This line of research, however, has yet to investigate whether identification, rather than detection, of biological motion is similarly related. Thus, an additional exploratory aim of this study was to examine this potential link. An estimate of children's social-cognitive abilities was obtained using parental report on the Social Communication Questionnaire (SCQ) and the Social Responsiveness Scale (SRS). Consistent with previous research, HF-ASD children who had higher scores on the SCQ, a screening instrument for ASD, tended to perform more poorly on the biological motion identification task. This relationship was specific to animate motion identification. That autism severity scores on the SRS were not found to relate to biological motion identification is not altogether surprising given that scores of children with HF-ASD tended to cluster toward the severe end of the broader autism phenotype, which is not surprising given that all of the children already possessed an ASD diagnosis. Had parents of TD children also completed this measure, this would have provided greater variability in scores relating to the broader autism phenotype, which may have revealed a relationship with biological motion identification. One additional limitation of these findings is that the parental report measures used in this study do not provide a direct measure of children's social-cognitive abilities.

The final study of this dissertation (Wright, Kelley, & Poulin-Dubois, revise resubmit) aimed to tie together two aspects of naïve biology, namely, the perception of biological motion and the animate-inanimate distinction by providing the first investigation of the nature of this relationship in both typical development and children with ASD. In this study, children viewed a series of split-screen presentations of point-light biological motion, contrasted with inanimate motion. The split-screen point-light display allowed for the measurement of a variety of attentional variables relating to both prioritization of attention to biological motion (e.g., total looking time, orienting) as well as active visual processing of biological motion compared to inanimate motion (e.g., saccades). Although empirical evidence supports the importance of motion cues in the development of an implicit animacy concept in infancy, results of this experiment did not show a relation between prioritization, or active visual processing of biological motion, and TD children's ability to form the A-I distinction. Thus, the results of this study suggest that unlike infants, TD school-aged children no longer prioritize biological motion as a cue that is relevant to differentiating animate and inanimate concepts. One potential explanation for these findings may be that children's concept of naïve biology has already integrated other non-obvious properties which are specific to animate entities (e.g., the capacity for growth, the concept of inheritance, the possession of internal parts, and internal thoughts) (Gelman & Markman, 1986; Inagaki & Hatano, 1996; Jipson & Gelman, 2007; Rosengren, Gelman, Kalish, & McCormick, 1991). When children's concept of naïve biology contains more sophisticated features, children no longer rely on motion to identify and differentiate animates.

Similar to TD children, prioritization of attention toward biological motion was not related to the A-I distinction among children with HF-ASD. However, the explicit process of visually comparing biological and non-biological motion (i.e., number of saccades) was related to the relative ability of children with HF-ASD to categorize animate and inanimate objects. That is, children who more frequently shifted their attention between animate and inanimate motion were better able to form the A-I distinction on the matching-to-sample and object sorting tasks. This relation was not due to differences in attentional shifting abilities between TD and HF-ASD groups, as groups did not differ on the mean number of saccades. However, group differences in overall attention patterns were found between children with HF-ASD compared to TD children.

While completing the split-screen biological motion task TD children were found to initially orient to biological motion on their first look, but across the total duration of the trials spent more time looking at the inanimate, compared to animate, motion. Children with HF-ASD on the other hand, initially oriented to biological motion on their first look, but did not show any clear preference for either the animate or inanimate motion across the duration of each trial. To account for these unexpected results one may speculate that among TD children, processing biological motion is more automatic and so children dedicated more of their attentional resources to the inanimate motion, which was more novel or difficult to decipher. Among children with HF-ASD it is possible that processing biological motion is not as automatic, and thus, children spend equal time examining biological and non-biological motion.

Limitations and Future Directions

The primary aims of this dissertation was to investigate the development of naïve biological reasoning among TD children and children with HF-ASD and also determine whether biological motion perception is related to the development of A-I categories. Although the general findings suggest that children with HF-ASD are unimpaired in the formation of both A-I taxonomic categories and also do not show deficits in the identification of biological motion, it is important to consider that the sample of children with ASD in the present study does not represent all children with the disorder, particularly children with ASD who have a co-morbid intellectual disability. Thus, the results of these studies may only be generalizable to other high-functioning children with ASD. Although the results from Study 3 showed that children with HF-ASD were unimpaired in their ability to categorize at the A-I level one must also be cautious about extending these results to the ability to categorize atypical exemplars of animate and inanimate categories. It may be expected that both TD children and children with HF-ASD would be less accurate in categorizing atypical members of A-I categories such as people in different life stages (e.g., infants, elderly), animals that do not move in a goal-directed way (e.g., star fish), or animals without appendages (e.g., snakes), or inanimates that appear to move in a goal directed way (e.g., robots). Thus, future research may wish to extend the results of this investigation to examine A-I level categorization of atypical exemplars among children with ASD. It may be interesting to contrast performance on matching-to-sample categorization tasks with inductive reasoning tasks that require children to extend specific properties to either atypical members of the animate or inanimate category.

Intuitively it makes sense that the A-I distinction may represent one of the building blocks for social cognition. That is, possessing at least an implicit form of the A-I distinction may be required in order to selectively attribute mental states to animates, but not inanimates. However, empirical research has yet to examine this developmental hypothesis. Future research may wish to more explicitly link infants' emerging concept of the A-I distinction with the ability to selectively attribute psychological characteristics such as intentionality, goal-directedness, desires, and knowledge states to animates, but not inanimates. Among pre-school children who are beginning to acquire explicit knowledge of animate and inanimate properties (i.e., motion, internal parts) it would be interesting to relate the development of naive biological knowledge with the development of naive psychological reasoning, including more complex social-cognitive abilities such as belief and desire reasoning.

Study 2 investigated whether children with HF-ASD identify biological and inanimate motion similar to TD age and IQ-matched peers. Overall, children with HF-ASD were unimpaired in their identification of animate and inanimate stimuli based on motion cues. This study tested whether biological motion was one important characteristic of animacy perception, however, other animate motion characteristics exist and remain to be examined among children with ASD. The animated 'shadow' paradigm used in this study could easily be modified to present children with other animate motion cues such as the ability to self-start, accelerate, decelerate, or change direction. One advantage to using this paradigm to examine additional animacy cues is that it can be administered as a guessing game with verbal children, but can also be administered as a violation of expectation (VOE) task with younger children or children who are unable to provide a verbal response. This paradigm has been previously tested using a VOE procedure to investigate infants' ability to associate changes in speed and direction with animate entities (Trauble et al., 2014). As a VOE task, children with ASD could be tested across the entire range of cognitive abilities, as this procedure relies on looking time as a measure of children's understanding.

Given the unexpected performance of TD children on the attention to biological motion task, wherein they demonstrated a preference for inanimate motion, a number of future directions for testing pre-school children with this procedure may be recommended. In Study 3, the split-screen stimuli differed from previous research in that these stimuli consisted of a series of novel pairings that included the inanimate motion of common vehicles. Previous research using the visual preference paradigm presented the same stimuli (human biological motion contrasted with unidentifiable scrambled motion) across repeated trials. If the split-screen visual preference task possesses robust sensitivity in detecting children's preference for biological motion, slight variations in stimuli would not affect the findings. Therefore, future research may wish to determine under which circumstances the preferential looking paradigm is sensitive in detecting such an effect. Future research should also test the optimal parameters and limits of the visual preference task with toddlers, as well as pre-school and school-aged children. This research should also aim to fully characterize the developmental trajectory of biological motion processing from infancy though to childhood and adolescence. Doing so will make it possible to determine whether visual preference is a sensitive measure for preschool children, and if not, whether other dependent variables such as orienting to biological motion are more appropriate. Among children with ASD, continued investigation of early disruptions in biological motion processing, particularly the functional brain connectivity related to these disruptions, may help to establish known neural signatures or endophenotypes of ASD (Kaiser & Pelphrey, 2012). The potential diagnostic utility of neural signatures has been investigated by Kaiser and Pelphrey (2012) who reported a 96% correct classification rate for TD and ASD children. Future research should aim to extend these investigations by mapping brain-behaviour correlates of biological motion processing into the infancy period to include infants with delayed development, premature infants, infants at-risk for an ASD, as well as toddlers at-risk for other neurological conditions such as attention-deficit hyperactivity disorder. This line of research may prove to be promising in assisting to identify or differentiate toddlers at risk for and ASD.

Investigations of children's preference for social, compared to non-social, aspects of the environment have gained momentum in the scientific community, particularly as these investigations relate to an emergent developmental theory of ASD. The social motivation hypothesis (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012; Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Webb et al., 2010) asserts that diminished social motivation, or attention to social aspects of the environment, has a cascading effect on the development of children's social-cognitive abilities. The theory suggests that children who attend to non-social aspects of their environment receive fewer naturalistic opportunities to learn from peers, thus affecting the development of social-cognitive abilities such as theory-of-mind (ToM). This attentional orientation toward non-social aspects of the environment has been well documented in ASD (Dawson et al., 1998; Webb et al., 2010) and has been proposed to relate to the social-cognitive difficulties experienced by individuals with ASD (Blake et al., 2003; Chevallier et al., 2012; Kaiser & Shiffrar, 2013; Klin et al., 2002; Pavlova, 2011). Although the present studies were not designed to evaluate the relation between attention to social stimuli and children's concurrent social-cognitive abilities, performance on the split-screen visual preference may be considered a low-level measure of children's relative preference for social (biological), compared with non-social (mechanical) stimuli. Further, parental reports of the social-cognitive abilities of children with HF-ASD were obtained on the SCQ. The observed trend relationship between increased attention to biological motion and fewer social-cognitive symptoms of ASD is in line with the social motivation hypothesis and worthy of further exploration.

Potential clinical implications that stem from this line of research relate to both current therapies aimed at remediating the social-motivational symptoms of ASD, as well as the potential utility of experimental measures of social attention for the evaluation of the efficacy of early intervention programs. The development of the Early Start Denver Model (ESDM; Rogers & Dawson, 2010) of intervention for toddlers with ASD was strongly influenced by the research suggesting that atypical social motivation is one of the earliest and most fundamental deficits in ASD (Dawson, Webb et al., 2002; Dawson, Webb & McPartland, 2005). The therapy was designed to increase the salience of social rewards, and thus, increase the likelihood that children pay attention to, and develop the motivation to interact with, the social world. Atypical social attention has been suggested to be a measurable construct that may be used to define the level of social impairment observed in children with ASD (Dawson, Bernier & Ring, 2012). Following from this, it may be suggested that a battery of experimental tasks measuring relative changes in social motivation may be a useful measure of the social components of treatment success in early intervention programs. Experimental paradigms including visual preference for social versus non-social images and motion (e.g., biological motion), as well as tasks that manipulate the minimum threshold for perception of biological motion could be used as potential indicators of increased social attention. As this line of inquiry unfolds, it will be important to also investigate whether experimental measures of social motivation positively correlate with the frequency of social approach behaviours in children with ASD.

A follow-up study is currently underway to address some of the issues related to the use of parental report measures of social-cognitive abilities. The primary goal of this study is to provide a comprehensive investigation of the hypothesized link between social versus non-social attention and the development of social-cognitive skills. In this study, a battery of tasks assessing social preference (e.g. static and dynamic visual preference), a laboratory-based assessment of children's implicit theory-of-mind abilities (Thoermer, Sodian, Vuori, Perst, & Kristen, 2012), as well as a parent report measure of social-cognitive skills are being administered. Both parents of TD children and parents of children with HF-ASD complete the SCQ, therefore making it possible to test whether this proposed relationship also holds in typical development. This study also includes a measure of naïve biological reasoning, which assesses children's understanding of the insides of animates and inanimates (Simons & Keil, 1995), as well as a measure of children's understanding of naïve physics (Baron-Cohen, Leslie, & Frith, 1986). Therefore, it will also be possible to examine the relation among children's development of naïve psychology (e.g., implicit theory of mind), naïve biology, and naïve physics. In particular, the hypothesis that naïve biology might underpin the development of children's ability to reason about the internal states of animates, thus, children's developing ToM is being empirically tested.

Conclusions

Although naïve theories of psychology (Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, 1989) and physics (Baron-Cohen, 1997; Binnie & Williams, 2002) have been extensively studied among children with ASD, there has been a lack of research investigating aspects of naïve biology, particularly the A-I distinction. While some aspects of naïve biology including biological motion perception (Annaz et al., 2012; Falck-Ytter et al., 2013; Freitag et al., 2008; Klin & Jones, 2008) and mature concepts such as illness, growth, and inheritance (Binnie & Williams, 2002; Peterson & Siegal, 1992) have been investigated, there is a lack of research investigating whether children with ASD form animate and inanimate taxonomic categories. The current set of studies not only addressed this question, but also provided a broader investigation of the potential relation between biological motion perception and the development of A-I categories in both typical development and children with HF-ASD. Results from this research confirmed that the A-I categorical distinction is the last category level to emerge in the development of children's explicit taxonomic concepts around 5 years of age. In contrast to what has been found in infancy, pre-school children no longer rely on perceptual features such as motion when forming the A-I distinction. Rather, children most likely rely on broader knowledge of naïve biology, which include abstract notions of birth, death, growth, and inheritance. This research was also the first to show that average-IQ children with ASD were not impaired in naïve biological understanding across multiple tasks, including A-I categorization and biological motion perception. Thus, this research established that deficits in naïve biology, if found, are not specific to ASD, but may be considered a more general correlate of cognitive ability. Promising future directions for research investigating the social motivation hypothesis from infancy through early childhood as social brain networks are being pruned will allow us to more fully understand the relationship between measures of social motivation, such as social orienting and the subsequent development of social-cognitive abilities.

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Appendix A: Recruitment Materials

Recruitment letter for typically-developing participants (Study 1)

Recruitment letter for participants with ASD (Studies 2 & 3)

Brochure to advertise study (Studies 2 & 3)

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UNIVERSITY

Dear Parents, June 2012

We would like to take this opportunity to thank you for your participation in studies conducted by our Cognitive and Language Development Laboratory. We are truly grateful for your enthusiasm and commitment to research. You may recall expressing interest in our future studies. We would like to invite you to take part in a new and exciting study examining how children learn different categories for objects. This research is funded by the Social Sciences and Humanities Research Council of Canada.

The Cognitive and Language Development Laboratory is presently involved in a study examining concept development in typically developing children and children with Autism Spectrum Disorder. Our research has been funded by federal and provincial agencies for the past twenty-five years and our team is internationally recognized for its excellent work on early child development. Our articles are frequently published in prestigious journals such as “Child Development” and “Developmental Science”. You might also have heard about our studies on national radio or on the Discovery Channel.

For the present study, your child will have the opportunity to participate in a few short games and cognitive tasks. The first task involves watching a video of moving objects on a black screen. Following this, your child will play a computer game where different images will be presented and your child will be asked to sort them into different categories. Then, the experimenter will play several interactive games with your child. In the final task, your child will be looking at a computer screen where a different set of moving objects will be presented. We will videotape your child’s behaviour including looking time at videos and all tapes will be treated as strictly confidential.

Overall, your participation will involve one approximately 60-minute-long visit to our laboratory at the Loyola Campus of Concordia University, located at 7141 Sherbrooke Street West, in Notre-Dame-de-Grace. Appointments can be scheduled at a time that is convenient for you and your child, including weekends. Free parking is available on the campus and we offer babysitting for siblings who come to the appointment. Upon completion of the study, a Certificate of Merit for Contribution to Science will be given to your child, and you will be offered a financial compensation of 20$ for participating. A summary of the results of our study will be mailed to you once it is completed.

For the purposes of this study, we are looking for children who have English as a 1st language, and who do not have any visual or hearing difficulties. If you are interested in having your child participate in this study, or would like any further information, please contact Kristyn Wright at (514) 848-2424 ext. 2279, or Dr. Diane Poulin-Dubois at (514) 848-2424 ext. 2219. For more information on our studies, please visit our website at http://crdh.concordia.ca/dpdlab/. We will try to contact you by telephone within a few days of receiving this letter.

We are looking forward to speaking with you in the near future.

Sincerely yours,

Diane Poulin-Dubois, Ph.D. Professor Department of Psychology	Monyka Rodrigues, B.A., Laboratory Coordinator Department of Psychology	Kristyn Wright, M.A. Ph.D. Clinical Psychology Student Department of Psychology

L'Hôpital de Montréal pour enfants
The Montreal Children's Hospital
Centre universitaire de santé McGill
McGill University Health Centre

Université Concordia University

Dear Parents, December 2012

The Cognitive and Language Development Laboratory, which is affiliated with the Centre for Research and Human Development at Concordia University, is presently involved in a study examining conceptual development in children with Autism Spectrum Disorder. Our research has been funded by federal and provincial agencies for the past twenty-five years and our team is internationally recognized for its excellent work on early child development. Our articles are frequently published in journals such as "Developmental Science" and "Research in Autism Spectrum Disorders." You might also have heard about our studies on national radio or on the Discovery Health Channel.

This research project is being carried out in collaboration with Dr. Lara Stern at the Montreal Children's Hospital, who has provided us with your name. Families who have participated in one of our previous studies as well as families who have never participated are invited to take part in this study. In this study, you will have the unique experience of learning more about your child and child development, while providing a valuable contribution to research in this field!

For the present study, your child will be invited to participate in a few short games. The first task involves a computer game where different images will be presented and your child will be asked to sort them into different categories. Next, your child will be watching a video of moving objects on a black screen, Following the video your child will play a game with the experimenter involving the grouping of toys into different categories. Your child will next play a guessing game on the computer with the experimenter. In the final task, your child will be looking at a computer screen where a different set of moving objects will be presented. We will videotape your child's behaviour including looking time at videos and all tapes will be treated as strictly confidential.

Overall, your participation will involve two to three approximately 60-minute-long visits to our laboratory at the Loyola Campus of Concordia University, located at 7141 Sherbrooke Street West, in Notre-Dame-de-Grace. Appointments can be scheduled at a time that is convenient for you and your child, including weekends. Free parking is available on the campus and we offer babysitting for siblings who come to the appointment. A summary of the results of our study will be mailed to you once it is completed.

For the purposes of this study, we are looking for children with Autism Spectrum Disorder who are between 4 and 11 years of age, who have English or French as a first language, and who do not have any visual or hearing difficulties. If you are interested in having your child participate in this study, or would like any further information, please contact Kristyn Wright or Monyka Rodrigues at (514) 848-2424 ext. 2279. For more information on our studies, please visit our website at http://crdh.concordia.ca/dpdlab/.

We are looking forward to speaking with you in the near future.

Sincerely yours,

Diane Poulin-Dubois, Ph.D.
Professor
Department of Psychology
Concordia University

Dr. Lara Stern
Psychiatrist
Montreal Children's Hospital
Autism Spectrum Disorders
Program

Kristyn Wright, M.A.,
Ph.D. Clinical Psychology
Student
Department of Psychology
Concordia University

Appendix B: Consent Forms

Concordia University consent form (Study 1)
Queen's University Letter of Information (Studies 2 & 3)
Queen's University consent form (Studies 2 & 3)
Montreal Children's Hospital consent form (Studies 2 & 3)
Montreal Children's Hospital Assent (Studies 2& 3)

UNIVERSITÉ Concordia UNIVERSITY

Parental Consent Form

This is to state that I understand that I have been asked if my child can participate in a research project being conducted by Dr. Diane Poulin-Dubois and graduate student Kristyn Wright of Concordia University in collaboration with Dr. Eric Fombonne of the Montreal Children's Hospital.

A. PURPOSE

I have been informed that the purpose of the research is to examine conceptual development and theory of mind in typically developing children and children with Autism Spectrum Disorder (ASD).

B. PROCEDURES

For the present study, you will be asked to complete a few short questionnaires about your child's vocabulary and social behaviour. Your child will view two short videos and will then participate in interactive tasks both on the computer and with a female researcher. A camera will monitor the eye movement of your child on the screen. Each video consists of moving objects on a black screen. Your child will also play a computer game where different images will be presented and your child will be asked to sort them into different categories by pressing keys on the keyboard. Your child will next participate in a series of imitation and story telling activities with the experimenter.

We will videotape your child's responses and all tapes will be treated in the strictest of confidentiality. That means that the researcher will not reveal your child's identity in any written or oral reports about the study. You and your child will be assigned a coded number, and that code will be used on all materials collected in this study. All materials and data will be stored in secure facilities in the Department of Psychology at Concordia University. Only members of the research team will have access to these facilities. Questionnaires and electronic data files will be identified by coded identification numbers, unique to each family. Information collected on paper (questionnaires) or videotapes (observed behaviours) will be entered into computer databases. Raw data will be kept for a minimum of 5 years. When it is time for disposal, papers will be shredded, hard-drives will be purged, and videotapes and computer disks will be magnetically erased. Additionally, since we are only interested in comparing children's understanding as a function of age, no individual scores will be provided following participation. The whole session should last approximately 60 minutes.

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, including the loss of financial compensation.
- I understand 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 would be interested in participating in other studies with my child in the future (yes/no): ______

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

MY CHILD'S NAME (please print) ____________________________________

MY NAME (please print) ____

SIGNATURE ___________________________ DATE ____________________

WITNESSED BY _________________________ DATE ____________________

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

___________________________	___________________________
Diane Poulin-Dubois, Ph.D.	Kristyn Wright, M.A.
Professor	Ph.D. Candidate
Department of Psychology	Department of Psychology
848-2424 ext. 2219	848-2424 ext. 2279
diane.poulindubois@concordia.ca	kr_wrigh@live.concordia.ca

Participant # _____________ Researcher: ___________________

LETTER OF INFORMATION

Does perception of biological motion relate to the formation of concepts and theory of mind in children with Autism Spectrum Disorder?

This research is being conducted by Dr. Elizabeth Kelley, Assistant Professor in Psychology, Queen's University, Kingston, Ontario, in collaboration with Dr. Poulin-Dubois, Professor of Psychology, Concordia University, Montreal, Quebec, and her graduate student, Kristyn Wright, MA. This study has been granted clearance according to the recommended principles of Canadian ethics guidelines,and Queen's policies.

The purpose of the current study is to better understand what influences children's ability to differentiate living and non-living things and understand others' thoughts, feelings and actions. We are interested in investigating how and why these abilities might differ in children with and without ASD. We will be administering a number of tasks looking at how your child groups objects together, how your child forms expectations about the types of movement objects are capable of, and how your child understands the goals and intentions of others. We will also be doing a general developmental assessment of your child. Also, we will ask you to provide us with information about your child's level of language and day-to-day skills in the form of a telephone interview, which can be done at a time that is convenient for you.

Your child may participate in any or all of these tasks, depending on his/her enjoyment of and attention to the tasks. To complete all of the tasks we may ask you to come back for a second visit; you are under no obligation to do so. If you cannot, this will not make your contribution any less valid or meaningful. Each of these tasks is important unto itself; the reason we hope to collect data on several tasks is to look at the relationship between them. Your child's behaviour will be recorded by a video camera and the video record will be scored for behaviors such as how they group different objects together, and how they respond to interactive tasks with the experimenter. Your child will also be videotaped while performing a series of basic developmental assessments. Please note that you may stop the testing procedure at any time without consequence. If your child begins to cry and can't be consoled, the procedure will be stopped. There are no known physical, psychological, economic, or social risks associated with this research.

Your child's participation in this study is entirely voluntary. You may withdraw your child at any time for any reason and may also request that the videotape and/or digital recording of your child be erased. Confidentiality of all information is assured; your child's record will be identified only by a participant number to ensure his/her identity remains confidential. It will not be revealed in any published papers, conference presentations, or class-room demonstrations. Our only interest is in investigating how children respond as a collective group. Dr. Kelley, Dr. Poulin-Dubois, and her research assistants will have sole access to the data sheets and videotape recording of your child. They will be stored in a locked laboratory. Should you be interested, you are entitled to a copy of the findings.

Neither you nor your child will benefit directly from participation in this research. You will be reimbursed $10 for each visit to the laboratory for transportation costs, and your child will receive a small toy in appreciation. However, our understanding of autism spectrum disorders will be furthered by this research. Gaining a better idea of how cognitive and social understanding develops in children with autism spectrum disorders will provide us with information that can be used to treat these children. Moreover, understanding early signs of social difficulties will allow us to be able to diagnose and treat children at an earlier age, which has been shown to be very important for treatment success.

In the event that you have any complaints, concerns, or questions about this research, please feel free to contact Dr. Elizabeth Kelley, Department of Psychology (613 533-2491 or kelleyb@post.queensu.ca), or Joan Stevenson, Chair of the General Research Ethics Board (533-6081)at Queen's University.

Again, thank you. Your interest in participating in this research study is greatly appreciated.

Elizabeth Kelley, PhD, Assistant Professor of Psychology

CONSENT FORM

Does perception of biological motion relate to the formation of concepts and theory of mind in children with Autism Spectrum Disorder?

Name (please print clearly): ____

1. **I have read the Letter of Information and have had any questions answered to my satisfaction. I give permission for my child, ____, to participate in the research entitled "Does preference for biological motion relate to understanding of animacy concepts and theory of mind in children with Autism Spectrum Disorder?", as described in the Letter of Information.**

2. I understand that this means that my child will watch events on a computer monitor, video screen, or stage, or presented live by an experimenter. I understand that my child may be asked to passively watch some events, while in other tasks s/he will be asked to participate by imitating, or engaging in a developmental assessment.

3. I understand that my participation in this study is voluntary and I may withdraw my child at any time without any consequence. I understand that this research study involves a number of tasks, and that my child will participate in as many as I choose. I understand that I may be asked to come back for a second visit, but I am under no obligation to do so and my contribution will be no less valid or important if I do not.

4. I understand that every effort will be made to maintain the confidentiality of the data collected from my child. Confidentiality of all information collected in course of this study is assured. I understand that my child's results will be identified via a participant number, in order to ensure that his or her identity cannot be revealed or inferred in published papers, conference presentations, or demonstrations. The participant number will be linked to my child's name only on this consent form, and all consent forms will be kept separate from the data. Only experimenters and research assistants in Dr. Kelley's and Dr. Poulin-Dubois' laboratory will have access to the data sheets and videotape recording of your child's performance, as they will be stored in a locked lab.

5. I am aware that if I have any questions, concerns, or complaints, I may contact Dr. Elizabeth Kelley, Department of Psychology (533-2491 or kelleyb@post.queensu.ca), or Joan Stevenson, Chair of the General Research Ethics Board (533-6081) at Queen's University.

I have read the above statements and freely consent to have my child participate in this research:

Child's Birthdate: __________________

Child's Gender: M F

Signature: ______________________________

Date: _______________________

L'Hôpital de Montréal pour enfants
The Montreal Children's Hospital
Centre universitaire de santé McGill
McGill University Health Centre

UNIVERSITÉ Concordia UNIVERSITY

Does biological motion processing relate to the formation of concepts and social-cognitive understanding in children with Autism Spectrum Disorder?

Consent Form

Primary Investigator: **Diane Poulin-Dubois, Ph.D., Concordia University**
Graduate Researcher: **Kristyn Wright, M.A., Ph.D. Candidate, Concordia University**

Co- Investigator: **Lara Stern, M.D., Montreal Children's Hospital**

Sponsor: **Diane Poulin-Dubois, Ph.D., Concordia University**

Natural Sciences and Engineering Research Council of Canada (NSERC)

You and your child have been asked to participate in a research study on **Autism Spectrum Disorder which includes Autistic Disorder (AD), Asperger's Syndrome (AS), and Pervasive Developmental Disorders Not Otherwise Specified (PDDNOS)**. Before you agree to participate, please read the following consent form and make sure you understand its contents. Do not hesitate to ask questions or to request further information about the study.

PURPOSE OF THIS RESEARCH STUDY

The purpose of the study is to determine whether children with and without ASD use motion information to group objects and learn about others' internal states(e.g., feelings, intentions, desires). Living and non-living things have different patterns of motion. It is thought that these different patterns of motion not only help children to tell the difference between living and non-living things, but also convey information about others' internal states. This study aims to compare children with and without ASD to determine if children with ASD perceive motion differently. We are interested in whether this relates to their ability to tell the difference between object kinds or understand others' internal states. This study could lead to a better understanding of how children with ASD learn, and eventually lead to educational programs that teach children about different types of motion.

PARTICIPATION SELECTION

We would like to recruit families with a child aged 4 to 11, diagnosed with ASD. To participate, children must be able to understand and follow simple instructions in either English or French. We will ask parents to fill out questionnaires about their child's social skills and behaviour.

PARTICIPATION PROCEDURE

1. Dr. Poulin-Dubois's research team will determine your eligibility for this project. The research team may have to consult your medical records in order to obtain additional information.
2. The research assistant will ask you a series of questions concerning the languages your child is exposed to, as well as the language your child most often uses.

3. As a parent/legal guardian of an affected child, you will also be asked to complete questionnaires on behaviours and personality traits of your child. These questionnaires will take about 45 minutes to complete in total and can be completed during your child's appointment.
4. As a participant (person affected by an ASD), the first session will include an evaluation of your child's strengths and weaknesses (Differential Abilities Scale, Second Edition), which will be administered by Kristyn Wright, M.A., doctoral student in clinical psychology. Your child will also participate in a series of tasks. These tasks will involve interaction with a touch-screen computer monitor, viewing different types of animated motion, and sorting objects into different categories. This first session will take approximately 120 minutes. During a second appointment, lasting approximately 60 minutes, your child will take part in a number of interactive tasks involving story-telling and making predictions about others' thoughts, feelings and knowledge.
5. The entire evaluation will take place at Concordia University, Loyola Campus and may be videotaped to enable reviewing at a later date. Videotapes will not be used for teaching purposes. These videotapes will be kept strictly confidential and will be locked in the files of Dr. Poulin-Dubois' laboratory at Concordia University for a period of 5 years, after which, all videotapes will be destroyed. Should you refuse that your child be videotaped they will still be eligible to participate in the cognitive assessment, as well as those tasks that do not require videotaping.

☐ I accept that my child's evaluation be videotaped
☐ I refuse that my child's evaluation be videotaped

6. You may be contacted by telephone in the weeks following the initial evaluation to obtain any missing information.

BENEFITS, RISKS AND DISADVANTAGES

Your child will not directly benefit from your participation in this study. The results of this research could, however, in the long term, benefit individuals with ASD as well as their families.
There are no known physical, psychological, economic, or social risks associated with this research.

You may, if you wish, receive a research report that would summarize your child's cognitive testing.

COMPENSATION:

You will be reimbursed $20 for each visit to the Cognitive and Language Development Laboratory to cover the cost of transportation. A certificate of merit will also be offered to your child.

CONFIDENTIALITY OF INFORMATION COLLECTED

The **information from the assessments, the questionnaires, and the videotapes obtained for the purposes of this study** will not be a part of you or your child's medical file at the Montreal Children's Hospital. It will be stored in the investigator's research files. Only anonymized data will be entered in the laboratory database specific to this research project. This secure database is kept at the Cognitive and Language Development Laboratory, Concordia University. Only experimenters and research assistants in Dr. Poulin-Dubois' laboratory will have access to the data and videotape recording of your child's performance.

Your personal results will not be accessible to outside parties such as employers, government agencies, insurance companies unless you specifically consent to this disclosure. This same rule of confidentiality applies to the disclosure of results to other members of your family and to your doctor.

COMMUNICATION OF RESULTS:

The Cognitive and Language Development Laboratory will keep you informed about the progress and results of our project through a newsletter, which will be sent to your residence.

VOLUNTARY PARTICIPATION:

You and your child's participation are completely free and voluntary. Your decision will not affect the quality of the health services you will receive at the Montreal Children's Hospital. You are also free to withdraw from this research project at any time without consequence. If you do withdraw, all existing data will be removed from the database and any videotapes of your child will be destroyed.

LEGAL RIGHTS

Furthermore, by signing this consent form, you do not give up any of your legal rights, nor do you release the researcher or the hospital of their legal and professional responsibilities.

REQUEST FOR MORE INFORMATION

You may request more information about this study at any time. The following individuals are available to answer your questions and concerns:

Dr. Diane Poulin-Dubois, Primary Investigator, at 514-848-2424, ext. 2219
Email: diane.poulindubois@concordia.ca

Kristyn Wright, M.A., Graduate Student, at 514-848-2424, ext. 2279
Email: kr_wrigh@live.concordia.ca

For any questions concerning your rights as a research participant, please contact the
Patient Representative (Ombudsman), at the Montreal Children's Hospital 514-412-4400 ext. 22223

Does perception of biological motion relate to the formation of concepts and social cognitive understanding in children with Autism Spectrum Disorder (ASD)?

CONSENT FORM

I hereby declare that I have read and understood this consent form, particularly the sections concerning the nature of the participation requested and the risks this entails. A member of the research team has explained the project to me, has answered all of my questions and has given me the time to make an informed decision.

I will receive a signed copy of this consent form. By signing this form, I am not giving up any of my legal rights, nor am I liberating the researcher or the hospital of their civil and professional responsibilities.

If you wish to receive a research report that would summarize your child's cognitive testing please check the appropriate box below:

- ☐ Yes, I wish to receive a report summarizing my child's cognitive testing to be mailed to my home address.
- ☐ No, I do not wish to receive a report summarizing my child's cognitive testing results.

Please check and initial one of the options below regarding future contact about other research studies of ASD or related developmental disorders. You/your child's participation in any research study is completely voluntary and you/your child should feel no pressure to participate if you are contacted about another research study.

☐ Yes, I may be contacted about participating in research projects on ASD or related developmental disorders being conducted by other researchers working with the Cognitive and Language Development Laboratory. I understand that I will be contacted by a research assistant first to tell me about the project. I give permission for my name and the following contact information to be given to the researchers:

email address
phone number
mailing address

☐ No, I do not want to be contacted about other ASD or related research projects. Do not give my contact information to the staff of any other research studies.

Name of Participant: ____________________________________

______________________________________ ______________________________________
Name of Parent or Legal Guardian

______________________________________ ______________________________________
Signature of Parent or Legal Guardian Date

The research project and the methods of participation were described to the participant. A member of the research group answered his/her questions and explained that his/her participation is free and voluntary.

______________________ ______________________ ______________
Name of person obtaining consent Signature of person obtaining consent Date

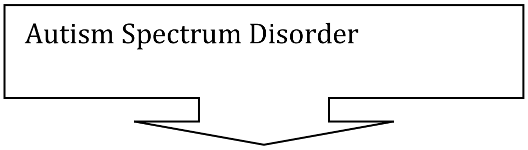
Medical Research Assent Form

For minors who can understand the study

Title of project: **Does biological motion processing relate to the formation of concepts and social-cognitive understanding in children with Autism Spectrum Disorder?**

What is this study about?

This study is about a group of conditions called Autism Spectrum Disorders (ASD).



- ✓ Autistic Disorder (AD)
- ✓ Asperger's Syndrome (AS)
- ✓ Pervasive Developmental Disorder Not Otherwise Specified (PDDNOS)

For this study a team of researchers are trying to find out how children with these conditions learn the difference between living and non-living things. We are also interested in learning how children understand people's behaviours. In order to do this, the researchers have to study both children who have Autism Spectrum Disorders (ASD) and children who do not have the disorder.

What do I have to do for this study?

- You will be asked to participate in a few tests, which will be done in 2 visits.
  - For the first visit you will play some computer games where you will give your answers by touching the screen or telling the experimenter what you think will happen. You will also be asked to make different pictures with blocks, find matching pictures, and draw pictures.
  - On the second visit you will play story-telling games with the experimenter.
- Your sessions with the experimenter may be videotaped.

☐ Yes, it is okay to videotape me.
☐ No, it is not okay to videotape me.

Why should I take part in this study?

Your participation in this study may help us to understand how children with ASD learn. This is important to know so that we can create ways of teaching children with ASD.

What other information should I know?

- All of the information that you give for this study will not be told to anyone else. The only people who can see this information are the research team at Concordia University. None of the information we collect will go into your medical file.
- To help protect your privacy we will not have your name on any of the tests or video recordings. Video recordings will be kept in a locked cabinet.
- You are free to decide if you want to participate in this study. You are also free to stop participating in this study at any time and no one will be mad at you.
- If you have any more questions, you can call

Dr. Diane Poulin-Dubois at (514) 848-2424 ext. 2219
or
Kristyn Wright at (514) 848-2424 ext. 2279

My Agreement:

I understand what this study is about, what I have to do, and I agree to take part in this study.

______________________________ _______________ _____________
Name of minor participant Date of birth Date

____
Signature of minor participant

Verbal assent of minor who is incapable of signing, but who is capable of understanding nature of project:

YES__________ NO___________

______________________________ ____________________
Name of Person who explained assent Date

____
Signature of Person who explained assent

Appendix C: Demographics Questionnaires

Concordia Cognitive and Language Development Laboratory

Participant Information

Child's Name: ____
First Last

Child's Date of Birth: ____________________ Child's Gender: ☐ M ☐ F
MM / DD / YY

Basic Family Information

Parent A's Full Name: ____ ☐ **M** ☐ **F**
First **Last**

Parent B's Full Name: ____ ☐ **M** ☐ **F**
First **Last**

Address (including **postal code**):

____

____

Phone numbers	**Where?** (e.g. home, Mom work, Dad cell)
1.	
2.	
3.	
4.	
5.	

E-mail: ____________________________________

Does your child have any siblings?

Name of Sibling	**Date of Birth**	**Gender**	**Can we contact you for future studies for this child?**
		M F	☐ **Yes** ☐ **No**
		M F	☐ **Yes** ☐ **No**
		M F	☐ **Yes** ☐ **No**

Does the participant live at home with his/her parent(s)? Yes No

If not, what are the participant's living arrangements?

1. Group Home
2. Independently
3. With other family members
4. Other (please explain)____

Who else lives in the home with the participant?

Relationship to the participant	Age	Gender	Diagnosis, if any

What is the participant's diagnosis, if any?
____

Does the participant carry any secondary diagnosis, and if so, what is it?
____

At what age was the participant diagnosed? _________________________________

Who diagnosed the participant?____
Has the diagnosis ever been called into question? Yes No
If yes, please explain.____
____

At what age did the participant begin treatment? ______________________________
What type of treatment was this? ____

What is the main type of treatment that the participant is currently receiving?
____

For how many hours per week?
At home?_____________ At school?___________

What is the participant's school day like?

1. S/he is mainstreamed without any extra help
2. S/he is mainstreamed and shares an aide with one or more other children
3. S/he is mainstreamed and has his/her own educational aide

4. S/he is mainstreamed for some classes (e.g. music, physed), but is in a special needs classroom for most academic subjects
5. S/he is in a special needs classroom all day
6. S/he is in a classroom for children with emotional/behavioural difficulties
7. Other (please explain)___________________________________

____

Please list any other types of treatment that the participant is receiving with approximately how many hours per week s/he is receiving them.

____

____

____

Is there any history of autism spectrum disorder in your immediate family? Yes No
If yes, please explain____

Is there any history of autism spectrum disorder in your extended family? Yes No
If yes, please explain____

Is there any history of language or reading problems in your immediate/extended family?
Yes No
If yes, please explain____

Is there any history of psychiatric disorders in your immediate/extended family? Yes No
If yes, please explain____

Did the participant experience seizures, ear infections, head trauma or serious illness as a young child?
Yes No
If yes, please explain____

Languages Spoken in the Home, School, or Childcare Setting

What percent of the time does your child hear **English**? _________ **%**
What percent of the time does your child hear **French?**_________ **%**
What percent of the time does your child hear **another language**? _________ **%**

In what language has your child been educated? ________________________

Has your child ever been educated in another language? **Yes______ No________**

If so, what language were they educated in? ________________________

From _____ years-old until ________ years-old

Health History

What was your child's birth weight? **__ __ lbs __ __ oz** OR **__ __ __ __ grams**
How many weeks was your pregnancy? ____________**weeks**

Were there any **complications** during the pregnancy? ☐ **Yes** ☐ **No**

If yes please detail ____

Has your child had any major **medical problems**?
If yes please detail____

Does your child have any **hearing or vision problems**?
If yes please detail____

Does your child **currently** have an ear infection? ☐ **Yes** ☐ **No**

Has your child had any ear infections **in the past**? ☐ **Yes** ☐ **No**
If yes at which ages____

Does your child have a **cold** today? ☐ **Yes** ☐ **No**
If yes, does he/she have pressure/pain in ears (if known)? ☐ **Yes** ☐ **No**
Is there any other relevant information we should know (health or language-related)?

Has another university contacted you to participate in one of their studies? ☐ **Yes** ☐ **No**
If yes, which university? ________________________________

Family and Child Background Information (optional)

If the participant is living at home, what is the marital status of the parent(s) s/he is living with?

- ☐ Married
- ☐ Separated
- ☐ Remarried
- ☐ Single
- ☐ Divorced
- ☐ Common-Law
- ☐ Widowed
- ☐ Other

In which of the following ranges does your annual household income fall?

- ☐ $25,000 or less
- ☐ $25,001-$35,000
- ☐ $35,001-$45,000
- ☐ $45,001-$55,000
- ☐ $55,001-$65,000
- ☐ $65,001-$75,000
- ☐ $75,001-$85,000
- ☐ $85,001-$95,000
- ☐ $95,001 or more

Parent A's Current Level of Education	**Parent B's Current Level of Education**
Check any/all that apply:	Check any/all that apply:
☐ Primary School	☐ Primary School
☐ Some High School	☐ Some High School
☐ High School	☐ High School
☐ Some College/University	☐ Some College/University
☐ College Certificate/Diploma	☐ College Certificate/Diploma
☐ Trade School Diploma	☐ Trade School Diploma
☐ Bachelor's Degree	☐ Bachelor's Degree

☐ Master’s Degree
☐ Doctoral Degree
☐ Professional Degree
☐ Not Applicable/Unknown
☐ Other (please specify):

☐ Master’s Degree
☐ Doctoral Degree
☐ Professional Degree
☐ Not Applicable/Unknown
☐ Other (please specify):

Parent A's Occupational Status (optional)
Check any/all that apply:

☐ Employed Full-Time
☐ Employed Part-Time
☐ Stay-at-Home-Parent
☐ Student
☐ Unemployed
☐ Not Applicable/Unknown
☐ On Temporary Leave (e.g., maternity, paternity, sick, etc.; **please also check status when not on leave**)
☐ Other (please specify):

____
____

Parent B’s Occupational Status (optional)
Check any/all that apply:

☐ Employed Full-Time
☐ Employed Part-Time
☐ Stay-at-Home-Parent
☐ Student
☐ Unemployed
☐ Not Applicable/Unknown
☐ On Temporary Leave (e.g., maternity, paternity, sick, etc.; **please also check status when not on leave**)
☐ Other (please specify):

____
____

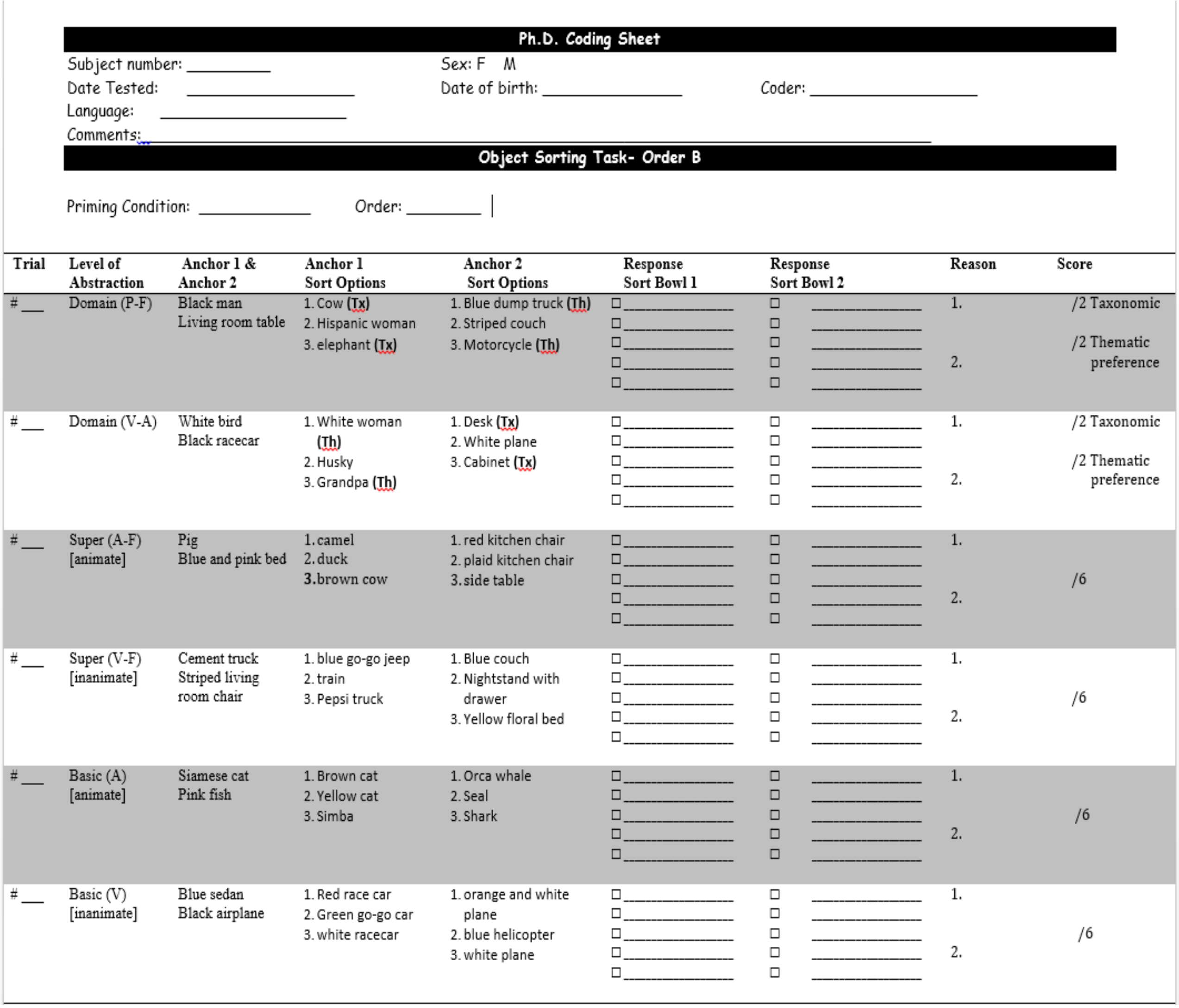
What are your child’s ethnic origins?
Check any/all that apply:

☐ Aboriginal
☐ African
☐ Arab
☐ West Asian
☐ South Asian
☐ East and Southeast Asian
☐ Caribbean
☐ European
☐ Latin/Central/South American
☐ Pacific Islands
☐ Canadian

☐ Other (please specify):

____

Appendix D: Sample Coding Sheet for Object Sorting Task



Ph.D. Coding Sheet

Subject number: __________ Sex: F M

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

Language: ______________________

Comments: ____

Object Sorting Task- Order B

Priming Condition: _____________ Order: _________

Trial	**Level of Abstraction**	**Anchor 1 & Anchor 2**	**Anchor 1 Sort Options**	**Anchor 2 Sort Options**	**Response Sort Bowl 1**	**Response Sort Bowl 2**	**Reason**	**Score**
# ___	Domain (P-F)	Black man Living room table	1. Cow **(Tx)** 2. Hispanic woman 3. elephant **(Tx)**	1. Blue dump truck **(Th)** 2. Striped couch 3. Motorcycle **(Th)**	☐_______________ ☐_______________ ☐_______________ ☐_______________ ☐_______________	☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________	1. 2.	/2 Taxonomic /2 Thematic preference
# ___	Domain (V-A)	White bird Black racecar	1. White woman **(Th)** 2. Husky 3. Grandpa **(Th)**	1. Desk **(Tx)** 2. White plane 3. Cabinet **(Tx)**	☐_______________ ☐_______________ ☐_______________ ☐_______________ ☐_______________	☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________	1. 2.	/2 Taxonomic /2 Thematic preference
# ___	Super (A-F) [animate]	Pig Blue and pink bed	1. camel 2. duck **3.** brown cow	1. red kitchen chair 2. plaid kitchen chair 3. side table	☐_______________ ☐_______________ ☐_______________ ☐_______________ ☐_______________	☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________	1. 2.	/6
# ___	Super (V-F) [inanimate]	Cement truck Striped living room chair	1. blue go-go jeep 2. train 3. Pepsi truck	1. Blue couch 2. Nightstand with drawer 3. Yellow floral bed	☐_______________ ☐_______________ ☐_______________ ☐_______________ ☐_______________	☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________	1. 2.	/6
# ___	Basic (A) [animate]	Siamese cat Pink fish	1. Brown cat 2. Yellow cat 3. Simba	1. Orca whale 2. Seal 3. Shark	☐_______________ ☐_______________ ☐_______________ ☐_______________ ☐_______________	☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________	1. 2.	/6
# ___	Basic (V) [inanimate]	Blue sedan Black airplane	1. Red race car 2. Green go-go car 3. white racecar	1. orange and white plane 2. blue helicopter 3. white plane	☐_______________ ☐_______________ ☐_______________ ☐_______________ ☐_______________	☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________ ☐ _______________	1. 2.	/6