RELATIONAL VOCABULARY IN PRESCHOOLERS WITH AUTISM SPECTRUM DISORDER: THE ROLE OF DYNAMIC SPATIAL CONCEPTS AND SOCIAL UNDERSTANDING

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ABSTRACT

Relational Vocabulary in Preschoolers with Autism Spectrum Disorder:

The Role of Dynamic Spatial Concepts and Social Understanding

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Approximately 75% of children diagnosed with Autistic Spectrum Disorder (ASD) are significantly language impaired. While many learn a reasonably-sized set of object words, few master the relational terms (verbs and prepositions) that are the architectural centerpiece of the sentence. Though learning relational terms poses difficulty even for typically developing children, these words are differentially harder for children with ASD. This research is the first to ask why. Three studies examine the abilities necessary to learn verbs and prepositions. Studies 1 and 2 ask whether children with ASD have greater problems dissecting events into the foundational units and categories that underlie relational term learning (i.e., the *path* or where the object moves, and the *manner* or how the object moves through space) than do typically developing children. Study 3 focuses on tools known to assist in mapping from these basic categories onto words. Are children with ASD able to use information about a speaker's social intent to discover which event components are labeled by a particular word? Finally, this dissertation offers an exploratory correlational analysis designed to assess the joint impact of conceptual abilities and mapping (social understanding) as predictors for relational term learning in the two populations. Thirty-four 3- to 6-year-old children (17 with ASD) participated in the studies. Despite some methodological difficulties with the conceptual tasks, results suggest that the strongest correlate of relational vocabulary size in typical children was conceptual, while the strongest for children with ASD was social understanding. These findings extend prior research by noting the strong relationship between the ability to read social intent and relational term learning. They also suggest that for children with ASD, difficulty understanding the intentions of others is a primary problem that blocks the road to full language competence.

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I dedicate this work to my parents, David and Snova Parish
and Richard and Lynell Morris,
my husband, Jeffrey Parish-Morris,
and my children, Ashley and Joshua Morris.
I love you all.

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CHAPTER 1
INTRODUCTION

The number of children diagnosed with an autism spectrum disorder (ASD) is growing steadily throughout the industrialized world (Croen, Grether, Hoogstrate, & Selvin, 2002). In fact, recent estimates suggest that as many as 1 in 110 children in the United States are affected by ASD (Rice et al., 2009), which translates to 1 in 88 boys. Of these children, approximately 75% have major problems with receptive and/or expressive language (Ghaziuddin & Mountain-Kimchi, 2004; Lord, Risi, & Pickles, 2004; Tager-Flusberg, 2006; Weismer, Lord & Esler, 2010; Zwaigenbaum, Bryson, Rogers, Roberts, Brian, & Szatmari, 2005). The remaining 25% score in the average or above-average range on language tests, but still experience lasting difficulties with pragmatics and semantics (Kelley, Paul, Fein, & Naigles, 2006). Though children with ASD are notoriously heterogeneous, they nonetheless tend to possess a common set of atypical language skills, social skills and visuo-spatial processing patterns. These *atypical* patterns present a valuable opportunity to examine the mechanisms underlying *typical* processes like language acquisition.

Children with ASD have difficulty with language in general, but even some of the more severe cases still acquire a set of nouns through intervention. Unfortunately, nouns alone are not enough to develop full language competence. To learn a language, children must acquire relational words like verbs and prepositions. Research has shown that typically developing children are slower to learn these kinds of words than simple nouns (Bornstein et al., 2004; Gentner, 1982; Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Golinkoff, Jacquet, Hirsh-Pasek, & Nandakumar, 1996; Halberda, 2003), and years of anecdotal reports combined with recent empirical studies suggest that relational words might be even harder for children with ASD (Ishikawa & Uda, 1996; Takata & Okuma, 1986; Watake, 1996; Williams, 1993).

Research has centered on two possible explanations for the lag in relational word acquisition in typical development: Either children are not conceptually ready to learn relational words (conceptual problem), or they have difficulty using social and linguistic cues to link words to relational concepts (mapping problem). It is not possible to determine which of these explanations accounts for the relational lag by studying typical children alone, however, because they develop concepts and mapping skills simultaneously, making it impossible for researchers to isolate individual effects. The social, spatial, and linguistic variability inherent in a group of children diagnosed with ASD, on the other hand, makes it possible to disentangle the differential contributions of conceptual readiness and social understanding to the learning of relational language. For this reason, the three studies included in this dissertation examine the driving forces behind relational language acquisition through the lenses of both typical and atypical development.

The first two studies presented here explore the spatial concepts that underlie relational words like verbs and prepositions, and the third addresses the social cues that help children map concepts to words. Research suggests that children with ASD have difficulty with the perceptual processes that are important for developing dynamic spatial concepts (such as motion processing and categorization), and that typical children already have these abilities in place before the age of two. It is thus hypothesized that children with ASD in Studies 1 and 2 will demonstrate weaker spatial concepts than typical controls, who are expected to demonstrate a firm conceptual basis for acquiring relational words. Study 3 explores the ability to "read" social intentions and extract cues that typically developing children use to determine the meaning of relational words. Based on prior research from our laboratory, it is hypothesized that whereas all typical children will demonstrate intact intention-reading abilities, only some children with ASD will appear to understand intentionality (Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007). Finally, exploratory correlational analyses will ask whether conceptual and social abilities differentially contribute to the relational vocabularies of children in each group, and how these factors relate to symptom severity in the ASD group. It is hypothesized that children with firm conceptual foundations as indicated by success in Studies 1 and 2 will have larger relational vocabularies regardless of group membership. In addition, given prior research showing that the ability to read social intentions is important for *noun* learning in children with ASD, it is hypothesized that *relational word* learning (which is harder) may be even more strongly affected by variability in social understanding, such that children demonstrating better intention-reading skills also have larger relational vocabularies.

Autism and Language

Communication deficits are central to the ASD diagnosis (American Psychiatric Association [*DSM-IV-TR*], 2000), but researchers have found that in most cases, children's ability to acquire object words like nouns is relatively robust. For example, children with ASD can learn the meaning of a noun by attending to a speaker's perceptually obvious social cues like eye gaze and pointing (Parish-Morris et al., 2007), and can use general principles of word learning like mutual exclusivity (Markman, Wasow, & Hansen, 2003) to map words to novel objects (Preissler & Carey, 2005). Some word learning biases that are present in typical development – such as preferring to attach a novel word to an *object* (as opposed to an action or object property) in a scene – are also evident (Swensen, Kelly, Fein, & Naigles, 2007). Others are not, such as the tendency to map a word to an object's shape rather than size, color, or texture (Tek, Jaffery, Fein, & Naigles, 2008). Overall, it appears that children with ASD have many of the prerequisite abilities needed to learn object words like "dog" and "house". However, a vocabulary comprised of nouns alone is insufficient when competent language is the goal: verbs and prepositions are required to link bare nouns like "dog" and "house" into meaningful sentences like "the dog ran into the house".

Children with ASD and relational words

What do we know about relational language (e.g., verbs and prepositions) in children with ASD? A number of case studies reported that some children with ASD are able to acquire verbs after extensive training (Ishikawa & Uda, 1996; Takata & Okuma, 1986; Watake, 1996; Williams, 1993), and a study of adults with ASD revealed that they make more errors using spatial and temporal words than with artifact words in naturalistic speech (Perkins, Dobbinson, Boucher, Bol & Bloom, 2006). There are, however, no empirical studies of relational language learning *per se.* In fact, until recently, very little was known even about vocabulary composition in this population.

Are relational words harder for children with ASD?

To begin exploring relational language in children with ASD, our laboratory used vocabulary data collected via the MacArthur Communicative Development Inventory (Dale & Fenson, 1996) and compared the proportion of relational words in the vocabularies of 2-year-olds with ASD to both national norms and to a language-matched typical comparison group. Based on anecdotal reports that children with ASD have special difficulty with words like verbs and prepositions, we hypothesized that the proportion of relational words in the vocabulary of children with ASD would be significantly smaller than in the vocabularies of typically developing children with comparable overall vocabulary size. Although this first stab at characterizing the vocabularies of children did not consider such important variables as parental education, it became clear that there was, in fact, a more pronounced discrepancy between nouns and verbs/prepositions in the population of children with ASD than in typical children (Parish-Morris, Lyuster, Tager-Flusberg, Hirsh-Pasek & Golinkoff, 2009). Concurrent with our pilot study, a more formal assessment of early vocabulary composition in ASD conducted by Lord and colleagues confirmed that children with ASD have a smaller proportion of relational words in their vocabularies than well-matched typically developing children (Lopez & Lord, 2009), and that this pattern holds for other developmentally delayed children as well. Taken together with our pilot study, this finding lends credence to anecdotal reports that ASD children have special difficulty learning relational words, even considering the difficulty experienced by typically developing children.

Why are relational words especially hard for children with ASD?

Two potential explanations for the relational word lag found in typical children may shed light on the *even more* pronounced problem found in children with ASD: either children lack the conceptual foundations necessary for relational language or they have difficulty connecting words to relational referents. Following a brief history of what is known about relational word learning in general, research on concepts and mapping in typical children and populations with ASD will be reviewed.

Relational Words are Hard Because of Concepts or Mapping

The early vocabularies of typically developing children across the world contain both object labels and relational terms, (Bornstein et al., 2004; Fenson et al., 1994), but typically developing children have a harder time learning relational words like verbs and prepositions than they do learning nouns (Gentner, 1982; Halberda, 2003; Imai et al., 2008; Imai, Okada & Haryu, 2005; Roseberry, 2010). Faced with abundant evidence of differential learnability, researchers have stopped asking *if* relational words are hard, and have begun to explore *why* they are hard. Two explanations are considered: difficulty with concepts and difficulty with mapping.

Conceptual Readiness for Relational Word Learning

Concepts such as *the object is above* and *the object is below* form the foundation for learning words like prepositions, and concepts like *the object moves along a path* (e.g., *descend*) and *the object moves by some manner* (e.g., *slither*) form the foundation for learning verbs. Theoretically, children cannot learn relational words until the appropriate relational concepts are in place. In order to develop these concepts, children must accomplish two tasks: First, they must be able to perceive and discriminate basic relational elements like *path/manner*, *containment/support,* and *figure/ground*, (Mandler, 1992, 2004, 2006; Parish-Morris, Pruden, Ma, Hirsh-Pasek, & Golinkoff, 2010; Pruden, Hirsh-Pasek, Golinkoff, & Hennon, 2006), which are the universal building blocks for later complex concepts of actions and relations (Talmy, 1985). Then they must be able to form categories of those elements. Categorization is crucial to language development because relational words like verbs and prepositions are not attached to particular objects; rather, they are attached to *categories* of relations. The members of each category may be more or less perceptually similar to one another, but they all have a common relation (e.g., a person running looks different than a dog running, but they are both *running*). Discrimination and categorization of relations are both necessary for concept formation.

Conceptual Readiness in Typically Developing Children

Do very young children have the prerequisite relational concepts necessary to learn words like verbs and prepositions? Over the past 20 years, researchers have studied how children discriminate and categorize perceptually available and universally encoded relations like path/manner, containment/support, figure/ground, and source/goal. A review of findings from research on these four pairs of relations leads to the conclusion that these concepts are in place very early in the life of a typical child, and that difficulty with relational concepts is therefore not the reason why relational words are hard for typically developing children to learn.

Path and Manner. Path is defined as an object's trajectory through space (Mandler, 2004, 2006), and *manner* is the way in which an object moves (Talmy, 1985). Path and manner are among the most comprehensively studied contrasting semantic constructs because they are available in all languages, perceptually salient, and lexicalized differently across languages (Papafragou & Selimis, 2010). For example, in English, the *manner* of movement is usually encoded in the verb of a sentence (e.g., "The boy *ran*") while the *path* of the action tends to be encoded in a prepositional phrase (e.g., "out of the house"). In Spanish, the *path* of a movement is encoded in the verb, (e.g., *exited*) and the *manner* can be included as an optional add-on, (e.g., *ran*). Thus, the literal translation of “El niño salió de la casa corriendo” would be, “The boy exited the house (running)” (Pulverman, Golinkoff, Hirsh-Pasek, & Sootsman Buresh, 2008).

The first research conducted in this area tested whether infants could discriminate between contrasting paths and manners. Using an animated starfish and comparing looking times to old and new paths/manners, research from our laboratory suggested that 7-month-olds are capable of distinguishing these dynamic spatial constructs (Pulverman & Golinkoff, 2004). In naturalistic scenes, 10-month-olds are able to distinguish *path* and *manner* (e.g., a girl crawling (*manner*) in front of a tree (*path*); Casasola, Hohenstein, & Naigles, 2003). Categorization of path and manner was likewise explored by researchers who found that 10- to 12-month-olds were able to form abstract categories of a *path* relation when they saw it across various *manners* (Pruden, Hirsh-Pasek, Maguire, & Meyer, 2005; Salkind, Sootsman, Golinkoff, Hirsh-Pasek, & Maguire, 2002). Consistent with Mandler’s (2004) suggestion that *path* may be a more basic and perceptually available conceptual primitive than *manner*, however, studies revealed that infants do not form categories of *manner* over various *paths* until they are 13- to 15-months-old (Pruden et al., 2005).

The finding that children demonstrate an understanding of *path* first and then *manner* is consistent with the developmental décalage in conceptual understanding reported by researchers examining other relational components like figure and ground (Göksun, Hirsh-Pasek, & Golinkoff, 2010), and suggests that preverbal infants have underlying concepts in place long before they have relational words to label them.

Figure and Ground. Like path/manner, figure and ground are perceptually available relational elements that are universally expressed but encoded differently across languages (Muehleisen & Imai, 1997). According to Göksun and colleagues (2010), the figure in a scene is the entity that can follow any path or move from any source, and the ground provides a stable context for the figure's movement. In the sentence, "Amy swims in the pool," for example, Amy is the figure and the pool is the ground (Göksun et al., 2010).

Emerging research suggests that concepts of figure and ground are in place well before children have a vocabulary of relational words. For example, Göksun and colleagues (2009) showed 7- to 9-month-olds and 10- to 12-month-olds four identical videos of a figure (e.g., a woman) crossing over train tracks. After the infants were familiar with the scene, they were shown two videos side by side in a preferential looking paradigm (Hirsh-Pasek & Golinkoff, 1996): one video clip showed the same figure crossing the railroad, and the other showed a different figure (e.g., a man) crossing the railroad. Results of a looking-time analysis revealed that the older infants, but not the younger ones, looked longer at the side of the screen that showed the new figure. This suggests that the ability to discriminate new figures presented against the same ground is an ability that develops over time, but appears to be in place by approximately 11 months of age (Göksun, Hirsh-Pasek, & Golinkoff, 2009).

Infants' ability to discriminate *grounds* in a dynamic scene was examined using a similar paradigm. In contrast to the figure study, the grounds used at test could be grouped into sub-categories according to how they are lexicalized in another language: Japanese. Whereas in English, the words "go across" are used to describe a woman crossing both a road and a grassy field, Japanese speakers use two different verbs: one for "go across a large open space" (e.g., grassy field) and another for "go across a bounded space” (e.g., train tracks or road). Results revealed that 13- to 15-month-olds were only able to discriminate grounds when the two being compared were lexicalized differently in Japanese (e.g., railroad track vs. grassy field, but not railroad track vs. road), suggesting that English-learning infants are initially sensitive to ground category boundaries that are not ultimately encoded in their ambient language (Göksun et al., 2009). In addition to demonstrating that infants are initially ready to make the distinctions necessary for any language, this research provides evidence that the developmental décalage evident in path/manner processing (i.e., path comes in first, manner later) is also present in figure/ground (i.e., the ability to discriminate new figures develops prior to the ability to discriminate new grounds). This pattern continues, as described below, in children’s developing understanding of sources and goals in events (i.e., goal categories develop prior to source categories) and containment/support relations (i.e., categories of containment are formed at younger ages than categories of support).

Source and Goal. Motion events that involve a figure traversing a *path* can be split into subtypes according to the *figure’s* movement with respect to a *ground*, and evidence suggests that prelinguistic infants are sensitive to the different characteristics of these subtypes. A figure can be said to be traversing a *goal path* when it *approaches* an end point or goal (e.g., “She *dashed into* the kitchen”). A *source path* involves a figure *departing from* an origin or source (e.g., “The robber *fled* the scene of the crime”; Jackendoff, 1983; Papafragou, 2010; Talmy, 1985). Interestingly, *source paths* and *goal paths* are not given equal attention by children or adults, either in the context of nonlinguistic processing or in verbal descriptions of events (Fisher, Hall, Rakowitz, & Gleitman, 1994; Lakusta & Landau, 2005; Lakusta, Wagner, O’Hearn, & Landau, 2007;

Wagner & Lakusta, 2009). Rather, goals tend to be primary. For example, infants as young as 12 months are able to distinguish sources (e.g., a ball rolls *out of* a tube) and goals (a ball rolls *into* a net) when they appear in *separate* motion events. When both a source and a goal are present in a *single* motion event, however, only the goal of the motion is encoded – even when the source is designed to be perceptually salient (Lakusta et al., 2007). This "goal bias" in discrimination is also present in categorization, as demonstrated by the finding that 14-month-olds can form a category of goals, but do not show evidence of forming source categories (Lakusta & Carey, 2008). As in path/manner and figure/ground research, the fact that *goals* are processed earlier than *sources* suggests a developmental progression in concept formation. Furthermore, the young age at which infants discriminate sources and goals (12 months) speaks to children's prelinguistic conceptual readiness to learn the relational words that label semantic action components (Lakusta et al., 2007).

Containment and Support. Evidence that children are conceptually ready to learn words like verbs and prepositions continues in the area of containment/support. The word *containment* describes the relationship between at least two objects, one of which fully or partially encloses the other (such as an apple *in* a bowl), and *support* describes the relationship between at least two objects, one of which rests on top of the other (such as an apple *on* a table). Containment and support relations have often been studied in tandem because in addition to being perceptually available and therefore straightforward to measure, the way in which these two relations are lexicalized (i.e., put into words) also differs across languages. In English, for example, the word "in" is used to describe containment relationships, regardless of whether the containment is loose (ice cream in bowl) or tight (plug in outlet), and the word “on” is used for support relationships (ring on post or apple on table), regardless of tightness-of-fit. Korean, on the other hand, cross-cuts these categories. The Korean word “kkita” is used to describe containment or support relations that are tight-fitting (e.g., plug in outlet, ring on post), while the word “nehta” is used if the containment or support relation is loose-fitting (ice cream in bowl, apple on table; McDonough, Choi, & Mandler, 2003) and these words supersede the containment and support relationships used in English.

A significant body of research suggests that typical infants are conceptually ready to learn words for containment and support relations before they have words for those relations, and that their understanding of these two concepts mature over time. For example, when 5.5-month-olds are shown a scene of a toy supported by a box, they pay no special attention, suggesting that they already expect objects to be supported on top of other objects. However, same-aged infants are surprised (as measured by increased looking time) when they see a toy apparently floating in midair *next to* a box (Hespos & Baillargeon, 2008). This suggests that they have basic expectations about the physical constraints of a support relation (i.e., the toy and the box must be touching for the toy to be supported), and are surprised when those expectations are violated. As these infants mature, their understanding of “support” is modified to include instances of objects resting *on top* but not *on the side* of a box, and is further defined regarding the how the size and shape of objects affect whether a support relation is possible or impossible (Hespos & Baillargeon, 2008).

Understanding the containment relation follows a similar pattern of development. For example, 7.5-month-olds do not react with surprise when they see a tall frog lowered completely into an appropriately tall container, but look much longer when the same frog disappears completely into a short container (Hespos & Baillargeon, 2006). As with *path* and *manner,* containment and support relations are not discriminated and categorized on exactly the same timeline. Rather, children discriminate both relations within the first year, and categorize containment by 6 months (Casasola, Cohen, & Chiarello, 2003). The support relation, however, is not robustly categorized until 14 months of age (Casasola, 2005), perhaps due in part to experience; children demonstrate a robust bias toward creating containment rather than support relations during spatial play (Casasola, Bhagwat, & Doan, 2009). In sum, these and extensive additional studies indicate that concepts of support and containment gradually come into place within the first two years, often before children have words to encode them (Aguiar & Baillargeon, 1998; Casasola, 2008; Casasola & Cohen, 2002; Choi, 2006a, 2006b; Choi & Bowerman, 1991; Choi, McDonough, Bowerman, & Mandler, 1999; Hespos & Baillargeon, 2008; Hespos & Spelke, 2004).

Taken as a whole, research on how children process semantic components like path/manner, figure/ground, source/goal and containment/support does not appear to support the hypothesis that lack of conceptual understanding underlies the difficulty typically developing children have with learning words like verbs and prepositions. On the contrary, it appears that by age two, children are well equipped with the concepts necessary to learn relational words. Are children with ASD similarly prepared?

Conceptual Readiness in Children with ASD

Research specifically targeting how children with ASD discriminate and categorize linguistically relevant event components like *path* and *manner* is nonexistent, which forces us to speculate about conceptual readiness based on theoretically related studies of general perception and cognitive processing. For example, in order to form dynamic spatial concepts like the ones underlying verbs, children must be able to perceive and process motion, attend to and integrate spatial relationships between entities, think abstractly (categorize and prototype), and successfully switch attention between multiple parts of a scene. Atypicality in one or more of these areas may impact whether children develop the concepts necessary for relational word learning. The following section briefly reviews research in two areas that are most likely to impact relational concept formation in children with ASD: (1) visuo-spatial processing, and 2) categorization/concept formation.

Visuo-spatial processing. A large body of research suggests that children with ASD process the world differently than do typical children, which may impact their ability to form relational concepts. Even the most basic visual stimuli (Gabor patches of varying spatial frequency) elicit atypical electrophysiological responses from children with ASD (Milne, Scope, Pascalis, Buckley, & Makeig, 2009), who also perform unevenly on behavioral tests of visuo-spatial cognition (Behrmann, Thomas, & Humphreys, 2006). Intact or superior performance has been found in certain *static* tasks such the embedded figures test (Edgin & Pennington, 2005; Joliffe & Baron-Cohen, 1997; Shah & Frith, 1983; but see Chen, Lemonnier, Lazartigues, & Planche, 2008), mental rotation tasks (Falter, Plaisted, & Davis, 2008), the block design subtest of the Wechsler (Caron, Mottron, Berthiaume & Dawson, 2006; Shah & Frith, 1993), as well as on visual search tasks (Joseph, Keehne, Connolly, Wolfe, & Horowitz, 2009; Kemner, van Ewijk, van Engeland & Hooge, 2008; O'Riordan & Plaisted, 2001; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001). Tasks involving complex dynamic processing (especially biological motion) and multiple-feature integration, however, can prove quite difficult for this population (Bertone & Faubert, 2006; Bertone, Mottron, Jelenic, & Faubert, 2003, 2005; Blake, Turner, Smoski, Pozdol, & Stone, 2003; Freitag et al., 2008; Gepner & Mestre, 2002; Klin & Jones, 2008; Koldewyn, Whitney, & Rivera, 2010; Milne, Swettenham, & Campbell, 2005; Spencer & O'Brien, 2006; Spencer, O'Brien, & Riggs, 2000; but see de Jonge, Kemner, de Haan, Coppens, van den Bergde, & van Engeland, 2007; Sanchez-Marin & Padilla-Medina, 2007; Vandenbroucke, Scholte, van Engeland, Lamme, & Kemner, 2008).

Thirty years ago, the "weak central coherence" theory of ASD sparked a landslide of research on visuo-spatial processing patterns in this population (Frith, 1989; Happé & Frith, 2006). Invoked to explain a multitude of phenomena at various times, the theory originally emphasized a *deficit* in processing information for overall meaning and global form (Frith, 1989). Over the years, however, research has shown that persons with ASD are capable of processing global information (Deruelle, Rondan, Gepner, & Fagot, 2006; Mottron, Burack, Iarocci, Belleville, & Enns, 2003), and the theory been altered to emphasize "a processing bias for featural and local information, accompanied by a relative failure to extract gist or 'see the big picture' in everyday life" (Happé & Frith, 2006, p. 6; Happé, 1999). Indeed, a preponderance of evidence suggests that people with ASD, on average, process local (detailed, featural) and global (general, configural) information in atypical ways. Abnormal processing patterns have been explored extensively and include evidence in support of enhanced perceptual functioning, inefficient visual information filtering, and featural rather than configural perceptual processing styles (Burack, 1994; Caron, Mottron, Rainville, & Chouinard, 2004; Frith, 1989; Iarocci, Burack, Shore, Mottron, & Enns, 2006; Joseph, Keehne, Connolly, Wolfe, & Horowitz, 2009; Mitchell & Ropar, 2004; Mottron, Dawson, Soulières, Hubert, & Burack, 2006; Plaisted, Swettenham, & Rees, 1999; Smith & Milne, 2009; Soulières et al., 2009; Vlamings, Jonkman, van Daalen, van der Gaag, & Kemner, 2010).

This pattern of over-attending to visual detail and sometimes missing the "big picture" is one of the most well-known perceptual idiosyncrasies of ASD, and has implications for children's ability to form concepts that are built on dynamic spatial relational components like *path* and *manner*. If children expend the majority of their time examining the specific details of objects in a scene, they might inadvertently miss the relationships between objects in the gestalt. This means that processing an event component like *path,* (defined as the relationship between a figure and a ground), might be especially challenging for this population, because it requires children to process multiple objects in a scene without getting stuck on the details of any one of the objects. An event component like *manner,* on the other hand, might be relatively easier to process since all relevant relational information is contained within a single object, thus reducing task demands. The dynamic nature of the concepts underlying verbs makes discrimination and categorization even more difficult, as children must analyze a relationship between two objects *whilst one moves in relation to the other* (see Bebko, Weiss, Demark & Gomez, 2006; Gepner & Feron, 2009; Kuhn, Kourkoulou, & Leekam, 2010; for discussions of temporal processing disturbances in ASD). Thus, the visuo-spatial processing patterns typical of children with ASD may not be ideal for encouraging relational concept formation, although this connection has never been explicitly studied.

Categorization. Even if the visuo-spatial processing patterns of children with ASD were conducive to perceiving relations between objects rather than features of those objects, it is unclear whether they would be able to form categories of relations. Researchers have been split for years on the issue of whether and to what extent persons with ASD are able to abstract common features from a series of exemplars and form a category that includes those exemplars (Minshew, Meyer, & Goldstein, 2002). For example, categorization in persons with ASD has been found to be impaired by some (Bott, Brock, Brockdorff, Boucher, & Lamberts, 2006; Johnson & Rakison, 2006; Klinger & Dawson, 2001; Santos, Rondan, Rosset, Da Fonseca, & Deruelle, 2008; Soulières, Mottron, Saumier, & Larochelle, 2007), intact by others (Molesworth, Bowler, & Hampton, 2005, Tager-Flusberg, 1985; Ungerer & Sigman, 1987), and variable by many, with performance on categorization tasks often depending upon whether a person is higher- or lower-functioning (Gastgeb, Strauss, & Minshew, 2007; Molesworth, Bowler, & Hampton, 2008).

Research on categorization of *relations* in people with ASD is just beginning, but the evidence accumulated thus far suggests it might be much more challenging than categorizing objects. For example, a recent study using pictures of landscapes suggests that adults with ASD have more difficulty when configural information is the basis of category membership than when category membership is determined by specific details (Froehlich, 2009). Thus, categorizing based on *dynamic* configural information, such as over multiple *path* events, might reasonably be expected to be extraordinarily challenging for children on the spectrum.

Based on the research described above, there is reason to doubt that children with ASD reliably develop the conceptual foundations necessary for learning relational words. However, if research reveals that relational concepts are intact, the problem of impaired relational language remains to be explained. Might children with ASD, like typical children, have particular difficulty mapping words onto relational concepts?

Connecting Words to Concepts: The Issue of Mapping

Research on early conceptual understanding in typically developing children suggests that the relational concepts necessary for word learning are in place early on, and that the *real* challenge of relational word learning lies in connecting words to their relational (and often ambiguous) referents (Gentner, 1982; Gentner & Boroditsky, 2001; Gillette, Gleitman, Gleitman, & Lederer, 1999; Golinkoff et al., 1996; Maguire, Hirsh-Pasek, & Golinkoff, 2006; Snedeker & Gleitman, 2004). The difficulty children experience with this task has been called "the mapping problem".

Infants and toddlers appear to encounter a *mapping problem* when learning relational terms for at least three reasons. First, relational terms like verbs encode various elements of meaning (i.e., relational elements such as *path* and *manner*) that can be packaged into a single word in ways that differ across languages (Talmy, 1985). As described above, for example, the relational components *containment/support* and *tight-fit/loose-fit* are packaged into words differently in Korean than they are in English (Choi, 2006a, 2006b). Second, events are often quite complex and a single verb might conceivably label any number of dynamic relations visible in a scene (Gentner, 1982, Tomasello & Merriman, 1995). Imagine a child riding in a stroller who hears the word "run" while a man jogs by. Does *run* refer to the man (figure), to the relationship between the man and the ground (support), the movement of the man's legs (manner), or to the direction traveled (path)? Third, different verbs might be used to describe the exact same relation depending upon the speaker's perspective (Gleitman, 1990; Gleitman & Gleitman, 1992). Is the bear *chasing* the rabbit (goal path) or is the rabbit *fleeing* the bear (source path)? Despite these challenges, children find a way to solve the puzzle of relational word learning.

How do children solve the mapping problem?

One theory to explain how relational words are acquired in the face of the mapping problem is the Emergentist Coalition Model (ECM; Hollich, Hirsh-Pasek, & Golinkoff, 2000). This model posits that children use *perceptual*, *social*, and *linguistic* cues to determine the referent of a novel word, and weight those cues differentially over developmental time. Initially, children's word learning strategy centers on perceptual salience, such that the most perceptually salient object always gets the label (Behrend & Scofield, 2006; Forbes & Farrar, 1993; Forbes & Poulin-DuBois, 1997; Smiley & Huttenlocher, 1995). For example, despite social cues indicating that the actual referent of a word was a boring object, 10-month-old infants attached novel words to perceptually salient objects that held their own interest (Pruden et al., 2006). In the second year, infants come to rely less on perceptual salience to learn novel words and begin to use information gleaned from the social world as a cue to word meaning (Baldwin, 1993). Whereas 10-month-olds mismapped a novel word onto an interesting object, research shows that 18-month-olds in the same paradigm were able to follow a speaker's social cues to word meaning and attach a novel word to the intended boring object (Hollich et al., 2000). Finally, children use linguistic information like transitive/intransitive frames

(Bunger & Lidz, 2004), word order (Swensen et al., 2007) and morphology (Göksun, Küntay, & Naigles, 2008; Jolly & Plunkett, 2008) to aid in mapping words to referents (Echols & Marti, 2004; Fisher & Song, 2006; Landau & Gleitman, 1985; Lee & Naigles, 2008). Using the ECM as a framework, the following section will summarize how typically developing children harness perceptual, social, and linguistic cues in the service of word learning. The perceptual, social, and linguistic profiles of children with ASD will then be reviewed, with an eye to how the characteristics of this population could help or hinder when faced with the challenge of mapping relational words.

Mapping and typical children

Perceptual cues. Infants are more likely to map a word to a shiny, attractive object than a boring white object (Hollich et al., 2000; Pruden et al., 2006), suggesting that they are sensitive to perceptual salience when learning object labels. Does perceptual salience play an equally important role in learning words for actions? Some suggest that it does, citing earlier acquisition of words for actions like *kiss* (Ma, Golinkoff, Hirsh-Pasek, McDonough, & Tardif, 2009). According to these and other theorists, *kiss* is easy to map because the act of "kissing" is visible to the naked eye and can be pointed out in the world. Words like *think* and *know,* on the other hand, are harder to learn because they label actions that cannot be seen (Gentner & Boroditsky, 2001; Ma et al., 2009; Maguire et al., 2006).

Experimental evidence for the importance of perceptual salience in mapping to relational referents comes from a recent study of verb learning in 2- and 3-year-old toddlers (Brandone, Pence, Golinkoff, & Hirsh-Pasek, 2007). Children were shown two actions, one of which produced an interesting result (a light turned on). The experimenter labeled one of the two actions. In the “conflict” condition, the action that did *not* produce a result was labeled, thus creating a conflict between the perceptually salient action and the speaker’s cues. When the action labeled had a result, speaker cues coincided with perceptual salience and the condition was considered “coincidental”. After training, word learning was tested using a split-screen preferential looking paradigm (Hirsh-Pasek & Golinkoff, 1996). Results revealed that 2-year-olds learned a novel verb when the experimenter labeled the action that had a salient result, but not when she labeled the action without a result. It wasn’t until age 3 that children could overcome the lure of perceptual salience to learn a word for an action without a result (Brandone et al., 2007).

Perceptual salience is a valuable cue that can take children a long way in word learning, especially when mapping to objects; but it is more difficult to rely on perceptual salience when mapping words to relational referents. When the referent of a word is dynamic and ephemeral, as in the case of a word like “run”, children might do well to use social cues as an aid in discovering what the speaker *intends* to label, regardless of what aspect of the scene is the most perceptually salient.

Social cues. Social information about word meaning is conveyed to infants in a variety of ways. Perceptually obvious cues such as eye gaze direction and gestures (e.g., looking at and pointing to a dog while saying “dog”) provide insight into what a speaker *intends* to label with a given word. The ability to infer a speaker’s intentions from behavioral cues is especially useful in situations that include multiple possibilities for word reference, as it serves to narrow the range of potential referents. For example, if a dog, a cat, and a couch are all visible when the word “dog” is uttered, a speaker’s looks and points are cues to what she *intends* to label (Behrend & Scofield, 2006; Behrend & Wittek, 2003).

Research suggests that toddlers use information about a speaker's intentions to learn words by the middle of the second year of life. In a now-classic study of how children begin to actively recruit a speaker's eye gaze information as a clue referential intent, Baldwin (1993) showed 13-, 16- and 19-month-olds two objects. In one condition, she uttered a novel word while looking at whichever object the child chose to attend to (the *follow-in* condition). In the *discrepant* condition, the experimenter looked at the object that the child was *not* attending to, and labeled it. Results revealed an interesting developmental pattern; the youngest infants did not learn a word in either condition. Sixteen-month-olds learned a new word, but only in the follow-in condition – they failed to use the speaker's direction of gaze in the discrepant condition to determine which object she was referring to. By 18 months, infants were able to disengage their attention from their preferred object, look at the speaker's face, follow her gaze to the other toy, and *interpret the gaze as an intentional cue to word reference,* which allowed them to learn the word (Baldwin, 1993; see also Dunham, Dunham, & Curwin, 1993).

The ability to read others' intentions might prove especially useful when faced with the difficult task of mapping verbs and prepositions to relational referents (Genter, 1982). Consider the verbs "topple" and "knock over". The actions labeled by these verbs look very similar at first glance (i.e., *toppling* the block tower by accident and *knocking over* the block tower on purpose have the same outcome), so it is difficult to use perceptual cues alone to determine which is which. The crucial difference between the two verbs lies in the *intention* behind the action being labeled, which must be inferred from the actor's behavior. Remarkably, research suggests that toddlers as young as 27 months attend to behavioral cues (e.g., putting hands over the mouth to express surprise) to decide whether an action was intentional or accidental, and that they use that information to help them determine the referent of a novel verb (Poulin-Dubois & Forbes, 2002, 2006).

Linguistic cues. In 1990, Lila Gleitman proposed the Syntactic Bootstrapping Hypothesis, suggesting that children use their knowledge of grammatical constraints on the relation between verb meaning and verb syntax to home in on the meaning of a verb (see also Landau & Gleitman, 1985). Over the years, a large body of research has accumulated to confirm that children are sensitive to various types of linguistic information from a very young age (e.g., argument structure, morphology) and they use this knowledge as a guide when mapping verbs and prepositions to relational referents (Fisher, 1996; Fisher et al., 1994; Fisher, Klingler, & Song, 2006; Fisher & Song, 2006; Gertner, Fisher, & Eisengart, 2006; Gleitman & Gleitman, 1992; Lidz, Gleitman, & Gleitman, 2003; Hoff & Naigles, 2002; Lee & Naigles, 2005; Naigles, 1990, 1996; Naigles, Bavin, & Smith, 2005; Naigles & Kako, 1993; Nappa, Wessel, McEldoon, Gleitman, & Trueswell, 2009; Scott & Fisher, 2009).

Knowledge of argument structure is particularly helpful in the task of verb learning, and research suggests that infants are sensitive to this type of information by the middle of the second year. For example, 16-month-olds were shown a video on a split screen. On one side of the screen, Cookie Monster was tickling Big Bird. On the other side, Big Bird tickled Cookie Monster. One half of the subjects heard, "Cookie Monster is tickling Big Bird," and the other half heard, "Big Bird is tickling Cookie Monster".

Results revealed that 16-month-old infants preferred to look at the scene that matched the syntactic frame they heard in an accompanying audio. This suggests that infants were aware of *agent-patient* relationships before they were able to speak in full sentences (Golinkoff et al., 1996; Hirsh-Pasek & Golinkoff, 1996). Other research demonstrates that 27-month-olds use the transitivity/intransitivity of a sentence frame to determine whether the referent of a novel verb is a causal or non-causal action (Naigles & Kako, 1993), and older children's verbal descriptions of novel verb meanings are influenced by whether the subject of a sentence is perceived as the agent or the patient of the action (Fisher & Song, 2006).

The research reviewed thus far suggests that linguistic cues, along with social and perceptual cues, help children to home in on the correct referent for a given word, and that full access to this coalition of cues may be especially valuable when learning relational words like verbs and prepositions. To what extent do children with ASD have access to this set of cues, and can they recruit them in the service of word learning?

Mapping and children with ASD

Perceptual cues. Like typically developing 12-month-olds (Pruden et al., 2006), children with ASD successfully attend to perceptual salience when learning the names for objects (Parish-Morris et al., 2007). However, research from our laboratory suggests that the lure of perceptual salience is very strong for these children, and may hinder word learning in situations where the most salient aspect of the scene is not the intended referent of a word. For example, typically developing 18-month-olds in a word learning paradigm were able to overcome the lure of a shiny, sparkly object in order to learn a word for a boring object (Pruden et al., 2006). In the exact same paradigm, many 4-year-old children with ASD remained fixated on the perceptually salient object, even after repeated attempts to redirect their attention to the boring referent. These children consequently failed to learn a word for the boring object, whereas the typically developing 18-month-olds succeeded (Parish-Morris et al., 2007; Pruden et al., 2006). Research has yet to explore the effect of perceptual salience on mapping verbs or prepositions to relational referents, but this study of noun learning suggests that children with ASD may encounter a problem with “sticky attention” (Bebko, McMorris, Wells, Schroeder, & Holden, 2008; Landry & Bryson, 2004; Wilson, Plumb, Williams, & Mon-Williams, 2006), wherein perseveration on the perceptually salient part of a scene hinders the ability to learn words for less salient referents.

Another potential issue is related to the finding that children with ASD are biased toward processing local perceptual details. This suggests that children viewing a dynamic event might focus on the details of individual objects in the scene rather than on the relations between them. For example, the details of the sparkly shoes worn by a running girl might capture more attention than the relationship between the girl’s movements through space and the sidewalk (*path*) or the relationship between the girl’s appendages and her torso (*manner*). An overly local allocation of attention may hinder children with ASD from identifying potential relational referents in a given scene, and may also cause them to miss important social cues that serve as clues to word meaning.

Social cues. Although some children with ASD can follow perceptually obvious social cues like pointing and eye gaze direction when explicitly instructed to do so, the population as a whole is significantly less attentive to social information than typical populations (Bar-Haim, Shulman, Lamy, & Reuveni, 2006; Baron-Cohen, 1995; Bhat, Galloway, & Landa, 2010; Kasari, Freeman, & Paparella, 2001; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009; Leekam & Ramsden, 2006; Riby & Doherty, 2009; Riby & Hancock, 2009). How might this lack of social attention impact their ability to learn relational words? As discussed earlier, the ability to use a speaker's behavioral cues to infer intentions is especially helpful in the case of learning verbs and prepositions, which tend to have ambiguous referents. Thus, if children with ASD perceive behavioral information (like pointing) but do not use it to infer a speaker's intentions, they might experience particular difficulty homing in on the referent of a relational word. Research from our laboratory suggests that this is precisely what happens when the referent of a novel noun is deliberately ambiguous (Parish-Morris et al., 2007; modified version of the study described in Akhtar, Carpenter, & Tomasello, 1996). Although on average, children with ASD were unable to learn the name of a novel object when the only source of information was a speaker's intentions, the children who demonstrated a better understanding of social intentions had larger vocabularies overall, highlighting the importance of social acuity to language outcome (Parish-Morris et al., 2007).

Linguistic cues. Research on how children with ASD use linguistic information to map relational words like verbs and prepositions is limited but promising. Two studies in particular stand out, both of which show that children with ASD can use sentence structure as a source of information about the meaning of a verb. The first was designed to test word order understanding. Results revealed that children with ASD comprehend the subject-verb-object construction, and that word order information helps children with ASD determine agent-patient roles in actions in much the same way that it helps typical children (Swensen et al., 2007). The second study examined verb learning in three groups: children with ASD, children with selective language impairment, and typically developing children (Shulman & Guberman, 2007; adapted from Naigles, 1990). Results revealed that children with ASD (but not SLI) used the presence of transitive or intransitive frames to guide their interpretation of a novel verb. Thus, sentence frame information is helpful in determining the referent of a novel verb, whether or not the word learner is diagnosed with an ASD (Shulman & Guberman, 2007).

The Present Studies

The research reviewed thus far suggests: (a) relational words are hard to learn, (b) they are hard either because of conceptual immaturity or problems with mapping words to the world, and (c) learning relational words might be triply hard for children with ASD (due to perceptual processing differences that could impact concept formation, as well as difficulty understanding the social cues that aid in mapping). This research is the first to ask, in a direct way, whether children with ASD are conceptually ready to learn relational words, and whether they possess the social acumen that aids in mapping to relational referents. Studies 1 and 2 address *concepts*: Do children with ASD have the conceptual foundations necessary for verbs like "jump"? Study 3 asks whether children with ASD understand the social intentions that are so helpful in narrowing the pool of relational word referents. An exploratory analysis is conducted to determine whether the relationship between concepts, intention understanding, and relational vocabulary size is different for children with ASD than it is for matched typical controls. It is hypothesized that children with stronger conceptual foundations will have larger relational vocabularies, as will children who demonstrate an understanding of social intentions.

CHAPTER 2
DISCRIMINATING AND CATEGORIZING EVENT COMPONENTS

The first portion of this dissertation aims to determine whether problems *conceptualizing* the foundational event components labeled by verbs like *run* account for the dearth of these words in the vocabularies of children with ASD. Two steps necessary for conceptualization (discrimination and categorization) are examined independently in events containing the semantic components *path* (the trajectory of an object relative to a ground) and *manner* (the way the object moves). Study 1a asks whether children discriminate *path*, 1b explores whether they can form a category of *path*, 2a asks whether children discriminate *manner,* and 2b explores whether they can form a category of *manner. Path* and *manner* are examined here for two reasons: First, significant normative data has already been collected to address typical infants' discrimination and categorization of *path* and *manner* (Pulverman et al., 2008; Pruden et al., 2005), providing a solid base of research to build upon. Second, *path* and *manner* are perceptually obvious event components that may therefore be easier for children to discriminate and categorize (Mandler, 2006; Talmy, 1985). Exploring visually obvious event components maximizes the likelihood that children with ASD will demonstrate discrimination and categorization.

General Method

Participants

Children with an autism spectrum disorder (ASD). Seventeen English-speaking children with ASD (12 male) participated in the present series of studies. Fifteen of the children participated at the Center for Autism Research (CAR) at the Children's Hospital of Philadelphia and two participated at the Temple University Infant Laboratory in

Ambler, Pennsylvania. A doctoral-level psychologist diagnosed 14 of the children at CAR using the Autism Diagnostic Observation Schedule (described below), one child seen at CAR was diagnosed using the ADOS at a different center with the diagnosis provided to CAR by that center, and parents of the two children tested at the Temple Infant Laboratory reported that a physician provided the diagnosis. Information regarding the type and duration of interventions received was collected from parents when possible. Children were recruited through advertisements in local newspapers, fliers sent to local organizations and support groups, notices sent to area schools for children with special needs, and a preexisting subject pool at the Center for Autism Research. Children ranged from 3 to 6 years of age, with an average age of 5 years, 1 month (see Table 1, below).

Mental age matched controls (MA). The control group was composed of 17 English-speaking children (16 male, 1 female) individually matched to the children with ASD on non-verbal cognitive ability (as measured by the Differential Abilities Scale) and then on chronological age. Children ranged from 3 to 6 years of age, with an average age of 4 years, 6 months (slightly younger than the children with ASD; see Table 1). All MA children were recruited from the Philadelphia area and surrounding suburbs, and were tested at the Temple University Infant Laboratory.

Table 1. Mean chronological age in months with standard deviations in parentheses, minimum/maximum and group size. Difference between groups was measured using an independent-samples t-test, revealing a trend toward the MA group being younger than the ASD group (by approximately 7 months).

	MA	ASD
Mean (SD)	54.12 (9.04)	61.44 (12.21)
Minimum/Maximum	39.32/74.74	38.65/80.45
N	17	17
Difference between groups, $t(32) = -1.98$, $p = .06$		

Measures

Three standardized assessments of cognitive ability, language ability, and relational word comprehension were administered (See Table 1). Children in the ASD group were also administered the Autism Diagnostic Observation Schedule – General.

Differential Abilities Scale (DAS). The DAS is a battery of cognitive and achievement tests designed to assess the verbal and nonverbal abilities of children ranging from 2 years 6 months to 17 years 11 months of age. Outcome measures include cluster scores representing verbal, spatial, and nonverbal reasoning abilities, and a number of subtests measuring specific abilities or processes. There are special scores for verbal ability, nonverbal reasoning ability, and spatial ability that are reported as percentiles and standard scores. Internal and external validity and reliability have been well established for the overall DAS (Elliott, 1990; Gordon & Elliott, 2001). There were high correlations between the DAS and the WPPSI-R on composite scores for 4 and 5 year olds, as well as high correlations between the WISC-R Full Scale IQ for school-aged children and the DAS. Norms were based on a demographically representative sample of 3,475 children. Test-retest reliability scores ranged from .79 to .94. Children in the present studies were given the version of the DAS that was appropriate for their chronological age, but due to lower cognitive ability in some children for each group, lower level raw scores of nonverbal reasoning ability (Table 2) were used to match children in the MA group to children in the ASD group.

Table 2. Mean DAS-II lower level raw scores for each group with standard deviations in parentheses, minimum and maximum scores and group size. Lower level raw scores were calculated by summing each child's raw scores from Picture Similarities and Pattern Construction subtests, with credit for all earlier questions. An independent-samples t-test revealed no differences between groups.

	MA	ASD
Mean (SD)	41.59 (17.35)	41.35 (19.59)
Minimum/Maximum	3/69	5/72
N	17	17

No difference between groups, $t(32) = .04$, $p = .97$

Preschool Language Scale, 4th Edition (PLS-4; Zimmerman, Steiner, & Pond, 2002). The PLS-4 was constructed to assess language skills in children from birth to 6 years 11 months. This measure was used because participants were between 3 and 6 years of age, and many were expected to have language/cognitive skills that comparable to younger children. The PLS-4 includes tasks that assess preverbal behaviors, as well as linguistic skills in the areas of semantics, morphology, syntax, integrative language skills, and preliteracy skills. Content validity was confirmed by comparing the PLS-4 to both the language strand of the Denver-II and the Fluharty-2 (Fluharty, 2000). The PLS-4 also differentiated between 44 children identified with autism spectrum disorders and 44 typically developing children. According to Zimmerman and Castilleja (2005):

> "…Nonverbal autistic children demonstrated (the) greatest lags on language tasks targeting semantics (especially on those addressing concepts) and social communication skills…The most salient feature of the study was that PLS-4 could be used to identify precursory and emerging language skills for children with extremely atypical communication styles." (p. 241)

Age equivalent (AE) scores from the PLS-4 were used in the present study, consistent with other studies of children with developmental delays (Weismer, Lord, & Esler, 2010; Table 3).

Table 3. Preschool Language Scale – 4th Edition mean age equivalent scores (in months) for total language, expressive language, and receptive language, standard deviations in parentheses, minimum and maximum scores, and group size. Independent-samples t-tests revealed no significant differences between groups.

Total language score	MA	ASD
Mean (SD)	61.00 (13.30)	56.00 (19.45)
Minimum/Maximum	33/78	20/83
N	17	17
No difference between groups, t(32) = .88, p = .39		
Expressive language score	MA	ASD
Mean (SD)	57.65 (9.97)	53.00 (18.34)
Minimum/Maximum	41/75	21/81
N	17	17
No difference between groups, t(32) = .92, p =.37		
Receptive language score	MA	ASD
Mean (SD)	60.53 (13.44)	57.47 (18.54)
Minimum/Maximum	28/78	21/81
N	17	17
No difference between groups, t(32) = .55, p =.59		

Test of Relational Concepts (TRC; Edmonston & Litchfield Thane, 1988). The TRC was used to assess children’s comprehension of relational words like verbs and prepositions (Table 4). Five categories of relational concepts are included on the TRC: temporal (e.g., before, after), spatial (e.g., over, under), quantitative (e.g., most, least), dimensional (e.g., tall, short), and other (e.g., same, different). The TRC is normed for children aged 3 to 8, and does not require a productive vocabulary. Children are shown pictures of different relationships and hear sentences like, “Show me the boy in front of the chair.” This measure provides additional information about how well children understand specific relational concepts that are not included in the PLS-4. The TRC has been used in research with deaf children and children with Williams Syndrome, as well as typically developing children (Edmonston & Litchfield Thane, 1988; Mervis & John, 2008). TRC concept scores were used in the present studies, which require children to respond correctly to antonyms to receive credit for understanding a concept that has two opposite meanings (i.e., must correctly identify both *under* and *over* to receive credit). This is a more stringent test of conceptual understanding than simply identifying one or the other. Three children in the experimental group and two children in the control group did not complete the TRC.

Table 4. Test of Relational Concepts mean concept score, standard deviation in parentheses, minimum/maximum scores, and group size (number of subjects with missing data in parentheses – data missing due to behavioral problems that interfered with test-taking). An independent-samples t-test revealed no significant differences between groups (although the standard deviation for the ASD group is larger than the MA group, indicating wider variation in ability level).

	MA	ASD
Mean (SD)	32.00 (9.55)	24.64 (19.18)
Minimum/Maximum	10/43	0/55
N (missing)	15 (2)	14 (3)

No difference between groups, $t(27) = 1.32$, $p = .19$

Autism Diagnostic Observation Schedule – General (ADOS-G). The ADOS-G is a semi-structured assessment that was administered to children suspected of having an ASD. As the gold standard diagnostic tool for research and clinical evaluation of autism spectrum disorders, the ADOS-G provides an estimate of the child's placement on the autism spectrum (Lord, Rutter, DiLavore, & Risi, 2002). In the present series of studies, the ADOS-G was administered by, or directly supervised by, a doctoral-level clinician at CAR. Of the 14 children administered the ADOS at CAR, 8 met criteria for autism, 5 for

ASD, and 1 partially met criteria (Table 5). In the case of the partial score, clinical judgment was used, and the child was classified as having ASD. Clinical judgment is the gold standard when ADOS-G classification does not agree with clinical diagnosis (Weismer et al., 2010). One child was administered the ADOS-G at a different location, and although the participant had met criteria at a younger age, he did not meet criteria after the most recent assessment. Clinical judgment at CAR was that the child was indeed on the spectrum. Two children seen at the Temple Infant Laboratory were not administered the ADOS-G because no trained clinician was available. According to parental report, physicians provided a diagnosis for those children.

Table 5. ADOS-G scores for the ASD group only. Thirteen subjects from CAR had data, with the fourteenth missing. The mean score for each area is given, along with cutoff scores for a diagnosis of autism and a diagnosis of ASD in the applicable areas. Three children were given Module 1, five were given Module 2, and five were given Module 3. Modules were selected by CAR clinicians based on individual children's language ability.

Module 1 (N = 3)	Mean (cutoff autism/ASD)
Communication	5 (4/2)
Reciprocal Social Interaction	8 (7/4)
Play	2.33
Stereotyped behaviors/restricted interests	4.67
Module 2 (N = 5)	**Mean (cutoff autism/ASD)**
Communication	4.8 (5/3)
Reciprocal Social Interaction	8 (6/4)
Imagination/creativity	1.2
Stereotyped behaviors/restricted interests	2.4
Module 3 (N = 5)	**Mean (cutoff autism/ASD)**
Communication	4 (3/2)
Reciprocal Social Interaction	8.6 (6/4)
Imagination/creativity	1.6
Stereotyped behaviors/restricted interests	3.8

Apparatus

Tobii Eye Gaze Tracker. A free-standing infrared eye gaze tracker was used to non-invasively track children's gaze behaviors while they watched test videos. The eye gaze tracker is a cutting-edge way to determine *where* on a computer monitor or television screen children look during testing, and using a tracker is beneficial to this research in at least two ways: First, the traditional looking paradigms provide data about overall looking to either side of a screen, but do not provide *process data*. Process data can only be obtained by tracking detailed patterns of looking to different parts of a screen over time. In this way, the gaze tracker allows an analysis of how children process the stimuli they see – not just that they see it. Information provided by the gaze tracker includes the number of looks to each area of interest on the screen, the length of each gaze to different parts of the scene, the sequence of looks to scene components, and overall time spent looking at either side of the screen by each individual child. Second, increased variability in the looking responses of ASD children as compared to typically developing children necessitates a fine-grained analysis of visual processing patterns. Detailed data provided by the gaze tracker promises to capture the wide variability inherent in children with ASD.

Software. The Tobii Software program was used to delineate areas of interest and assemble raw gaze data, which was then exported as text and imported to SPSS for analyses.

Calibration. Tobii software requires a special phase, *calibration,* to ensure that individual children's eyes are tracked accurately. After standardized testing was completed but before test videos began, the Tobii system was calibrated to capture each child's gaze. As the Tobii tracked children's gaze, a small, animated cat appeared sequentially in each corner of the television screen and the center. Once children looked toward the cat, the experimenter pressed a button and moved the cat to the next position. In the event that some calibration points did not register, calibration for those points was repeated.

Procedure

Children participated in the present studies at either the Temple University Infant Laboratory or the Center for Autism Research at the Children's Hospital of Philadelphia (CAR). Upon arriving at the study site, children were invited to engage with toys in a child-friendly playroom while parents signed consent forms (Appendix A) and were provided with answers to any questions they might have. When the parent and child were ready, the experimenter or a clinician brought the child into a quiet, neutral room for the first part of the visit, which included three standardized tests (four, in the case of children with ASD tested at CAR). Parents rarely accompanied children in the typical group, but when they did, they were asked refrain from prompting their children. Children with ASD occasionally required a parent present for purposes of behavioral control, as judged by the clinician administering standardized tests. Parents were asked not to prompt their children. After standardized testing was complete, children were given an opportunity to play and relax in the playroom for a few minutes. During this time, children were offered a snack and a drink, and typically used the restroom. Standardized testing took approximately 2 hours for each child in the typical group, depending upon whether the individual child needed to take breaks (e.g., restroom). Standardized testing generally took longer for the children with ASD, particularly those that underwent the ADOS-G.

The ADOS-G contributed an additional 45 minutes to 1 hour to the standardized testing session, and children often required a break between the first three tests and the ADOS-G. At the Center for Autism Research, children typically took a lunch break prior to participating in the second part of the visit.

The second portion of the visit was conducted in a small, neutral room, and included seven short videos (approximately 3 minutes each) and a behavioral reenactment task. Five entries marked ** are included in the present report, and will be described more fully below. Data from three videos is not reported here, as those videos were part of a larger research program. There is no established link in the literature between path/manner discrimination/categorization and the constructs explored in those three videos (face processing and intention parsing), so it is not expected that the inclusion of these videos had an effect on the present results. The entire second portion of the visit took approximately 45-60 minutes to complete, depending upon the child's level of cooperation and need for breaks. Studies were presented in the following order:

1. Face-processing task (configural versus featural processing)
2. Path or manner discrimination (counterbalanced) **
3. Parsing intentions video 1
4. Path or manner discrimination (counterbalanced) **
5. Parsing intentions video 2
6. Path or manner categorization (counterbalanced) **
7. Failed intention task **
8. Path or manner categorization (counterbalanced) **

Children sat in a booster seat in a neutral room facing a large computer monitor and a small Tobii gaze tracker. A web camera recorded the child's head and shoulders while the eye-tracker recorded information about gaze direction and duration (Figure 1). Stimuli were presented using the Intermodal Preferential Looking Paradigm (IPLP; Hirsh-Pasek & Golinkoff, 1996). This paradigm was successfully used to study the foundations of language in children with ASD (Swensen et al., 2007), and in typically developing children as young as 7 months of age (Pruden et al., 2005). It does not require verbal responses from children, and is therefore especially useful in populations that demonstrate variable language ability.

In order to keep the children's attention and motivate them to continue with the study, reward charts were created for children in both groups. Children were able to pick special stickers to place on the reward chart after each video/activity. The charts had the children's names on them and were sent home with the children after the visit (Appendix B). Children were encouraged to sit independently in the booster seat and watch videos, but some children insisted on sitting on their parent's lap. In those cases, the parents wore dark sunglasses to avoid interference with the gaze-tracker. Children with ASD often (but not always) needed their parent in the room during video testing for assistance with behavior even if the child sat independently. Thus, some parents accompanied their children into the video room and sat behind the child. Parents who accompanied their children into the gaze-tracking room were asked to refrain from describing the videos. They were, however, permitted to verbally encourage their child to continue watching the videos, as did the experimenter (e.g., "Look at that!" "Keep watching the movie," "You're doing great, keep looking,"). Children in both groups required significant verbal encouragement to continue watching the videos for such an extensive period of time. However, none of the videos had a verbal element – that is, all training and test clips were silent. Neutral verbal encouragement to continue watching was therefore not considered to interfere with the purpose of the videos.

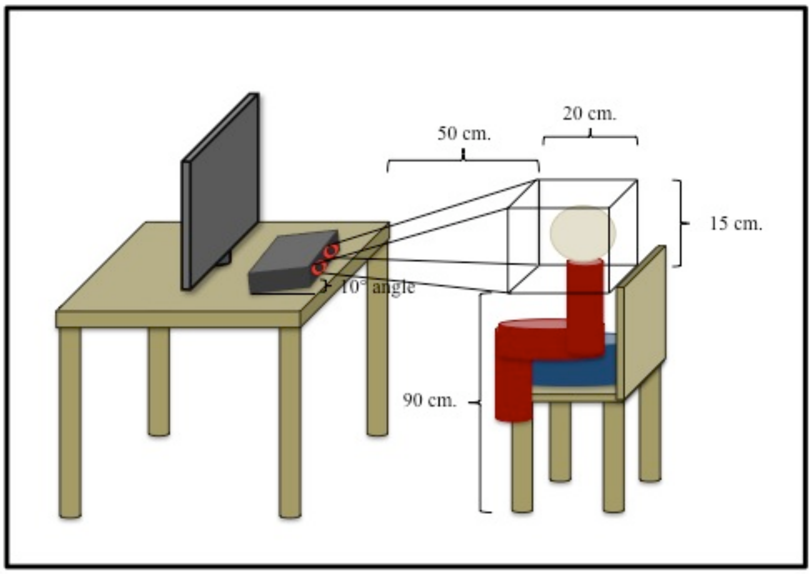


Figure 1. Gaze tracking setup.

After the second part of the visit was complete, children were encouraged to return to the playroom and show their parents the reward chart. The children at the Temple Infant Laboratory were permitted to choose an age-appropriate toy prize, and were given a "Certificate of Appreciation." All parents received $50, and parents of children seen at CAR were also compensated for travel expenses (consistent with CAR policy). Children were encouraged in age-appropriate ways to continue participating during parts one and two of the visit, but the study was stopped if the children were clearly uncomfortable. No children in the present sample were excluded due to refusal to participate in significant portions of the study, although in 5 cases (3 in the ASD group), the final standardized test (TRC) was not completed due to behavioral difficulties. In some situations, children did not complete the tests in a single visit, and returned within a week to complete testing. This was done in order to minimize stress on the participants and obtain the most accurate data possible.

Study 1a: Discriminating *Path*

Study 1a explored whether participants could distinguish between two different *paths* in an animated event (e.g., starfish travels *over* a ball, starfish travels *under* a ball). Discriminating the *path* of a figure (e.g., starfish) relative to a ground (e.g., ball) is the first step in developing the conceptual foundations necessary for words that like *ascend* and *enter.* Arguably the most fundamental semantic action component (Mandler, 2004), *path* is successfully discriminated by typical infants as young as 7 months of age (Pulverman & Golinkoff, 2004). Based on prior research with typical infants, it was expected that typical children in the present study would successfully discriminate *path*.

Design and Stimuli

The present stimuli have been used extensively in research on path/manner processing in typically developing infants (Pulverman et al., 2008) and are thus expected to be valid for use in the present study. Two path/manner pairs were selected for the two conditions of Study 1a: twist-over/twist-under and flap-past/flap-around (Table 6). Twist over/under is described here, but the structure of flap past/around is exactly the same. These particular stimuli were chosen because in prior research, they were found to be the strongest indicators of ability in typically developing children (Shannon Pruden, personal communication). A complete list of the *paths* and *manners* used in the present study, as well as counterbalanced study orders, can be found in Appendix C.

Table 6. Structure of Study 1a. Each child saw condition A videos *or* condition B videos throughout all four studies (see Appendix C).

Condition	Salience	Familiarization	Tests 1 & 2
A	twist under - twist over	twist under x 4	twist under - twist over Novel: twist *over*
B	flap around - flap past	flap around x 4	flap around - flap past Novel: flap *past*

Salience. Children were shown a 12-second video of a starfish performing a manner (e.g., *twist*) and a path (e.g., *over a ball*) on one side, and the same starfish performing the same manner (e.g., *twist*) along a different path (e.g., *under a ball*) and on the other side (Figure 2). The Salience trial served two purposes. First, it determined whether children had an a priori preference for either of the test videos. Second, it served as a baseline when assessing whether the Familiarization trials affected children's looking patterns during Test trials.

Set A: Twist under – twist over

Set B: Flap around – flap past

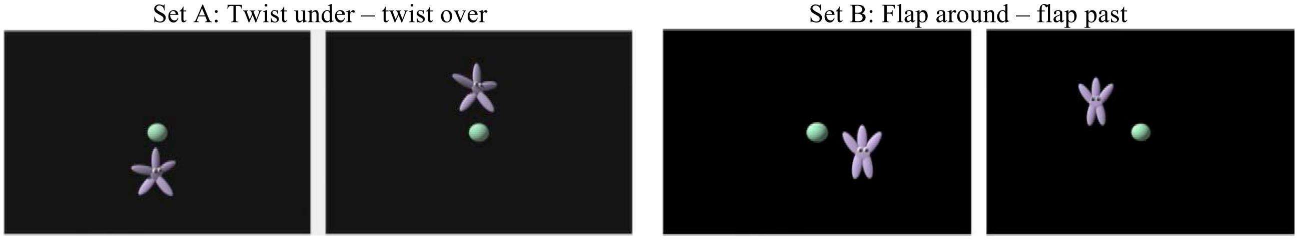


Figure 2. Study 1a split-screen stimuli shown during Salience trial. Half of the participants were shown set A and half were shown set B (see Appendix C for counterbalancing).

Familiarization. Children were familiarized with four 12-second video clips of a starfish performing one of the path/manner combinations seen during Salience (e.g., *flapping over a ball*; Figure 3).

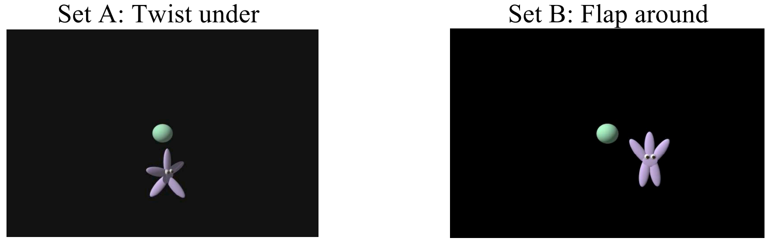


Figure 3. Study 1a Familiarization stimuli. Half of the participants were shown set A and half were shown set B (see Appendix C for counterbalancing).

Test 1. During the first test phase (T1), children saw the same split-screen stimuli from Salience for 12 seconds. To determine whether Familiarization with a certain *path* affected children's preference for looking at one event or the other, measures of looking to each side of the split-screen during the Test trials were compared to each individual child's looking patterns during the Salience trials. A significant increase in looking to the event containing a *path* that was *not* seen in Familiarization indicates recognition that the *path* is "new" or different, and is taken as evidence of discrimination. Discrimination might also be evidenced by a significant *decrease* in looking to the event containing the same *path* that was seen during Familiarization, as reducing attention indicates recognition that the stimulus is "old" or has the same *path* as Familiarization.

Test 2. Same as T1.

Centering. Between each trial (Salience, Familiarizations 1-4, Tests 1-2), a child-directed animation accompanied by a sound renewed children's interest in the stimuli and reoriented their looking to the center of the screen. This was designed to help avoid the problem of looking to one side of the screen only.

Areas of Interest (AOIs) and Dependent Variables

Areas of Interest (AOI). In the absence of further specification, Tobii software provides data about eye gaze direction and duration on the screen as a whole. For the purposes of the present research, areas of interest (AOIs) were created around each of the path/manner pairs in the split-screen video. This allowed the Tobii software to compile data for those particular areas of the screen individually. At test, the *Novel AOI* encompassed the path/manner pair that was *not* seen during the Familiarization phase, and the *Familiar AOI* covered the path/manner pair that *was* seen during Familiarization (Figure 4). The Novel and Familiar AOIs of Set A each covered 7.59% of the screen. The Familiar AOI of set B covered 8.42% and the Novel AOI covered 7.72%.

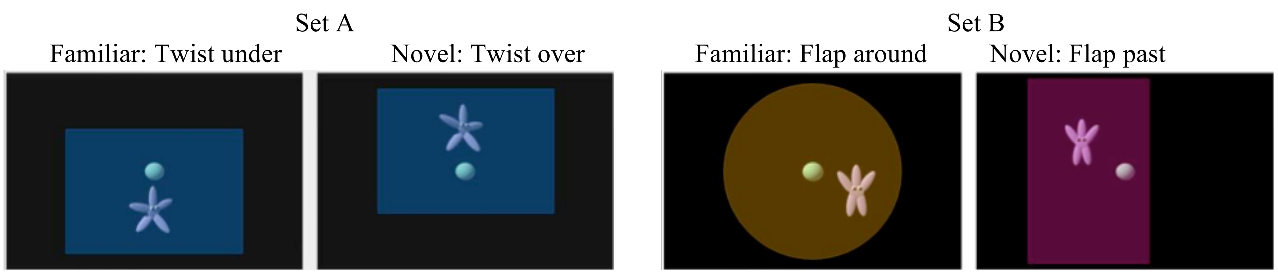


Figure 4. AOIs for the Salience and Test trials of Study 1a. Test stimuli were the same as Salience stimuli. AOIs were not visible to participants.

Variables. The primary independent variable of interest was group (ASD or MA). The dependent variables of interest were based on the Tobii eye-gaze software definition of visual fixation. A "Fixation" is recorded when a child spends 30 or more milliseconds looking at a single spot on the screen, and the total duration of each fixation is also recorded. In the present analyses, the sum of the duration of all fixations to each AOI (Total Fixation Duration; TFD), the number of looks to each AOI (Fixation Count; FC), and the first AOI looked at (First Look; FL) were the dependent variables of interest.

Raw scores, proportions, and binomial forms of the data were analyzed. Significantly altering looking behaviors between Salience and the Test trials was considered evidence of discrimination. Given prior research showing that some children prefer to look at novel stimuli, while others prefer to look at familiar stimuli (Wetherford & Cohen, 1973), no specific hypotheses were made as to novelty preference – that is, significantly changed looking to either the familiar *path* or the novel *path* during Tests 1 and 2 as compared to Salience is taken to indicate discrimination.

Results of Study 1a

Preliminary analyses. To ensure that the participants in the final sample for each test had in fact been familiarized to the stimuli, children's attention during the Familiarization phase was examined. Attention was defined as the sum of the durations of fixations that occurred during the Familiarization phase. Data from children with attention scores below .20 (i.e., children who fixated on the screen less than 20% of the time during the 48-second familiarization phase) or failed to look at both screens at least once over the three split screen trials were excluded from analyses. One member of the MA group and no members of the ASD group were excluded from data analyses for Study 1a.

Total Fixation Duration (TFD). **Raw data** were explored using within-groups paired-samples t-tests. A significant increase in looking to the Novel AOI from Salience to T1 or T2 indicated recognition that the path was "new" or different from the path seen during Familiarization. A significant decrease in looking at the Familiar AOI from Salience to T1 or T2 indicated recognition that the stimulus was "old" or had the same path as Familiarization. Results revealed that the MA group had a smaller raw duration of looking on the Familiar path in T2 than Salience, $t(15) = 3.17$, $p = .006$, and a smaller raw duration of looking on the familiar path in T2 than T1, $t(15) = 2.35$, $p = .03$. Importantly, the MA group looked significantly longer at the Novel path than the Familiar path in T2 $t(15) = -2.75$, $p = .01$. There were no differences in raw duration of looking in the ASD group. This suggests that the MA group, but not the ASD group, noticed that the Familiar path was the same as the one seen during Familiarization and thus reduced their looking to that event.

Raw duration of looking data for Salience, T1 and T2 were converted to **proportion of looking** at the event with the Novel path. Proportion was calculated by dividing each child's raw duration of looking on the Novel AOI by their raw duration of looking on the Novel and Familiar stimuli combined. This means that if children found the Novel and Familiar paths equally interesting during the Salience trial, the proportion of looking to each AOI should be .50. If the Familiarization phase affected looking, children should look more to one side than the other. Due to large individual differences in stimulus preference during Salience, individual children's proportions of looking to the Novel path during T1 and T2 were compared to their own preferences as established during Salience (Swensen et al., 2007). Results of within-groups paired-samples t-tests revealed that children in the MA group significantly increased their proportion of looking at the Novel *path* in T2 as compared to Salience, $t(15) = -2.44$, $p = .03$. This result corroborates the raw duration of looking finding described above. A one-sample t-test also confirmed that the proportion of time spent looking at the Novel *path* during T2 was significantly greater than expected by chance in the MA group, $t(15) = 2.30$, $p = .04$.

Proportion of total fixation duration spent on the Novel and Familiar stimuli were recoded into **binomial variables** where 0 indicated that the proportion of total fixation duration on the Novel path *increased* from one phase to another (e.g., Salience to T1), and a score of 1 indicated that the proportion of total fixation duration on the Novel path *decreased* from one phase to another. A 2x2 Chi-Square revealed no differences between groups. A 1x2 Chi-Square revealed, consistent with findings using raw scores and proportions, that significantly more members of the MA group increased the proportion of time spent looking at the Novel *path* from Salience to T2, Chi-square = 4.000, $p = .05$, and significantly more children in the MA group looked at the Novel *path* for a longer period of time than looked at the Familiar *path* during T2.

Total Fixation Count (FC). Between-group comparisons of **raw data** revealed that despite equal TFD during the Familiarization phase, ASD and MA groups differed in the number of raw fixations made during Familiarization. The MA group had significantly more fixations on the screen during Familiarization than did the ASD group, $t(31) = 2.11$, $p = .04$. Within-groups paired-samples t-tests revealed that children in the MA group made significantly fewer fixations on the Familiar path during T2 than during Salience, $t(15) = 2.61$, $p = .02$, which is consistent with the finding that TFD on the Familiar path also drops significantly between Salience and T2. This is not a case of "all looking times/fixations shrinking over time," as there were no significant drops in looking to the Novel path from Salience to T2.

Proportion of fixations on the Novel event during Salience, T1 and T2 revealed no significant differences within- or between-groups. A between-groups 2x2 Chi-square analysis on **binomial variables** revealed a trend toward differential looking toward the

Novel path during T1, Pearson Chi-square = 3.46, $p = .06$. A follow-up 1x2 Chi-square revealed that the difference was driven by a larger number of children in the ASD group making a greater number of fixations on the Familiar than Novel stimuli in T1 than expected by chance (Chi-square = 6.25, $p = .01$).

First Look (FL). Tobii software measures how long each child takes to fixate on a given AOI. Children who looked more quickly to the Novel vs. the Familiar AOI in Salience, T1, and/or T2 was given a score of 1, indicating that they looked more quickly to the Novel *path* than the Familiar *path*. There were no significant differences in the number of children who looked to the Novel *path* first between groups. A within-groups 1x2 Chi-Square revealed that significantly fewer children in the ASD group looked first to the Novel *path* than the Familiar *path* in T1 than expected by chance.

Discussion of Study 1a

Children in the MA group demonstrated a strong preference for looking at the Novel path during T2 in comparison to Salience, which suggests that they discriminated between the two paths. Children with ASD did not demonstrate discrimination in comparison with Salience, or even between T1 and T2. However, binomial tests suggest that a greater number of children with ASD made more fixations on the Familiar than at the Novel stimuli in T1 than expected by chance, and more looked at the Familiar stimuli first in T1. This finding is consistent with a preference for sameness that has been suggested in the literature (Boucher, 1977) and the suggestion that children with ASD might experience difficulty when required to disengage visual attention (Bebko et al., 2008; Landry & Bryson, 2004; Wilson et al., 2006). Interestingly, the MA group was more actively engaged with the Familiarization stimuli than was the ASD group, as evidenced by a greater fixation count despite equal total fixation duration during the Familiarization trials. This means that the MA group scanned more, explored more, and perseverated less while becoming familiar with the *path* stimuli than did the ASD group, which is consistent with the aberrant patterns of visual attention reported in this population the past (Sasson, Turner-Brown, Holtzclaw, Lam, & Bodfish, 2008). Reduced scanning and exploration by the ASD group during familiarization might be theoretically related to reduced emphasis on “big picture” processing (Happé & Frith, 2006), and may have contributed to the lack of difference between Salience and Test trials in this group.

Study 1b: Categorizing Path

Study 1b was designed to test whether participants could abstract an invariant *path* of motion (e.g., over) when viewing scenes where a single *path* was traversed by various *manners* (e.g., flap, side-bend, toe touch, spin). In other words, did children notice that an animated starfish was *going over the ball* in each of four Familiarization trials, even though the starfish went under while flapping, side-bending, toe touching, and spinning?

Design and Stimuli

The same path/manner pairs from Study 1a were shown in Study 1b. Salience and Test trials were exactly the same in both studies, but the content of the Familiarization trials in 1b differed from the content in the Familiarization trials of 1a. In the Familiarization trials of 1a, children saw the same video clip 4 times in a row. In 1b, on the other hand, children saw 4 *different* videos, each with a different *manner*, but with a common *path*. The purpose behind showing four different exemplars was to encourage children to notice the common element – the *path* – and form a category of that element

(Gentner, 2003). The novel *path* from the 1a test trials (*over, past*) was the in-category exemplar in the test trials of 1b, and the familiar *path* from test trials in 1a (e.g., *under, around*) was the out-of-category exemplar in the test trials of 1b (see Table 7). This design was intended to show that children who discriminated a given path (e.g., *over*) could then go on to form a category of that same path. Side of match was counterbalanced across participants, such that if the Novel *path* from the discrimination study appeared on the right side of the screen during the Test trials, then the out-of-category *path* in the categorization study appeared on the left.

Table 7. Structure of Study 1b. Each child saw condition A videos or condition B videos throughout all four studies (see Appendix C).

Condition	**Salience**	**Familiarization**	**Tests 1 & 2**
A	twist under - twist over	flap, side-bend, toe-touch, and spin *over*	twist under - twist over Out-of-category: twist *under*
B	flap around - flap past	toe-touch, spin, twist, and side-bend *past*	flap around - flap past Out-of-category: flap *around*

Salience. Children saw a split screen with the same two path/manner pairs as 1a.

Familiarization. Children saw 4 different 12-second clips during Familiarization. Each of the clips showed the starfish moving along a common *path*, but by four different manners (none of which were seen during Salience; Figure 5).

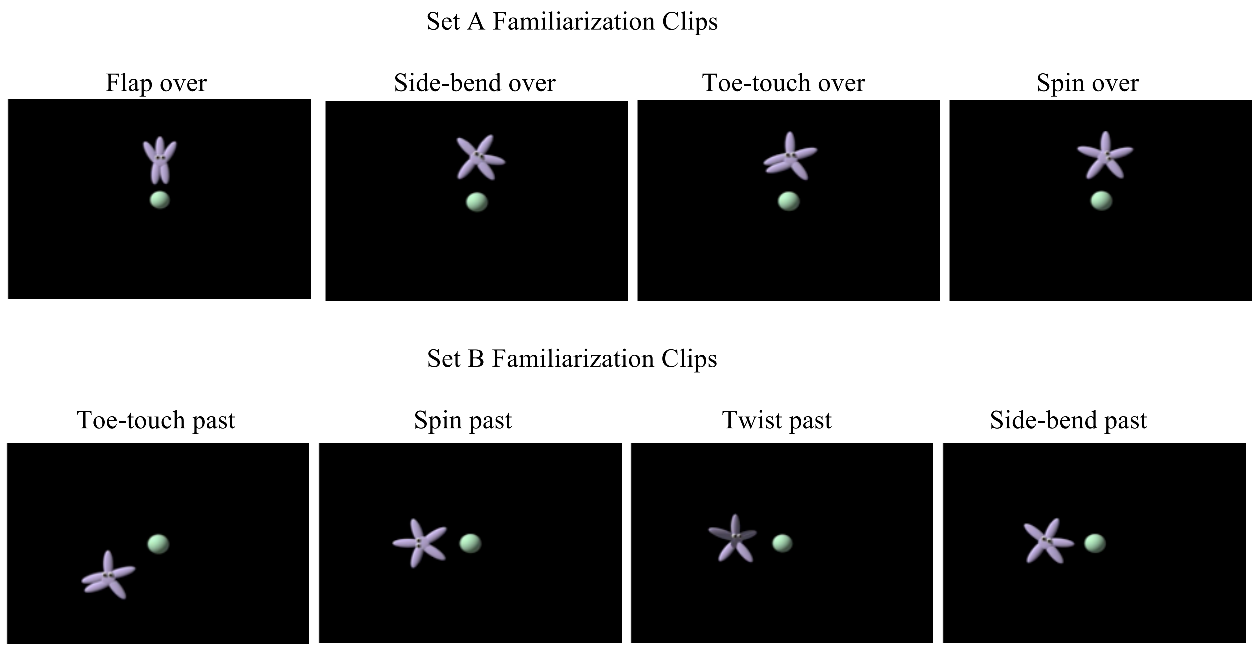


Figure 5. Familiarization clips for Study 1b. Each clip was shown for 12 seconds. Children were shown videos either from set A or set B.

Test 1. Same split-screen video as Salience.

Test 2. Same as T1.

Centering. Between each trial (Salience, Familiarizations 1-4, Tests 1-2), a child-directed animation accompanied by a sound renewed children's interest in the stimuli and reoriented their looking to the center of the screen. This was designed to help avoid the problem of looking to one side of the screen only.

Areas of Interest (AOIs) and Dependent Variables

Areas of Interest (AOIs). As in 1a, areas of interest (AOIs) were created for each of the path/manner pairs in the split-screen video (Figure 6). Rather than being *novel* and *familiar* as in the discrimination task, however, the categorization task required *in-category* and *out-of-category* designations. For example, children who see the starfish bending, flapping, twisting, and toe-touching *over the ball* in the Familiarization trials should recognize the common *path* (e.g., over) as consistent across the four exemplars. In that case, the category *over* should have been formed during familiarization, so the *in-category* event at test would show the starfish traversing *over* the ball. Conversely, the path/manner pair showing the starfish traversing a *different* path than was seen during familiarization was encompassed by the *out-of-category* AOI. The in-category and out-of-category AOIs of Set A each covered 7.59% of the screen. The out-of-category AOI of set B covered 8.42% and the in-category AOI covered 7.72%.

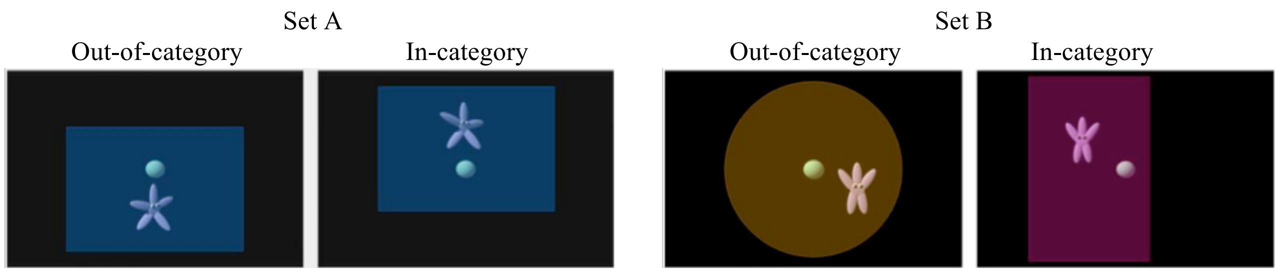


Figure 6. AOIs for the Salience and Test trials of Study 1b. Test stimuli were the same as Salience stimuli. AOIs were not visible to participants.

Variables. As in 1a, the primary independent variable of interest was group (ASD or MA). The sum of the duration of all fixations to each AOI (Total Fixation Duration; TFD), the number of looks to each AOI (Fixation Count; FC), and the first AOI looked at (First Look; FL) were dependent variables of interest. Raw scores, proportions, and binomial forms of the data were analyzed. Significantly altering looking behaviors between Salience and the Test trials was considered evidence of categorization. No specific hypotheses were made as to novelty preference – that is, increased looking to either the in-category exemplar or the out-of-category exemplar during T1 or T2 relative to salience was taken to indicate categorization.

Results of Study 1b

Preliminary analyses. One member of the ASD group and no members of the MA group were excluded due to insufficient looking during Familiarization.

Total Fixation Duration (TFD). Within-groups paired-samples t-tests on **raw data** were revealed that the MA group trended toward decreased total fixation duration on the in-category exemplar in T1 versus Salience, $t(16) = 1.74$, $p = .10$, but did not decrease their looking to the out-of-category exemplar in T1 versus Salience. This indicates recognition that the in-category event seen in T1 had the same path seen during Familiarization. There were no significant differences or trends in the ASD group.

Raw TFD data for Salience, T1 and T2 were converted to **proportion of looking** at the out-of-category action. Results of between- and within-groups t-tests revealed no differences when compared within-or between phases for either group, and neither did analyses of **binomial variables**.

Total Fixation Count (FC). Independent samples t-tests on **raw fixation count data** revealed that that the ASD group made more fixations on both the in-category (trend) and out-of-category events during the Salience trial than did the MA group (in-category, $t(31) = -1.78$, $p = .09$; out-of-category, $t(31) = -3.13$, $p = .004$). This suggests a higher overall level of *involvement* with the Salience stimuli by the ASD group, despite comparable overall length of looking (as measured by TFD, above). Paired-samples t-tests revealed that the MA group trended toward making fewer raw fixations on the event with the in-category path in T1 than in Salience, $t(16) = 1.85$, $p = .08$, which indicates recognition that it is the same path seen during Familiarization. This finding is consistent with the raw TFD findings above, wherein children in the MA looked for a shorter period of time at the in-category path in T1 versus Salience. In T2, however, MA group looking rebounded and the number of fixations on the in-category path increased relative to T1, $t(16) = -2.00$, $p = .06$. Paired-samples t-tests further revealed that the ASD group had significantly fewer fixations on the in-category *and* out-of-category events in T1 and T2 as compared to Salience, because a high number of fixations occurred during Salience and overall looking dropped significantly after the Familiarization phase. For this reason, it is important to look at proportion of fixations as well as raw fixation counts.

Proportions of fixations on the in- versus out-of-category events during Salience, T1 and T2 revealed no significant differences between groups, but did reveal a significant trend toward an out-of-category preference in number of fixations for the ASD group (they fixated proportionately more frequently on the out-of-category event during Salience, T1, and T2; *p*s = .10, .06, .08), and looked at the out-of-category event proportionately more often than expected by chance in Salience, T1 and T2. This finding is indicative of an a priori preference for the out-of-category event that was *not* affected by the Familiarization phase. Chi-square analyses on **binomial variables** were not interpretable for the ASD group due to the strong a priori preference for fixating on the out-of-category event, and no differences from chance were found in a 1x2 Chi-square for the MA group.

First Look (FL). Chi-Square tests revealed that more children than expected by chance in the ASD group looked first at the out-of-category event in T2, but this finding is not interpretable given the out-of-category fixation count bias seen in Salience, T1, and T2. There were no differences from chance rates in the MA group.

Discussion of Study 1b

Based on reductions in raw fixation duration and number of raw fixations on the event with an in-category *path* in T1 relative to Salience, and in the absence of a corresponding reduction in looking to the out-of-category path that would have suggested that the effect was due to an overall reduction in looking, the results of study 1b weakly suggest a trend in the MA group towards categorizing a single *path* over multiple *manners.* This finding rests on raw looking times and fixation counts, however, which are less conclusive than proportions. Evidence of categorization by the ASD group was obscured by a powerful a priori bias toward making an increased number of fixations on the out-of-category event during Salience and both Test trials.

A valuable feature of infrared gaze tracking technology is that it measures more than the total duration of looking to each AOI in a scene. The number of times a child fixates within a given AOI (fixation count) can be interpreted as a measure of engagement with the stimuli, and might be a more sensitive measure of categorization than total fixation duration. In this case, although children with ASD did not look at the out-of-category path for a longer period of *time* than the in-category path in any of the trials, a pattern emerged within fixation counts. Children in the ASD group demonstrated a strong a priori preference for processing the out-of-category rather than the in-category *path* during Salience, T1, and T2, as evidenced by a larger proportion of fixations. This finding is most likely attributable to the fact that the familiar *path* from 1a was the out-of-category exemplar in 1b (Table 8).

Table 8. Comparison of Study 1a (*path* discrimination) and 1b (*path* categorization). Children were randomly assigned to either Condition A or Condition B. The paths in **bold** were fixated significantly more frequently by the ASD group.

Condition A	Salience	Familiarization	Tests 1&2
Discrimination	twist under - twist over	twist under x 4	Novel: twist *over* = R Familiar: twist *under* = L
Categorization	**twist under** - twist over	flap, side-bend, toe-touch, spin *over*	**Out-of-category: twist *under* = L** In-category: twist *over* = R

Condition B	Salience	Familiarization	Tests 1&2
Discrimination	flap around - flap past	flap around x 4	Novel: flap *past* = R Familiar: flap *around* = L
Categorization	**flap around** - flap past	toe-touch, spin, twist, side-bend *past*	**Out-of-category: flap *around* = L** In-category: flap *past* = R

There are at least two possible explanations for this pattern of results: side bias (wherein children always look toward the left side of the screen) or delayed discrimination. The "side bias" explanation is unlikely because each *path* video was separated by a *manner* video (or by Study 3), and there was no "left side bias" in the *manner* video results. Furthermore, there was no preference for fixating on the left side of the screen during the Salience phase of *path* discrimination in either Condition – a robust preference emerged only in the Salience and Test trials of *path* categorization.

The second possibility, delayed discrimination, may provide a better explanation. If children with ASD recognized the Familiar *path* from 1a in the Salience trial of 1b, this is evidence of *path* discrimination (albeit delayed). "Delayed discrimination" is supported by the Study 1a finding that more children in the ASD group made an increased number of fixations on the Familiar relative to the Novel stimuli in T1 than expected by chance, and more looked at the Familiar stimuli first than the Novel stimuli in T1. This "carry-over effect" from 1a to 1b makes it difficult to draw conclusions about categorization, even when comparing Test trials to children's own preferences during Salience. Thus, although children in the ASD group did not provide evidence of categorization in this study, interference from robust perseveration on the Familiar *path* from the discrimination study makes it impossible to determine whether they are or are not able to form a category of *path*.

Why might children perseverate on the Familiar *path* event from Study 1a? Based on research showing abnormal patterns of visual processing of complex stimuli requiring integration (for a review, see Happé & Frith, 2006), suggestions that children with ASD might prefer sameness over novelty in some situations (Boucher, 1977), and evidence that children with ASD might experience difficulty disengaging attention in visual tasks (Bebko et al., 2008; Landry & Bryson, 2004; Wilson et al., 2006) it is possible that children in the ASD group required more time to process the path shown for 48 seconds in Study 1a, continuing to process it through the Test trials. The stimuli from the Test trials of Study 1a was also the stimuli in the Salience trial of Study 1b, so if children processed slowly during Tests 1 and 2 of Study 1a, they may have only shown a preference in the "third test trial" (i.e., Salience of Study 1b). Resolving this issue in future research would require adding more test trials to the discrimination study, thus revealing whether discrimination reliably emerges when children are given additional processing time.

Study 2a: Discriminating Manner

Studies 1a and 1b explored the conceptual underpinnings of *path* words like "ascend" and "enter". In study 2a, the conceptual foundation of words like "skip" and "hobble" was explored by asking whether children could discriminate between two *manners* of motion.

Design and Stimuli

Two manner pairs were compared in each of the two conditions in Study 2a: flap/bend down (past) and twist/toe touch (under; Table 9). As with the *path* studies, these particular stimuli were chosen because in prior research, they were found to be the strongest indicators of ability in typically developing children (Shannon Pruden, personal communication).

Table 9. Structure of Study 2a. Each child saw either condition A videos *or* condition B videos throughout all four studies (see Appendix C).

Condition	**Salience**	**Familiarization**	**Tests 1 & 2**
A	flap past - bend down past	flap past x 4	flap past - bend down past Novel: *bend down* past
B	toe touch under - twist under	twist under x 4	toe touch under - twist under Novel: *toe touch* under

Salience. Children saw a split screen with two path/manner pairs (e.g., *flap past the ball, bend down past the ball*; Figure 7). The manners were different from one another, but both starfish traversed the same path relative to the ball.

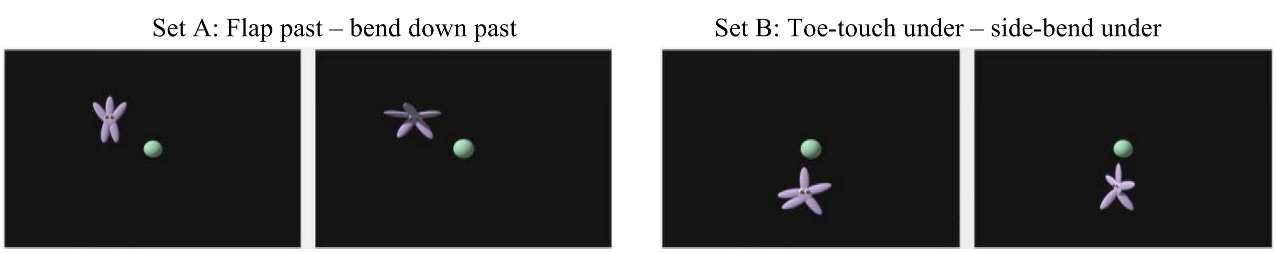


Figure 7. Study 2a split-screen stimuli shown during Salience trial. Half of the participants were shown set A and half were shown set B (see Appendix C for counterbalancing).

Familiarization. Children were familiarized with four 12-second video clips of the starfish performing one of the path/manner combinations seen during Salience (e.g., *flap past the ball*, Figure 8).

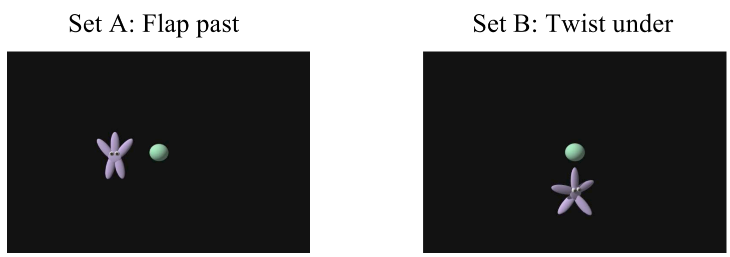


Figure 8. Study 2a Familiarization stimuli. Half of the participants were shown set A and half were shown set B (see Appendix C for counterbalancing).

Test 1. During the first test phase (T1), children saw the split-screen stimuli from Salience for 12 seconds to determine whether the Familiarization phase affected their looking behaviors.

Test 2. Same as T1.

Centering. Between each trial (Salience, Familiarizations 1-4, Tests 1-2), a child-directed animation accompanied by a sound renewed children's interest in the stimuli and reoriented their looking to the center of the screen. This was designed to help avoid the problem of looking to one side of the screen only.

Areas of Interest (AOIs) and Dependent Variables

Areas of Interest (AOI). Areas of interest (AOIs) were created around each of the path/manner pairs in the split-screen video (Figure 9). The *Novel AOI* encompassed the path/manner pair that was *not* seen during the Familiarization phase, and the *Familiar AOI* covered the path/manner pair that *was* seen during Familiarization. The Novel and

Familiar AOIs of Set A each covered 7.75% of the screen, and the AOIs of Set B each covered 7.83% of the screen.

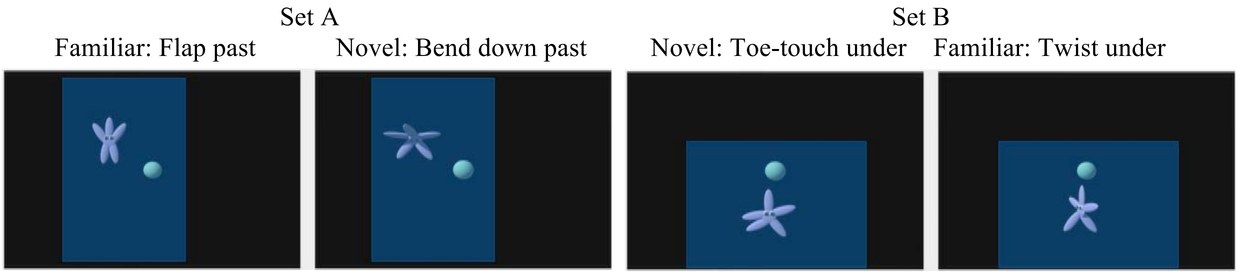


Figure 9. AOIs for the Salience and Test trials of Study 2a. Test stimuli were the same as Salience stimuli. AOIs were not visible to participants.

Variables. The primary independent variable of interest was group (ASD or MA). The sum of the duration of all fixations to each AOI (Total Fixation Duration; TFD), the number of looks to each AOI (Fixation Count; FC), and the first AOI looked at (First Look; FL) were dependent variables of interest. Raw scores, proportions, and binomial forms of the data were analyzed. Significantly altering looking behaviors between Salience and the Test trials was considered evidence of discrimination. Given prior research showing that some children prefer to look at novel stimuli, while others prefer to look at familiar stimuli (Wetherford & Cohen, 1973), no specific hypotheses were made as to novelty preference – that is, significantly increased or decreased looking to either the familiar *manner* or the novel *manner* during Tests 1 and 2 as compared to Salience is taken to indicate discrimination.

Results of Study 2a

Preliminary analyses. Five members of the MA group and one member of the ASD group were excluded due to insufficient looking during the Familiarization phase (5) or failure to look at both sides of the split screen (1).

Total Fixation Duration (TFD). **Raw data** were explored using within-groups paired-samples t-tests. Results revealed that children in the ASD group looked less at the Familiar stimuli during T1 than they did during Salience, suggesting that they recognized the *manner* they saw throughout Familiarization and had little interest in continuing to look at it, t (15) = 3.49, p = .003. Possible reasons for the lack of perseveration observed here are discussed below. Children in the MA group did not significantly reduce their total fixation duration on the Familiar stimuli in T1 relative to Salience, but they did reduce duration of looking to the Familiar manner between Salience and T2, t (11) = 2.6, p = .03. Only the children in the ASD group fixated significantly longer on the Novel stimuli than to the Familiar stimuli during T1, t (15) = 2.27, p = .04, suggesting that they discriminated the *manner* and preferred to look at novelty.

Raw TFD data for Salience, T1 and T2 were converted to **proportion of looking** at the Novel event. Due to large individual differences in stimulus preference during Salience, individual children's proportions of looking to the Novel manner during T1 and T2 were compared to their own preferences as established during Salience (Swensen et al., 2007). Results of between- and within-groups t-tests revealed no differences in proportion of total fixation duration spent on the Novel manner versus the Familiar manner compared within-or between phases for either group.

Proportion of total fixation duration spent on the Novel and Familiar stimuli were recoded into **binomial variables** where 0 indicated that the proportion of total fixation duration on the Novel manner increased from one phase to another (e.g., Salience to T1), and a score of 1 indicated that the proportion of total fixation duration on the Novel manner decreased from one phase to another. A 2x2 Chi-Square revealed no significant between-group differences in the number of children who increased or decreased their proportion of total duration of looking to the Novel manner between Salience and T1 or Salience and T2. However, the groups trended toward differences in the test trials such that more MA than ASD children increased their looking to the Novel manner between T1 and T2 (Pearson Chi-Square = 3.46, $p = .07$). A 1x2 Chi-Square revealed that more ASD children increased their proportion of TFD on the Novel manner from Salience to T1 than expected by chance (Chi-Square = 4.000, $p = .05$).

Total Fixation Count (FC). Comparisons of **raw data** revealed that the ASD group made more fixations during the Familiarization phase than did the MA group. This suggests that they may have been more engaged in studying the stimuli, even though their total duration of looking was not different from the MA group during that phase. There were no other significant differences in raw comparisons, **proportions of fixations** on Novel versus Familiar stimuli, or **binomial variables**.

First Look (FL). Chi-Square tests determined that there were no differences in the number of children who looked to the Novel manner first either between- or within-groups/phases.

Discussion of Study 2a

In contrast to Study 1a, wherein children with ASD did not demonstrate *path* discrimination, the results of Study 2a suggest that children in the ASD group successfully discriminated between two *manners*. Children with ASD demonstrated a preference for looking at the Novel rather than the Familiar exemplar in T1 (as measured by raw fixation duration), and greater-than-chance numbers of children in the ASD group increased their proportion of looking to the Novel *manner* between Salience and T1 (chi-square test). Children in the MA group, on the other hand, did not show any significant differences from looking during Salience until T2. This is not taken to mean that children in the MA group were unable to discriminate manners, however. In light of research suggesting that typically developing infants are able to discriminate *manners* by 7 months of age (Pulverman & Golinkoff, 2004), it is more likely that children in the MA group simply did not engage very deeply in the 48 seconds of repeated manner videos, and may have tuned out by the time T1 and T2 appeared. This is consistent with the finding that despite equal total looking duration, children with ASD were more engaged than the MA group with the stimuli during Familiarization (as demonstrated by a greater raw number of fixations on the screen). The reverse pattern was present in Study 1a (*path* discrimination), such that children in the MA group made more fixations during the Familiarization phase than did the ASD group, and children in the MA group demonstrated discrimination of *path* as evidenced by increased looking to the novel *path* in T2 relative to Salience. This finding suggests that perhaps the amount of processing children do in the Familiarization trials has a strong effect on whether or not they discriminate relational components like *path* and *manner*. Based on this finding, future research should emphasize ways to engage children in looking at the stimuli, and examine patterns of engagement during training as they relate to performance outcomes.

Study 2b: Categorizing Manner

Study 2b was designed to determine whether children could abstract an invariant *manner* of motion (e.g., bend down) across various *paths* (e.g., over, under, around, in front). In order to demonstrate successful categorization, children must notice that the animated starfish is always *bending down* during four Familiarization trials, even though the starfish bends down while traveling over, under, around, and in front of the ball. Then, in the Test trials, they must demonstrate recognition that the starfish is traversing a path via the same *manner* seen during Familiarization in one of the two events on the split screen.

Design and Stimuli

Two manner pairs were included in the two conditions of Study 2b: flap/bend down (*manner*) past (*path*) and twist/toe touch (*manner*) under (*path*; Table 10). Flap/bend down is described here, but the structure of the twist/toe touch condition is exactly the same. Children who saw flap/bend down during discrimination also saw it during categorization, as with twist/toe touch. As with studies 1a and 1b, the *familiar* manner from 2a is the *out-of-category* exemplar in 2b.

Table 10. Structure of Study 2b. Each child saw condition A videos or condition B videos throughout all four studies (see Appendix C).

Condition	**Salience**	**Familiarization**	**Tests 1 & 2**
A	flap past - bend down past	*bend down* over, around, under, and in front	flap past - bend down past Out-of-category: *flap* past
B	toe touch under - twist under	*toe touch* past, in front, around, and over	toe touch under - twist under Out-of-category: *twist* under

Salience. Children saw a split screen with two path/manner pairs as in 2a. The *manners* were different from one another, but they both traversed the same *path* (see Figure 7).

Familiarization. The Familiarization phase of 2b was structured differently than Familiarization in 2a. In 2a, children saw 4 identical clips of a starfish moving in the same manner along the same path. In 2b, on the other hand, children saw 4 different clips during Familiarization. Each of the clips had a common *manner* (e.g., bend down), but the starfish moved along four different paths (e.g., over, around, under, in front), none of which were the same as the path seen in the split-screen videos (e.g., past; Figure 10).

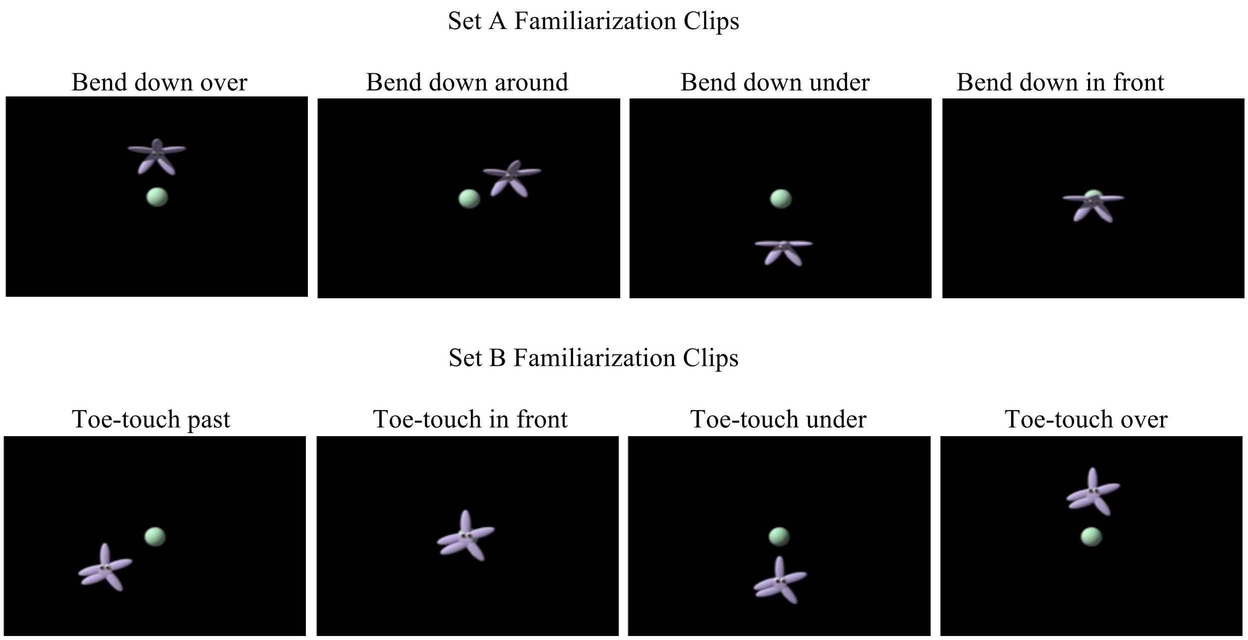


Figure 10. Familiarization clips from Study 2b. Each clip was shown for 12 seconds. Children were shown videos either from set A or set B.

Test 1. Same as Salience (see Figure 7).

Test 2. Same as Test 1.

Centering. Between each trial (Salience, Familiarizations 1-4, Tests 1-2), a child-directed animation accompanied by a sound renewed children's interest in the stimuli and reoriented their looking to the center of the screen. This was designed to help avoid the problem of looking to one side of the screen only.

Areas of Interest and Variables

Areas of Interest (AOIs). Areas of interest (AOIs) were created for each of the path/manner pairs in the split-screen video (Figure 11). Rather than being labeled *novel* and *familiar* as in the discrimination task, however, the categorization task of 2b required *in-category* and *out-of-category* designations. For example, children who saw the starfish bending down over, under, around, in front of the ball in the Familiarization trials should recognize that the common *manner* (e.g., bending down) was consistent across the four exemplars. In that case, the category *bending down* should be formed during Familiarization, so the Test event where the starfish traverses a path while *bending down* is the *in-category* event. Conversely, the path/manner pair showing the starfish performing a different manner than was seen during Familiarization was encompassed by the *out-of-category* AOI.

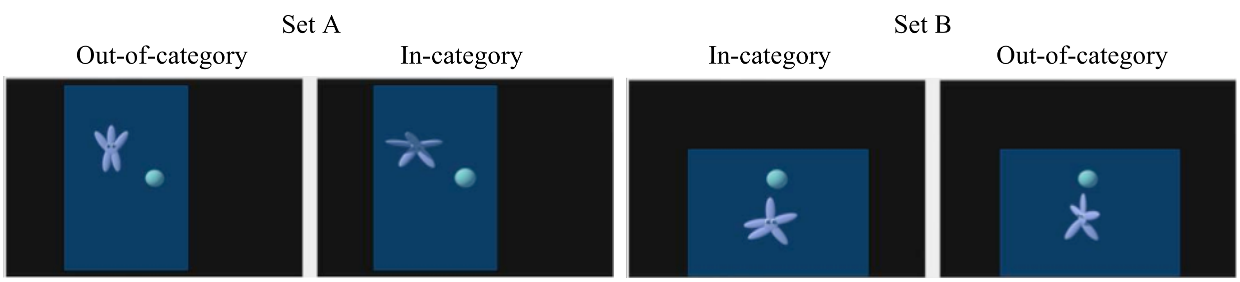


Figure 11. AOIs for the Salience and Test trials of Study 2b.

Variables. As in 2a, the primary independent variable of interest was group (ASD or MA). The sum of the duration of all fixations to each (Total Fixation Duration; TFD), the number of looks to each AOI (Fixation Count; FC), and the first AOI looked at (First Look; FL) were dependent variables of interest. Raw scores, proportions, and binomial forms of the data were analyzed. Significantly altering looking behaviors between Salience and the Test trials was considered evidence of categorization.

Results of Study 2b

Preliminary analyses. Four members of the MA group and 1 member of the ASD group were excluded due to insufficient looking during the Familiarization phase.

Total Fixation Duration (TFD). **Raw data** were explored using within-groups paired-samples t-tests. Results revealed that the ASD group trended toward less raw time spent looking at the in-category *manner* in T1 (p=.11) and T2 (p=.07) than in Salience, which suggests that they may have recognized the event as having the same *manner* seen during Familiarization. There was not a concurrent increase in looking to the out-of-category *manner*, and there were no differences in TFD when **proportions** or **binomial variables** were examined.

Total Fixation Count (FC). Independent samples t-tests on **raw fixation data** revealed a that the ASD group made significantly more fixations than MA on the in-category event during T2, $t(27) = -1.74$, $p = .04$. Paired-samples t-tests revealed that the MA group made fewer raw fixations on the in-category manner in T2 than in T1, $t(12) = 3.50$, $p = .004$. **Proportion of fixations** on the in- versus out-of-category events during Salience, T1 and T2 were not different within- or between-groups. Chi-square analyses on **binomial variables** trended toward confirming the raw fixation findings described above; the number of children in the MA group that increased their proportion of fixations on the out-of-category manner between T1 and T2 trended toward being greater than expected by chance (Chi-square = 3.000, $p = .08$).

First Look (FL). No differences were found between or within groups.

Discussion of Study 2b

Although neither group clearly categorized *manner* over various *paths,* only the group of children with ASD demonstrated any change in their looking patterns in comparison to Salience. Children with ASD spent less time looking at the in-category *manner* in T1 and T2 relative to Salience, but did not show a corresponding increase in looking times to the out-of-category *manner*. Although this may indicate that children formed a category of *manner* during Familiarization and were bored by category members at Test, it is less powerful proof of categorization than it would be if children had simultaneously increased their looking at the out-of-category exemplar.

In the *path* studies (1a and 1b), children demonstrated a clear “carry-over effect” from the discrimination to the categorization study. That is, in Study 1b, they preferred to continue looking at the Familiar *path* from Study 1a. This was not the case in the *manner* studies. Although the Familiar *manner* from 2a was the out-of-category event in 2b (and the Novel *manner* was the in-category event), children did not demonstrate an a priori preference for either event during Salience. This suggests that *manner* processing might be slightly more flexible than *path* processing in this population, perhaps because of a reduced processing load (e.g., only one object must be processed in *manner* events).

Children in the MA group did not show evidence of categorization, perhaps due to increased focus on processing the different *paths* seen during Familiarization (consistent with increased visual processing of *path* events found in Study 1a). This may have diverted their attention from the fact that the starfish traversed four different paths *by the same manner*. Typically developing infants are able to form a category of *manner* by 13 to 15 months of age, however (Pruden et al., 2005), so this is not taken as evidence that typical 5-year-olds are unable to form this category. Rather, features of the task itself in relation to the abilities of typical 5-year-olds might be the reason for their apparent failure to demonstrate categorization. Perhaps a testing paradigm requiring linguistic production would be more appropriate for typically developing children in this age group, as it is for adults in path/manner studies (Papafragou & Selimis, 2010).

General Discussion of Studies 1a, 1b, 2a, and 2b

The results of the current studies are not directly comparable to earlier research on discrimination and categorization in preverbal infants (Pruden et al., 2005; Pulverman et al., 2008), as children in the present study are approximately 4 years older and saw four sets of *path/manner* stimuli rather than just one (raising the possibility of carryover effects). Although typically developing children clearly *possess* the path/manner concepts studied here, their looking patterns do not replicate typical infant patterns. The following discussion is therefore speculative. Linguistically demanding measures of *path/manner* processing do exist for older children (Papafragou & Selimis, 2010), but one of the challenges of studying children with ASD is wide heterogeneity of ability in language and cognitive skill. This makes it difficult to find a task that fits the majority of children diagnosed with ASD *and* that is appropriate for a control group. Although the MA and ASD groups of the present study were comparable on measures of overall language ability, cooperation on a more linguistically demanding measure of path/manner processing (as in the verbal description task of Papafragou & Selimis, 2010) was not viable given the range of functioning in the present sample.

Looking across the first four studies, it is clear that between-group differences in performance are rare. *Within-group* differences emerged, however, which some might argue are more interpretable than between-group comparisons when studying children with ASD. Again, these findings are discussed with a note of caution, as the control sample did not replicate findings from prior studies.

The first notable pattern in the ASD group emerged in the discrimination tasks. Whereas children with ASD demonstrated that they could discriminate *manner* in 2a*,* they did not evidence *path* discrimination in 1a*.* Thus, failure to discriminate *path* in 1a was not due to a domain-general difficulty with discrimination *per se.* Nor was it due to a practice effect, since half of the participants saw the *manner* videos first and half saw the *path* videos first. The explanation for this finding may lie in the differential processing demands associated with *path* versus *manner* tasks. For example, in order to discriminate a *manner* of motion, children need only attend to the starfish and what the starfish is doing (the starfish's legs move *relative to* its torso) – it is not necessary to integrate the ball into a "big picture" of the scene. To discriminate *path*, on the other hand, children must recognize and process the dynamic spatial relationship between two objects in the scene – you must note the starfish's movement relative to an outside referent (the ball). For this reason, it may be that *manner* tasks are easier for children with ASD than *path* tasks. This finding contrasts with the well-researched developmental décalage seen in typically developing infants, wherein *path* discrimination and categorization is measurable at younger ages than *manner* discrimination and categorization (Pruden et al., 2005; Pulverman et al., 2008).

A second finding is that children in the ASD group generally showed more evidence of discriminating/categorizing in the *manner* tasks than the *path* tasks. Two possibilities to explain this finding are considered: First, as discussed above, reduced processing demands may make *manner* tasks more accessible to this population. Second, and more intriguingly, the children in this sample were all native speakers of English – a *manner* dominant language. Thus, it makes sense that children of this age would attend more to *manner* than to *path* (Maguire et al., 2010). Indeed, research suggests that as infants become more proficient in their native language, they gradually refine their attention to focus on those event components that are most often lexicalized (Pulverman et al., 2008; for a review, see Göksun et al., 2010). In this case, *manner* is the relevant event component. Unclear, however, is whether children with ASD attended preferentially to *manner* because their native language is English, or whether the increased attention to *manner* is a consequence of detail-focused perceptual processing style and would also be present in a *path*-heavy language like Spanish. Cross-linguistic research on populations with ASD is required to untangle this question.

The final pattern concerns perseverance in the ASD group. Although children with ASD did not demonstrate clear discrimination of *path* in the Test trials of 1a, an effect of Familiarization was evident in a carry-over preference for the familiar *path* from 1a that persisted through the categorization task of 1b. This carry-over effect was not evident in the *manner* tasks. Why might children perseverate on *path* but not *manner* events? One possible explanation draws again on the differential processing demands of each task. Perhaps it just took children with ASD longer to process the *path* in 1a because they had to integrate the starfish, the ball, and the relationship between them, rather than just the starfish as in the *manner* discrimination of 2a. When the same stimuli from 1a reappeared in 1b, children fixated on it. This would be consistent with the preference for sameness (or perseveration) noted in the literature (Boucher, 1977). An alternative explanation is that because children with ASD were more engaged with the *manner* stimuli than the *path* stimuli, they discriminated faster and thus “finished” discriminating during T1 and T2 of 2a, rather than carrying over into the Salience and Test trials of Study 2b.

As a whole, the findings from studies 1a, 1b, 2a, and 2b suggest that perceptual processing style may impact concept development from the very beginning, by affecting how children with ASD look at events. Early differences in attention allocation may impact concept formation, which might then have downstream effects on how children with ASD acquire relational vocabulary; e.g., they might not start with concepts from infancy as in typical development, but rather learn to use verbs/prepositions in context-specific ways through rote learning (Forbes & Farrar, 1993). One way for children to acquire these words in spite of perceptual processing differences is by using their knowledge of social intentions to connect words to world. This possibility is explored in Study 3.

CHAPTER 3
SOCIAL CUES TO WORD MEANING

Study 3: Accessing Social Intent in the Face of Atypical Toy Use

Whereas studies 1a, 1b, 2a, and 2b explored children's *conceptual* readiness to learn relational words like verbs and prepositions, Study 3 asks whether children possess an understanding of *social intention* – an important tool that helps children *map words to those concepts*. Children's ability to read an actor's unspoken intention was examined using a classic behavioral re-enactment task (Meltzoff, 1995) modified to measure children's ability to figure out what an actor *intends* to do, even when they fail to accomplish their goal (Parish-Morris et al., 2007). Based on prior research, it was expected that children with ASD would have more difficulty discerning the intentions of an experimenter performing an action with two toys than MA children, especially if the action that was performed was contrary to the child's own expectations about toy use.

Method

Participants. The children who participated in Studies 1a, 1b, 2a, and 2b also participated in Study 3.

Materials. Two sets of four recognizable objects were used (Appendix D). The *canonical* set consisted of several children's toys (a wooden pegboard with pegs, a wooden mallet, and a wooden post with a stackable ring). The *non-canonical* set also included familiar objects (a plastic toy train, plastic train tracks, a toy pot with a lid).

Procedure. Children were tested in a within-subjects design, with canonical or non-canonical object sets received in a block. Each child was tested on two different pairs of objects in the canonical set and with two different pairs of objects in the non-canonical set. The action performed by the experimenter either coincided with the affordances and typical usage of the toys and was therefore *canonical* (e.g., put the ring on the post) or *conflicted* with them and was therefore *non-canonical* (e.g., put the train in the pot; see Appendix D). Based on prior research (Parish-Morris et al., 2007), it was expected that most children with ASD would successfully re-enact the failed intention of the experimenter in the *canonical* condition only, and that MA children would re-enact the failed intention of an experimenter in both the *canonical* and *non-canonical* conditions.

Sitting on the floor facing the child, the experimenter placed one set of four toys on the floor in front of the child. While gesturing to the toys and trying to establish joint attention, the experimenter said, “Look at these toys. What can you do with them?” The child then explored the toys for approximately 30 seconds. The experimenter recorded the child’s actions with the toys during the free exploration phase. After 30 seconds, the experimenter made sure to attract the child’s attention, and then selected one pair of two objects and attempted to perform an action with them (object pairs were counterbalanced). She failed to complete the intended action three times in three different ways and verbally expressed her dismay each time (i.e., “Oh no!” “Uh-oh” “Oops!”). This modification to Meltzoff’s original procedure was designed to increase the likelihood that children would understand the unintentional nature of the experimenter’s actions during this phase. After the third attempt, the experimenter said, “Can you help me? Can you do it for me?” and pushed the toys toward the child. After the child performed an action with the pair of toys, the experimenter picked up the second pair of objects from the set and repeated the pattern. After performing an action with both pairs of objects in the first set, the experimenter removed the four objects and replaced them with four objects from the second set (train, track, pot, lid). The above sequence was repeated. Object pair orders (e.g., hammering first or stacking first) were counterbalanced between children, but all children saw the canonical set first (hammer and pegboard, ring and post; see Appendix D).

Coding. Coding was done online by the experimenter. The first action performed on each pair of objects was classified into one of three categories:

1) *Mimic* – child performed the exact action demonstrated by the experimenter (e.g., the child attempted to hammer the pegs but missed).
2) *Intent* – child completed the adult's action (e.g., hammered the pegs).
3) *Other* – child performed a specific action, but the action was neither the demonstrated action nor the intended action of the adult.
4) *Canonical* – child performed the canonical action in the non-canonical set (e.g., made the train go on the tracks even after seeing the train put into the pot).

Results

The number of times that children produced each kind of response within each set was the dependent variable of interest. A MANOVA revealed between-group differences in response type for the non-canonical condition only, as hypothesized. Planned one-tailed independent-samples t-tests revealed more "intent" responses by the MA group than the ASD group, $t(32) = 1.65$, $p = .055$, and more "mimic" responses by the ASD group than the MA group, $t(32) = -1.85$, $p = .035$ (Table 11). No other differences approached significance.

Table 11. Average number of responses (out of two) with standard deviation in parentheses. Only the Non-canonical set has a separate code for canonical actions, because the canonical response and the intent response are one and the same in the Canonical set.

Canonical	MA	ASD
Intent	1.94 (.24)	1.76 (.56)
Mimic	.06 (.24)	.18 (.53)
Other	.00 (.00)	.06 (.24)
Non-canonical	**MA**	**ASD**
Intent	1.76 (.56)	1.35 (.86)
Mimic	.00 (.00)	.18 (.39)
Other	.18 (.53)	.29 (.59)
Canonical	.06 (.24)	.18 (.53)

Discussion of Study 3

The current results replicate an earlier finding suggesting that children with ASD are able to complete a failed intention when their expectations about the toys are in line with the experimenter's intent, but have a harder time than MA children when the experimenter's intent violates the toys' canonical uses (Parish-Morris et al., 2007). This suggests that expectations about typical toy use held by some children with ASD are not easily overridden by social cues. As pointed out in the 2007 paper, this finding is not in conflict with prior studies showing that children with ASD are able to complete the failed intention of an experimenter using novel objects (Aldridge, Stone, Sweeney, & Bower, 2000; Carpenter, Pennington, & Rogers, 2001), because this research purposefully violates the canonical uses of well-known toys and is thus a more stringent test of intentional understanding (Huang, Heyes, & Charman, 2002).

Interestingly, the ASD group demonstrated higher rates of mimicking the experimenter than the MA group. Imitation is considered delayed in persons with ASD, although object-oriented imitation is generally less impaired (for reviews, see Rogers, Young, Cook, Giolzetti, & Ozonoff, 2008, and Williams, Whiten, & Singh, 2004). One possibility to explain the present elevation in imitation is that children may have interpreted the experimenter's actions in a way that made imitation a reasonable response. For example, it may be that children saw the non-canonical action performed by the experimenter and used their cognitive wherewithal to rationalize that there must be some *reason* for failing such a simple task three times in a row (e.g., maybe it was a game, or maybe it was so nonsensical that it was humorous). At that point, they may have mimicked to participate. However, this possibility is questionable because children heard language suggesting that the experimenter was not happy with the results of her actions (i.e., "Oops"). Imitation of the object-oriented action might be a reasonable response if children with ASD did *not* attend to the social cues of the experimenter. It must be noted that only three children with ASD mimicked in one of the two trials of the non-canonical set, and none of the MA children mimicked in any trials.

CHAPTER 4
CORRELATIONAL ANALYSES

Are children's conceptual and social skills as measured by the present studies predictive of their relational vocabulary size? Prior research has shown that typically developing children have both concepts and social understanding from an early age, which makes it difficult to tease apart the differential contributions of each to language outcome. However, the variability inherent in our present research population allows us to explore the relationships between conceptual readiness for language, intention understanding, and vocabulary size in Analysis 1. For children with ASD, a second set of analyses explores how performance on Study 3 relates to scores on the ADOS-G, PLS-4, and DAS-II.

Analysis 1: Correlations with the Test of Relational Concepts

Correlational analyses were conducted to examine how conceptual readiness and social understanding are associated with relational language outcome as measured by the TRC. Based on the theory that relational concepts are a necessary prerequisite to relational language, it was hypothesized that children demonstrating weaker relational concepts would have smaller relational vocabularies than those who showed evidence of discrimination and categorization. The second hypothesis was that children with better intention-reading skills would have larger relational vocabularies. This hypothesis was motivated by the prior finding that performance on the failed-intention task of Study 3 is highly correlated with overall vocabulary size in children with ASD (Parish-Morris et al., 2007). Although not directly tested in this study, it is further conjectured that intentional understanding will be more powerfully related to relational vocabulary size than to noun vocabulary. Relational referents (like actions) are inherently more ambiguous than less-relational referents (like objects), so relying on perceptual cues to word meaning might be insufficient for learning verbs and prepositions. When the referent of a word is hard to "pin down" using perceptual cues alone (as in the case of relational referents), the ability to follow a speaker's gaze or read other social cues gives children an idea what the speaker *means* to label; this can help children narrow the list of possible referents for a given word (Behrend & Scofield, 2006).

Method

Analyses. Correlational analyses comparing performance on Studies 1a, 2a, 2b, and 3 to TRC concept scores were conducted separately for each group. Study 1b was not included in the correlational analyses due to a significant a priori preference in the ASD group and no proportional evidence of categorization in the MA group.

Variables. Binomial variables from Studies 1a, 2a and 2b were scored if they were evidence of "success" on the particular task. The variable in Study 1a was whether or not children increased their proportion of fixation duration spent on the novel *path* in T2 as compared with Salience, regardless of whether the increase was significant (0 = increased looking to novel in T2 relative to Salience, 1 = decreased looking to novel in T2 relative to Salience). In Study 2a, the variable was whether or not children increased their proportion of looking duration to the Novel *manner* in T1 versus Salience. In Study 2b, the variable was whether or not children decreased their total raw fixation duration on the in-category (Familiar) *manner* between Salience and T2. The average number of "intent" responses given by each child in the non-canonical condition was the variable of interest from Study 3.

Results

Pearson's correlation analyses revealed significant within-group relationships between scores on the TRC and performance in Studies 1a and 3 (Table 12) but not 2a or 2b. There was a trending correlation between Study 1a and TRC scores in the MA group, $r(11) = -.54$, $p = .08$, which suggests that typically developing children who discriminated *path* also had higher scores on the TRC. Mean TRC score for MA children who discriminated *path* was 34.88 (N=8) while the mean TRC score for MA children who did not discriminate *path* was 22.00 (N=3). A significant correlation between scores in the non-canonical portion of Study 3 and the TRC, $r(14) = .63$, $p = .02$ was revealed in the ASD group, but not the MA group. Thus, children with ASD that had better intention-reading skills also had larger relational vocabularies.

Table 12. Correlations between the TRC and study performance by group.

	TRC	1a
<u>MA</u>		
1a (path discrimination)		
Pearson correlation	-.55	
Significance (2-tailed)	.08 *	
N	11	
3 (social intent)		
Pearson correlation	-.06	.31
Significance (2-tailed)	.82	.33
N	15	12
<u>ASD</u>		
1a (path discrimination)		
Pearson correlation	.02	
Significance (2-tailed)	.95	
N	12	
3 (social intent)		
Pearson correlation	.63	-.16
Significance (2-tailed)	.02 **	.59
N	14	14

Discussion of Correlations with the TRC

These results suggest that the ability to discriminate *path* correlates with relational vocabulary in the MA group, and that a better understanding of social intentions is associated with larger relational vocabularies in the ASD group but not the MA group (likely due to near-ceiling performance in the latter). Presumably, MA children of this age group already possess the conceptual foundations necessary for relational term learning, so perhaps a third variable like general attention is responsible for relationship between *path* discrimination and vocabulary size are in the MA group. Although total duration of looking during the familiarization trials of Study 1a did not differ by group, a general measure of attention was not included in the present series of studies so this possibility cannot be ruled out.

Looking patterns in the ASD group were not significantly predictive of relational vocabulary in the present series of studies, but performance on the non-canonical task of Study 3 was. Why might better performance on this measure of intentional understanding predict larger relational vocabularies in the ASD group? One possibility is that if children with ASD have aberrant patterns of visual perception that hinder relational conception, then varying levels of social intentional understanding might mean the difference between mapping or failing to map a relational word to its referent. In other words, this might be an issue of compensation: children who have a better understanding of the intentions of others might be able to "work around" perceptual abnormalities and find a way to learn relational words.

The present data show a promising link between social understanding and relational language in children with ASD, but do not shed light on the differential contribution of social understanding to nouns as compared to verbs and prepositions (see below for a discussion of social intentions as they relate to undifferentiated total language scores). Future research is needed to tease apart the specific contribution of intentional understanding to these different types of words.

Analysis 2: Correlations with the ADOS-G

The ADOS-G (Autism Diagnostic Observation Schedule – General) is the gold-standard diagnostic tool for determining where a child falls on the autism spectrum. It has a number of subsections, including scores that might shed light on the validity of the task used in Study 3 as a measure of social understanding. Although it was hypothesized that performance on Study 3 would correlate with the ADOS-G measure of reciprocal social interaction, the overall analysis is exploratory in nature and includes measures of non-verbal cognitive ability and total language in addition to the ADOS-G and Study 3.

Method

ADOS-G scores from 13 children with ASD were correlated with their Study 3 scores from the non-canonical task (a measure of social intentional understanding), TRC concept scores, DAS-II lower level raw scores, and PLS-4 total language age equivalent scores. Performance on the non-canonical set of Study 3 was selected for correlational analyses because it was found to be especially predictive of language in the correlations of Analysis 1 and in prior research with this population (Parish-Morris et al., 2007). The subscores used from the ADOS-G were reciprocal social interaction (RSI) and communication (note: higher scores on the ADOS indicate greater impairment). Scores for three children in the ASD group were not available because a physician outside of CAR provided the diagnosis, and the test for one child was missing.

Results

Pearson correlations revealed a number of significant relationships between variables (see Table 13). Interestingly, the measure of intentional understanding (non-canonical set of Study 3) correlated with both the reciprocal social interaction and communication portions of the ADOS-G, as well as with the TRC, but ADOS-G scores did not correlate significantly with the TRC. This suggests that Study 3 captures a social skill that is specific to language.

Upon noting the high correlation between children's scores on the DAS-II, the TRC and Study 3, a partial correlation was performed to determine whether the relationship between intentional understanding and relational language held after controlling for the effects of non-verbal cognitive skill. The correlation dropped from .63 to .45, $p = .12$.

Table 13. Correlations between the ADOS-G scores of children in the ASD group and Study 3, the TRC, the DAS-II, and the PLS-4. Reciprocal social interaction = RSI and communication = COM. Higher scores on the ADOS indicate greater impairment. Each correlation coefficient is accompanied by *p*-value in parentheses, with the number of subjects with data listed below.

	RSI	COM	Study 3	TRC	DAS-II
COM	.69 (.01)* N = 13				
Study 3	-.62 (.02)* N = 13	-.87 (.00)* N = 13			
TRC	-.12 (ns) N = 10	-.44 (ns) N = 10	.63 (.02)* N = 14		
DAS-II	-.04 (ns) N = 13	-.24 (ns) N = 13	.53 (.03)* N = 17	.84 (.00)* N = 14	
PLS-4	-.26 (ns) N = 13	-.38 (ns) N = 13	.63 (.01)* N = 17	.95 (.00)* N = 14	.88 (00)* N = 17

Discussion of Correlations with the ADOS-G

Children's scores on the reciprocal social interaction or communication portions of the ADOS-G were not correlated with their performance on any of the three standardized language/cognitive tests administered in this study (TRC, DAS-II, PLS-4). They were, however, correlated with performance on the non-canonical set of Study 3. Negative correlations between the ADOS-G scores and Study 3 mean that as children's difficulty with reciprocal social interaction and communication increases, their ability to infer the social intentions of another person decreases. Correlations with these portions of the ADOS-G validates that Study 3 is indeed measuring a social phenomenon. However, performance on Study 3 also correlates with children's TRC scores, which suggests a special relationship to language. This finding has potentially important clinical implications – if children can be taught to infer the unspoken intentions of others, their ability to learn relational words might be simultaneously improved.

Gathering multiple measures from a single child, as attempted here, has the potential to paint a multi-dimensional and nuanced picture of individual differences in visual processing and social intentional understanding. The behavioral challenges of many children in the present study, however, made it extremely difficult to obtain "complete" data for any one child, and thus limited the individual differences analyses that could reasonably conducted with such a small sample size. The heterogeneity of the population with ASD is both the reason why extensive individual testing is important, and also why it is so uniquely challenging.

CHAPTER 5
DISCUSSION AND CONCLUSION

General Discussion

Children with ASD are characterized in part by impaired social communication and language skills (DSM-IV-TR, 2000), and have special difficulty mastering relational words like verbs and prepositions (Lopez & Lord, 2009; Parish-Morris et al., 2009). Why? The present series of five studies explored whether the foundational concepts underlying relational language were intact in this population, and whether one tool for mapping – social intentional understanding – was related to relational language ability. Two primary findings emerged from the present dissertation: children with ASD process *manners* more reliably than *paths*, and intentional understanding as measured by a modified behavioral reenactment task predicts relational vocabulary size in this population.

Finding 1:Children with ASD process manners better than paths

A visual processing style that emphasizes the details or features of a scene rather then the configuration of elements therein might theoretically lend itself to processing *manners* better than *paths*. *Manner* is an intrinsic relation (the starfish's appendages move relative to its own center) and *path* is extrinsic (the starfish moves relative to an outside reference point). Thus, *manner* has fewer processing requirements – attention need not be switched between multiple objects in a scene. In the *path* videos of the present studies, attention must be switched between the starfish and the ball in order to process the relationship between them. Children in the MA group appeared to process this extrinsic relationship, as demonstrated by significantly more fixations during the

Familiarization phase of the *path* discrimination study, but not more overall time spent looking. This pattern of rapid scanning during the Familiarization phase was present only in the MA group, and only the MA group succeeded in discriminating between two *paths*.

Children with ASD, on the other hand, performed exactly as might be predicted by the “detail-oriented” processing style account (Mottron et al., 2006) in both the *path* and *manner* studies. In other words, over-allocating their attention to visual detail (e.g., the starfish) may have resulted in a relative failure to attend to the “big picture” of the scene (e.g., the relationship between the starfish and the ball; Happé & Frith, 2006). In the *manner* studies (2a and 2b), this visual processing style was not deleterious, since discriminating and categorizing *manner* does not require children to switch attention between multiple objects – they could succeed by attending to the starfish alone. Successful performance in the *path* studies (1a and 1b), in contrast, required children to process the dynamic relationship between two objects on the screen, and they did not appear to succeed on these tasks.

The present findings suggest that patterns of visual processing common to children with ASD may affect relational concept development at the most basic level, especially when those relations are extrinsically defined (e.g., *path*). Are children with ASD impaired at processing extrinsic relations generally, or is the difficulty experienced here due to the *dynamic* nature of these relations? Future research should explore whether children experienced difficulty on these *path* tasks due to a global impairment in processing extrinsic relations, or whether *dynamic* extrinsic relations are particularly problematic because of motion processing issues. Static stimuli, such as the simple dot patterns used by Quinn and colleagues to study early discrimination and categorization of static extrinsic relations like "above" and "below," is a potential way to answer this question (Quinn, 1994).

Finding 2: Intentional understanding predicts relational language in children with ASD

For the language of children with ASD, understanding social intentions is key. In fact, correlational analyses revealed that the ability to read social intentions was more strongly associated with relational vocabulary size in children with ASD than measures of conceptual readiness. This result was not expected, as it was initially hypothesized that conceptual readiness was an essential first step on the path to relational vocabulary, and that issues of mapping were secondary and only mattered if concepts were firmly in place. Perhaps social issues are so very pervasive in this population that they trump other potential contributors to language development. The present data does not prove that children with ASD lack the foundational concepts necessary for relational word acquisition, but it does suggest that perhaps this population is able to compensate for perceptual problems if they have a better understanding of the intentions of others in word learning situations.

Implications for Theory: Concepts, Mapping, and the ECM

The original question sparking this research was why children have a harder time learning relational words like verbs and prepositions than less relational words like most nouns. Are relational words hard to learn because children have difficulty forming the concepts underlying those words, or because they lack the social skills to help them map words to relational referents? The results of the present studies seem to suggest that for 3- to 6-year-old children with ASD, social intentional understanding has the biggest influence on relational vocabulary size. This finding is preliminary, because the data do not permit clear conclusions about the presence of relational concepts in children with ASD. However, this finding is in line with the arguments made by proponents of social-pragmatic theories of language development.

Even though children with ASD appear to have perceptual processing patterns that are not conducive to relational concept formation, some nonetheless learn relational words. How? According to the ECM, children initially rely on perceptual salience as a cue to word meaning. In situations where perceptual salience is not a sufficient cue to word meaning (as in the case of many relational referents), social cues to a speaker's intentions provide crucial information about word meaning (Behrend & Scofield, 2006). It appears that children with ASD have challenges on both fronts – perceptual and social – but that even the slightest social intention-reading advantage may translate into a significantly larger relational vocabulary.

Implications for Intervention

Although many interventions for children with ASD already concentrate on teaching joint attention and other social skills, teaching children how to infer the hidden intentions of a speaker in a word-learning situation might have positive downstream effects on relational language development. For children on the cusp of verb learning, this type of targeted intervention could lead to faster vocabulary growth than children receiving general social skills training. A randomized controlled intervention study wherein children are taught to read social cues and infer a speaker's hidden intention is necessary to draw firm conclusions about the relationship between this particular aspect of social understanding and language, but the present findings are promising.

Limitations

The conclusions that can be drawn based on the research presented in this dissertation are narrow for a number of reasons. First, our sample size of 17 children per group is small. It is possible that many of the trends reported in this dissertation might become significant if more than 17 subjects had been obtained. Furthermore, although the discrimination studies of the present dissertation yielded interesting results, the results of Studies 1b and 2b (categorization) were disappointingly unclear for both the MA and ASD groups. This lack of clarity may be due in part to methodological issues. First, children were required to sit through nearly an hour of videos, because the present studies were part of a larger set of videos shown to the participants. Second, all four videos that comprised Studies 1 and 2 were seen by all children, which means that counterbalancing forced children to *override* earlier novelty preferences from the discrimination videos to demonstrate evidence of category formation in the categorization videos. Third, the children in Studies 1 and 2 were much older than the infants that typically see these stimuli, and many of the older children did not tolerate the repetition well, requiring significant verbal encouragement from the experimenter to continue with the study. Finally, convincing preschoolers (ASD or typical) to sit and watch repetitive videos for nearly 45 minutes was a very difficult task and impacted the quantity and quality of gaze data that was collected. Future research would benefit from a shorter protocol. A modified (but still non-verbal) method for exploring conceptual readiness in older children would improve our chances of obtaining clear results.

Conclusion

The present studies were designed to explore the reason behind the relational language lag that exists in typical children and, to a greater extent, children with ASD. What are the differential contributions of conceptual readiness and social skills to relational language outcome in these two populations? The unique perceptual patterns and social variability of children with ASD provided a valuable opportunity to explore how processing conceptual foundations like *path* and *manner* and understanding social intentions relates to vocabulary size. Although firm conclusions cannot be drawn based solely on the findings reported here, these five studies nonetheless represent a first foray into exploring the intersection of conceptual readiness and social understanding in children with ASD. Importantly, the findings reported here draw attention to the powerful impact that intention-reading abilities may have on relational word learning, and suggests that interventions targeting this aspect of social understanding may improve children's ability to learn relational words like verbs and prepositions.

REFERENCES CITED

Aguiar, A. & Baillargeon, R. (1998). Eight-and-a-half-month-old infants' reasoning about containment events. *Child Development, 69*(3), 636-654.

Aldridge, M.A., Stone, K.R., Sweeney, M.H., & Bower, T.G.R. (2000). Preverbal children with autism understand the intentions of others. Developmental Science, 3, 294-301.

Akhtar, N., Carpenter, M., & Tomasello, M. (1996). The role of discourse novelty in early word learning. *Child Development, 67,* 635-645.

American Psychiatric Association. (2000). Diagnostic and statistical manual of mental disorders (Revised 4th ed.). Washington, DC: Author.

Baldwin, D.A. (1993). Infants' ability to consult the speaker for clues to word reference. *Journal of Child Language, 20*(2), 395-418.

Bar-Haim, Y., Shulman, C., Lamy, D., & Reuveni, A. (2006). Attention to eyes and mouth in high-functioning children with autism. *Journal of Autism and Developmental Disorders*, *36*, 131-137.

Baron-Cohen, S. (1995). Mindblindness: An Essay on Autism and Theory of Mind. Cambridge, MA: MIT Press.

Bebko, J.M., McMorris, C.A., Wells, K., Schroeder, J.H., & Holden, J.J.A. (2008, May). ‘Sticky’ attention: Children with autism's ability to disengage their attention without an external cue. Paper presented at the International Meeting for Autism Research, London, England.

Bebko, J.M., Weiss, J.A., Demark, J.L., & Gomez, P. (2006). Discrimination of temporal synchrony in intermodal events by children with autism and children with developmental disabilities without autism. *Journal of Child Psychology & Psychiatry, 47*(1), 88-98.

Behrend, D., & Scofield, J. (2006). Verbs, Actions, and Intentions. In K. Hirsh-Pasek & R.M. Golinkoff, (Eds.), *Action Meets Word* (pp. 286-307). New York: Oxford University Press.

Behrend, D.A. & Wittek, A. (2003, April). Toddlers use verbs as cues to an actor’s intentions. Paper presented at the meetings of the Society for Research in Child Development, Tampa, FL.

Behrmann, M., Thomas, C., & Humphreys, K. (2006). Seeing it differently: visual processing in autism. *Trends in Cognitive Sciences, 10*(6), 258-264.

Bertone, A. & Faubert, J. (2006). Demonstrations of Decreased Sensitivity to Complex Motion Information Not Enough to Propose an Autism-Specific Neural Etiology. *Journal of Autism and Developmental Disorders, 36*(1), 55-64.

Bertone, A., Mottron, L., Jelenic, P., & Faubert, J. (2003). Motion Perception in Autism: A "Complex" Issue. *Journal of Cognitive Neuroscience, 15*(2), 218-225.

Bertone, A., Mottron, L., Jelenic, P., & Faubert, J. (2005). Enhanced and diminished visuo-spatial information processing in autism depends on stimulus complexity. *Brain: A Journal of Neurology, 128*(10), 2430-2441.

Bhat, A., Galloway, J. and Landa, R. (2010), Social and non-social visual attention patterns and associative learning in infants at risk for autism. *Journal of Child Psychology and Psychiatry, 51,* 989-997.

Blake, R., Turner, L.M., Smoski, M.J., Pozdol, S.L., & Stone, W.L. (2003). Visual recognition of biological motion is impaired in children with autism. *Psychological Science, 14*(2), 151-157.

Bornstein, M.H., Cote, L.R., Maital, S., Painter, K., Sung-Yun, P., Pascual, L., Pêcheux, M., Ruel, J., Venuti, P., & Vyt, A. (2004). Cross-Linguistic Analysis of Vocabulary in Young Children: Spanish, Dutch, French, Hebrew, Italian, Korean, and American English. *Child Development, 75*(4), 1115-1139.

Bott, L., Brock, J., Brockdorff, N., Boucher, J., & Lamberts, K. (2006). Perceptual similarity in autism. *Quarterly Journal of Experimental Psychology*, 59, 1237-1254.

Boucher, J. (1977). Alternation and sequencing behaviour, and response to novelty in autistic children. *Journal of Child Psychology and Psychiatry, 18,* 67-72.

Brandone, A., Pence, K. L., Golinkoff, R. M., & Hirsh-Pasek, K. (2007). Action speaks louder than words: Young children differentially weight perceptual, social, and linguistic cues to learn verbs. *Child Development, 78,* 1322-1342.

Bunger, A., & Lidz, J. (2004). Syntactic bootstrapping and the internal structure of causative events. In *Proceedings of the 28th annual boston university conference on language development.* Boston, MA: Cascadilla Press.

Burack, J.A. (1994). Selective attention deficits in persons with autism: Preliminary evidence of an inefficient attentional lens. *Journal of Abnormal Psychology, 103,* 535-543.

Caron, M.J., Mottron, L., Berthiaume, C., & Dawson, M. (2006). Cognitive mechanisms, specificity and neural underpinnings of visuospatial peaks in autism. *Brain: A Journal of Neurology, 129*(7), 1789-1802.

Caron, M.J., Mottron, L., Rainville, C., & Chouinard, D. (2004). Do high functioning persons with autism present superior spatial abilities? *Neuropsychologia, 42,* 467-481.

Carpenter, M., Pennington, B. F., & Rogers, S. J. (2001). Understanding of others' intentions in children with autism. *Journal of Autism and Developmental Disorders, 31,* 589-599.

Casasola, M. (2005). When Less Is More: How Infants Learn to Form an Abstract Categorical Representation of Support. *Child Development, 76*(1), 279-290.

Casasola, M. (2008). The development of infants' spatial categories. *Current Directions in Psychological Science, 17,* 21-25.

Casasola, M., & Cohen, L.B. (2002). Infant categorization of containment, support and tight-fit spatial relationships. *Developmental Science, 5*(2), 247-265.

Casasola, M., Cohen, L.B., & Chiarello, E. (2003). Six-Month-Old Infants' Categorization of Containment Spatial Relations. *Child Development, 74*(3), 679-693.

Casasola, M., Hohenstein, J., & Naigles, L. R. (2003, April). Ten-month-old infants' discrimination of manner and path in motion events. Paper presented at the biennial meeting of the Society for Research in Child Development, Tampa, FL.

Casasola, M., Bhagwat, J. & Doan, S. (2009, April). Does infant spatial play mirror infant categorization of containment and support? Talk given at the Spatial language and cognition: Cross-linguistic and developmental perspectives symposium at the biennial meeting of the Society for Research in Child Development, Denver, CO.

Chen, F., Lemonnier, E., Lazartigues, A., & Planche, P. (2008). Non-superior disembedding performance in children with high-functioning autism and its cognitive style account. *Research in Autism Spectrum Disorders, 2*(4), 739-752.

Choi, S. (2006a). Influence of language-specific input on spatial cognition: Categories of containment. *First Language, 26*(2), 207-232.

Choi, S. (2006b). Preverbal spatial cognition and language-specific input: Categories of containment and support. In R. Golinkoff & K. Hirsh-Pasek (eds.), *Action meets word: How children learn verbs* (pp. 191-207). Oxford University Press.

Choi, S., & Bowerman, M. (1991). Learning to express motion events in English and Korean: The influence of language-specific lexicalization patterns. *Cognition, 41*, 83-121.

Choi, S., McDonough, L., Bowerman, M., & Mandler, J.M. (1999). Early sensitivity to language-specific spatial categories in English and Korean. *Cognitive Development, 14*, 241-268.

Croen, L.A., Grether, J.K., Hoogstrate, J., & Selvin, S. (2002). The changing prevalence of autism in California. *Journal of Autism and Develomental Disorders, 32,* 207-215.

Dale, P.S., & Fenson, L. (1996). Lexical development norms for young children. *Behavior Research Methods, Instruments, & Computers, 28,* 125-127.

de Jonge, M.V., Kemner, C., de Haan, E.H., Coppens, J.E., van den Bergde, T.J.T.P., & van Engeland, H. (2007). Visual Information Processing in High-Functioning Individuals With Autism Spectrum Disorders and Their Parents. *Neuropsychology, 21*(1), 65-73.

Deruelle, C., Rondan, C., Gepner, B., & Fagot, J. (2006). Processing of compound visual stimuli by children with autism and Asperger syndrome. *International Journal of Psychology, 41*(2), 97-106.

Dunham, P. J., Dunham, F., & Curwin, A. (1993). Joint attentional states and lexical acquisition at 18 months. *Developmental Psychology, 29,* 827-831.

Echols, C. H., & Marti, C. N. (2004). The identification of words and their meanings: From perceptual biases to language-specific cues. In D.G. Hall & S.R. Waxman (Eds.), *Weaving a Lexicon*. Cambridge, MA: MIT Press.

Edgin, J. O., & Pennington, B. F. (2005). Spatial cognition in autism spectrum disorders: Superior, impaired, or just intact? *Journal of Autism and Developmental Disorders, 35,* 729-745.

Edmonston, N.K., & Litchfield Thane, N. (1988). TRC: Test of Relational Concepts. Austin, TX: Pro-Ed.

Elliott, C.D. (1990). The nature and structure of children's abilities: Evidence from the Differential Abilities Scales. *Journal of Psychoeducational Assessment, 8,* 376-390.

Falter, C.M., Plaisted, K.C., & Davis, G. (2008). Visuo-spatial Processing in Autism - Testing the Predictions of Extreme Male Brain Theory. *Journal of Autism & Developmental Disorders, 38*(3), 507-515.

Fenson, L., Dale, P., Reznick, S., Bates, E., Thal, D., & Pethick, S. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development, 59* (Serial No. 242).

Fisher, C. (1996). Structural limits on verb mapping: The role of analogy in children's interpretations of sentences. *Cognitive Psychology, 31,* 41-81.

Fisher, C., Hall, D.G., Rakowitz, S., & Gleitman, L.R. (1994). When it is better to receive than to give: Syntactic and conceptual constraints on vocabulary growth*. Lingua, 92,* 333-375.

Fisher, C., Klingler, S.L., & Song, H. (2006). What does syntax say about space? 2-year-olds use sentence structure to learn new prepositions. *Cognition, 101*(1), B19-B29.

Fisher, C., & Song, H. (2006). Who's the Subject? Sentence Structure and Verb Meaning. In: *Action meets word: How children learn verbs.* Hirsh-Pasek, Kathy (Ed.); Golinkoff, Roberta Michnick (Ed.); New York, NY, US: Oxford University Press, pp. 392-425.

Fluharty, N.B. (2000). *Fluharty Preschool Speech and Language Screening Test-Second Edition.* PRO-ED, Austin, TX.

Forbes, J.N., & Farrar, J.M. (1993). Children's initial assumptions about the meaning of novel motion verbs: biased and conservative? *Cognitive Development, 8,* 273-290.

Forbes, J.N., Poulin-Dubois, D. (1997). Representational Change in Young Children's Understanding of Familiar Verb Meaning. *Journal of Child Language, 24(2),* 389-406.

Freitag, C.M., Konrad, C., Häberlen, M., Kleser, C., von Gontard, A., Reith, W., Troje, N.F., & Krick, C. (2008). Perception of biological motion in autism spectrum disorders. *Neuropsychologia, 46*(5), 1480-1494.

Frith, U. (1989). *Autism: explaining the Enigma.* Blackwell.

Froehlich, A.L. (2008). Categorization in Autism. Dissertation, University of Utah.

Gastgeb, H., Strauss, M., & Minshew, N.J. (2006). Do individuals with autism process categories differently? The effect of typicality and development. *Child Development, 77,* 1717-1729.

Gentner, D. (1982). Why nouns are learned before verbs: Linguistic relativity versus natural partitioning. In S.A. Kuczaj, II (Ed.), *Language development Vol. 2: Language, thought, and culture* (pp. 301-334). Hillside, NJ: Lawrence Erlbaum Associates.

Gentner, D. (2003). Why we're so smart. In D. Gentner and S. Goldin-Meadow (Eds.), *Language in mind: Advances in the study of language and thought* (pp.195-235). Cambridge, MA: MIT Press.

Gentner, D., & Boroditsky, L. (2001). Individuation, relativity, and early word learning. In M. Bowerman & S.C. Levinson (Eds.), *Language acquisition and conceptual development* (pp. 215-256). New York, NY: Cambridge University Press.

Gepner, B. & Féron, F. (2009). Autism: A world changing too fast for a mis-wired brain? *Neuroscience and Biobehavioral Reviews, 33,* 1227-1242.

Gepner, B. & Mestre, D. (2002). Rapid visual-motion integration deficit in autism. *Trends in Cognitive Sciences, 6*(11), 455.

Gertner, Y., Fisher, C. & Eisengart, J. (2006). Learning words and rules : Abstract knowledge of word order in early sentence comprehension. *Psychological Science, 17*(8), 684-91.

Ghaziuddin, M. & Mountain-Kimchi, K. (2004). Defining the Intellectual Profile of Asperger Syndrome: Comparison with High-Functioning Autism. *Journal of Autism and Developmental Disorders, 34*(3), 279-284.

Gillette, J., Gleitman, H., Gleitman, L., & Lederer, A. (1999). Human simulations of vocabulary learning. *Cognition, 73,* 135-176.

Gleitman, L. (1990). Structural sources of verb meaning. *Language Acquisition, 1,* 3-55.

Gleitman, L.R. & Gleitman, H. (1992). A Picture Is Worth a Thousand Words, but That's the Problem: The Role of Syntax in Vocabulary Acquisition. *Current Directions in Psychological Science, 1*(1), 31-35.

Göksun, T., Hirsh-Pasek, K., & Golinkoff, R.M. (2009). Processing figures and grounds in dynamic and static events. In J. Chandlee, M. Franchini, S. Lord, & G. Rheiner (Eds.), Proceedings of the 33rd Annual Boston University Conference on Language Development, 199-210. Somerville, MA: Cascadilla Press.

Göksun, T., Hirsh-Pasek, K, & Golinkoff, R.M. (2010). Trading Spaces: Carving up events for learning language. *Perspectives on Psychological Science, 5,* 33-42.

Göksun, T., Küntay, A.C., & Naigles, L.R. (2008). Turkish children use morphosyntactic bootstrapping in interpreting verb meaning. *Journal of Child Language, 35,* pp. 291-323.

Golinkoff, R.M., Hirsh-Pasek, K., Bailey, L.M., & Wenger, N.R. (1992). Young children and adults use lexical principles to learn new nouns. *Developmental Psychology, 28*(1), 99-108.

Golinkoff, R.M., Jacquet, R.C., Hirsh-Pasek, K., & Nandakumar, R. (1996). Lexical Principles May Underlie the Learning of Verbs. *Child Development, 67*(6), 3101-3119.

Golinkoff, R., Mervis, C. & Hirsh-Pasek, K. (1994). Early object labels: The case for a developmental lexical principles framework. *Journal of Child Language*: *20th Anniversary Issue, 21*(1), 125-156.

Gordon, B. & Elliott, D. (2001). Assessment with the Differential Ability Scales. In J. Andrews, D.H. Saklofske, & H.L. Janzen (Eds.), *Handbook of Psychoeducational Assessment: Ability, Achievement, and Behavior in Children* (pp 65-101). San Diego, CA: Academic Press, Inc.

Halberda, J. (2003). The development of a word-learning strategy. *Cognition, 87*, B23-B34.

Happé, F. (1999). Autism: Cognitive deficit or cognitive style? *Trends in Cognitive Sciences, 3*(6), 216-222.

Happé, F., & Frith, U. (2006). The Weak Coherence Account: Detail-focused Cognitive Style in Autism Spectrum Disorders. *Journal of Autism & Developmental Disorders, 36*(1), 5-25.

Hespos, S.J., & Baillargeon, R. (2006). Décalage in infants' knowledge about occlusion and containment events: Converging evidence from action tasks. *Cognition, 99*(2), B31-B41.

Hespos, S.J., & Baillargeon, R. (2008). Young infants' actions reveal their developing knowledge of support variables: Converging evidence for violation-of-expectation findings. *Cognition, 107,* 304-316.

Hespos, S.J., & Spelke, E.S. (2004). Conceptual precursors to language. *Nature, 430,* 453-456.

Hirsh-Pasek, K., & Golinkoff, R.M. (1996). *The origins of grammar: Evidence from early language comprehension*. Cambridge, MA: MIT Press.

Hoff, E. & Naigles, L. (2002). How children use input to acquire a lexicon. *Child Development, 73,*(2), 418-433.

Hollich, G.J., Hirsh-Pasek, K., Golinkoff, R.M. (2000). Breaking the language barrier: An emergentist coalition model for the origins of word learning. *Monographs of the Society for Research in Child Development, 65*(3), v-123.

Huang, C.T., Heyes, C., & Charman, T. (2002). Infants' behavioral re-enactment of "failed attempts": Exploring the roles of emulation learning, stimulus enhancement, and understanding of intentions. *Developmental Psychology, 38,* 840-855.

Iarocci, G., Burack, J.A., Shore, D.I., Mottron, L., & Enns, JT. (2006). Global-Local Visual Processing in High Functioning Children with Autism: Structural vs. Implicit Task Biases. *Journal of Autism & Developmental Disorders, 36*(1), 117-129.

Imai, M., Li, L., Haryu, E., Okada, H., Hirsh-Pasek, K., Golinkoff, R., et al. (2008). Novel noun and verb learning in Chinese-, English-, and Japanese-speaking children. *Child Development, 79,* 979-1000.

Imai, M., Okada, H., & Haryu, E. (2005). Mapping novel nouns and verbs onto dynamic action events: Are verb meanings easier to learn than noun meanings for Japanese children? *Child Development, 76,* 340-355.

Ishikawa, Y. & Uda, M. (1996). The use of everyday situations to teach 2-word sentences: Parent participation in the training. *Japanese Journal of Special Education, 33(5),* 65-71.

Jackendoff, R.S. (1983). *Semantics and cognition.* Cambridge, MA: MIT Press.

Johnson, C., & Rakison, D.H. (2006). Early categorization of animate/inanimate concepts in young children with autism. *Journal of Developmental and Physical Disabilities, 18*, 73-89.

Joliffe, T., & Baron-Cohen, S. (1997). Are people with autism and Asperger syndrome faster on the embedded figures test? *Journal of Child Psychology and Psychiatry, 38,* 527-534.

Jolly, H.R., & Plunkett, K. (2008). Inflectional Bootstrapping in 2-year-olds. *Language and Speech, 51*(1&2), 45-59.

Joseph, R.M., Keehn, B., Connolly C., Wolfe, J.M., & Horowitz, T.S. (2009). Why is visual search superior in autism spectrum disorder? *Developmental Science, 12*(6), 1083-96.

Kasari, C., Freeman, S., & Paparella, T. (2001). Joint attention and symbolic play in young children with autism: a randomized controlled intervention study. *Journal of Child Psychology and Psychiatry, 47*(6), 611-620.

Kemner, C., van Ewijk, L., van Engeland, H., & Hooge, I. (2008). Brief report: eye movements during visual search tasks indicate enhanced stimulus discriminability in subjects with PDD. *Journal of Autism and Developmental Disorders, 38*(3), 553-557.

Kelley, E., Paul, J.J., Fein, D., & Naigles, L.R. (2006). Residual Language Deficits in Optimal Outcome Children with a History of Autism. *Journal of Autism & Developmental Disorders, 36*(6), 807-828.

Klin, A, & Jones, W. (2008). Altered face scanning and impaired recognition of biological motion in a 15-month-old infant with autism. *Developmental Science, 11*(1), 40-46.

Klin, A., Lin, D.J., Gorrindo, P., Ramsay, G., & Jones, W. (2009). Two-year-olds with autism orient to non-social contingencies rather than biological motion. *Nature, 459*(7244), 257-261.

Klinger, L., & Dawson, G. (2001). Prototype formation in children with autism and Down syndrome. *Development and Psychopathology, 13*, 111-124.

Koldewyn, K., Whitney, D., & Rivera, S.M. (2010). The psychophysics of visual motion and global form processing in autism. *Brain: A Journal of Neurology, 133*(2), 599-610.

Kuhn, G., Kourkoulou, A., & Leekam, S.R. (2010). How Magic Changes Our Expectations About Autism. *Psychological Science, 21,* 1487-1493.

Lakusta, L., & Carey, S. (2008, March). Infants' categorization of sources and goals in motion events. Paper presented in S. Pruden, & T. Göksun (Chairs), Conceptual primitives for processing events and learning relational terms. Symposium at the 16th International Conference on Infant Studies, Vancouver, Canada.

Lakusta, L., & Landau, B. (2005). Starting at the end: The importance of goals in spatial language. *Cognition, 96,* 1-33.

Lakusta, L., Wagner, L., O'Hearn, K., & Landau, B. (2007). Conceptual foundations of spatial language: evidence for a goal bias in infants. *Language Learning and Development, 3,* 179-197.

Landau, B., & Gleitman, L.R. (1985). *Language and experience: Evidence from the blind child*. Cambridge, MA: Harvard University Press.

Landry R., & Bryson, S. 2004. Impaired disengagement of attention in young children with autism. *Journal of Child Psychology and Psychiatry, 45*(6), 1115-1122.

Lee, J.N. & Naigles, L.R. (2008). Mandarin learners use syntactic bootstrapping in verb acquisition. *Cognition, 106*(2), 1028-1037.

Leekam, S.R. & Ramsden, C.A.H (2006). Dyadic Orienting and Joint Attention in Preschool Children with Autism. *Journal of Autism & Developmental Disorders, 36*(2), 185-197.

Lidz, J., Gleitman, H., & Gleitman, L. (2003). Understanding how input matters: Verb learning and the footprint of universal grammar. *Cognition, 87*(3), 151-178.

Lopez, K. & Lord, C. (2009, May). Language Development among Children with Autism Spectrum Disorders. Poster presented at the International Meeting for Autism Research, Chicago, IL.

Lord, C., Risi, S., & Pickles, A. (2004). Trajectory of Language Development in Autistic Spectrum Disorders. In Rice, ML. & Warren, S.F. (Eds.) *Developmental language disorders: From phenotypes to etiologies.* Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers, pp. 7-29.

Lord, C., Rutter, M., DiLavore, P.C., & Risi, S. (2002). *Autism Diagnostic Observation Schedule*. Los Angeles, CA: Western Psychological Services.

Ma, W., Golinkoff, R.M., Hirsh-Pasek, K., McDonough, C., & Tardif, T. (2009). Imageability predicts the age of acquisition of verbs in Chinese children. *Journal of Child Language, 36,* 405-423.

Maguire, M.J., Hirsh-Pasek, K., & Golinkoff, R. (2006). A unified theory of word learning: Putting verb acquisition in context. In K. Hirsh-Pasek & R.M. Golinkoff (Eds.), *Action meets word: How children learn verbs*. New York: Oxford University Press.

Maguire, M.J., Hirsh-Pasek, K., Golinkoff, R.M., Imai, M., Haryu, E., Vanegas, S., Okada, H., Pulverman, R., & Sanchez-Davis, B. (2010). A developmental shift from similar to language-specific strategies in verb acquisition: A comparison of English, Spanish, and Japanese. *Cognition, 114,* 299-319.

Mandler, J.M. (1992). How to build a baby: II. Conceptual primitives. *Psychological Review, 99,* 587-604.

Mandler, J.M. (2004). The foundations of mind: Origins of conceptual thought. New York: Oxford University Press.

Mandler, J.M. (2006). Actions Organize the Infant's World. In K. Hirsh-Pasek & R.M. Golinkoff, (Eds.), *Action Meets Word* (pp. 111-133). New York: Oxford University Press.

Markman, E.M., Wasow, J.L., & Hansen, M.B. (2003). Use of the mutual exclusivity assumption by young word learners. *Cognitive Psychology, 47*, 241-275.

McDonough, L., Choi, S., & Mandler, J.M. (2003). Understanding spatial relations: Flexible infants, lexical adults. Cognitive Psychology, 46(3), 229-260.

Meltzoff, A.N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 19-month-old children. *Developmental Psychology, 31,* 838-850.

Mervis, C.B. & John, A.E. (2008). Vocabulary Abilities of Children With Williams Syndrome: Strengths, Weaknesses, and Relation to Visuospatial Construction Ability. Journal of Speech, Language & Hearing Research, 51(4), 967-982.

Milne, E., Scope, A., Pascalis, O., Buckley, D., & Makeig, S. (2009). Independent component analysis reveals atypical electroencephalographic activity during visual perception in individuals with autism. *Biological Psychiatry, 65*(1), 22-30.

Milne, E., Swettenham, J., & Campbell, R. (2005). Motion perception and autistic spectrum disorder: a review. *Current Psychology of Cognition, 23,* 3-33.

Minshew, N.J., Meyer, J., & Goldstein, G. (2002). Abstract reasoning in autism: A dissociation between concept formation and concept identification. *Neuropsychology, 16*(3), 327-334.

Mitchell, P. & Ropar, D. (2004). Visuo-spatial abilities in autism: A review. *Infant and Child Development,* 13(3), 185-198.

Molesworth, C.J., Bowler, D.M., & Hampton, J.A. (2005). The prototype effect in recognition memory: Intact in autism? *Journal of Child Psychology and Psychiatry, 46,* 661-672.

Molesworth, C.J., Bowler, D.M., & Hampton, J.A. (2008). When prototypes are not best: Judgments made by children with autism. *Journal of Autism and Developmental Disorders, 38,* 1721-1730.

Mottron, L., Burack, J.A., Iarocci, G., Belleville, S., & Enns, J.T. (2003). Locally oriented perception with intact global processing among adolescents with high-functioning autism: evidence from multiple paradigms. *Journal of Child Psychology and Psychiatry, 44*(6), 904-913.

Mottron, L., Dawson, M, Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders, 36*, 27-43.

Muehleisen, V., & Imai, M. (1997). Transitivity and the incorporation of ground information in Japanese path verbs. In K. Lee, E. Sweetwer, & M. Verspoor (Eds.), Lexical and syntactic constructions and the construction of meaning (pp. 329–346). Amsterdam: John Benjamins.

Naigles, L. (1990). Children use syntax to learn verb meanings. *Journal of Child Language, 17,* 357-374.

Naigles, L. (1996). The use of multiple frames in verb learning via syntactic bootstrapping. *Cognition*, 58, 221-251.

Naigles, L., Bavin, E., & Smith, M. (2002) Generalizing novel verbs to different structures: Evidence for the importance of understanding meaning. *Proceedings of the Boston University Conference on Language Development* (pp. 417-428). Somerville, MA: Cascadilla Press.

Naigles, L., & Kako, E. (1993). First contact: Biases in verb learning with and without syntactic information. *Child Development*, 64, 1665-1687.

Nappa, R., Wessell, A., McEldoon, K.L., Gleitman, L.R. & Trueswell, J.C. (2009). Use of Speaker's Gaze and Syntax in Verb Learning. *Language Learning and Development, 5*(4), 203-234.

O'Riordan, M., & Plaisted, K. (2001). Enhanced discrimination in autism. *Journal of Experimental Psychology, 54A,* 961-979.

O'Riordan, M.A., Plaisted, K.C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance, 27,* 719-730.

Papafragou, A. (2010). Source-goal asymmetries in motion representation: Implications for language production and comprehension. *Cognitive Science, 34,* 1064-1092.

Papafragou, A. & Selimis, S. (2010). Event categorisation and language: A cross-linguistic study of motion. *Language and Cognitive Processes, 25,* 224-260.

Parish-Morris, J., Hennon, B., Hirsh-Pasek, K., Golinkoff, R.M., & Tager-Flusberg, H. (2007). Children with autism illuminate the role of social intention in word learning. *Child Development, 78*(4), 1265-1287.

Parish-Morris, J., Lyuster, R., Tager-Flusberg, H., Hirsh-Pasek, K., & Golinkoff, R.M. (2009, May). Vocabulary in 2-year-olds with Autism Spectrum Disorder: A Magnified Verb Problem? Poster presentation, International Meeting for Autism Research, Chicago, IL.

Parish-Morris, J., Pruden, S., Ma, W., Hirsh-Pasek, K., & Golinkoff, R.M. (2010). *A World of Relations: Relational Words.* In: Malt, B. and Wolff, P. (Eds), Words and the Mind: How Words Capture Human Experience. NY: Oxford University Press, pp. 219-232.

Perkins, M.R., Dobbinson, S., Boucher, J., Bol, S., & Bloom, P. (2006). Lexical knowledge and lexical use in autism. *Journal of Autism and Developmental Disorders, 36,* 795-805.

Plaisted, K., Swettenham, J., & Rees, L. (1999). Children with Autism Show Local Precedence in a Divided Attention Task and Global Precedence in a Selective Attention Task. *Journal of Child Psychology & Psychiatry & Allied Disciplines, 40*(5), 733-743.

Poulin-Dubois, D. & Forbes, J.N. (2002). Toddlers' attention to intentions-in-action in learning novel action words. *Developmental Psychology, 38,* 104-114.

Poulin-Dubois, D. & Forbes, J.N. (2006). Word, Intention, and Action: A Two-Tiered Model of Action Word Learning. In: *Action meets word: How children learn verbs.* Hirsh-Pasek, Kathy (Ed.); Golinkoff, Roberta Michnick (Ed.); New York, NY, US: Oxford University Press, pp. 262-285.

Preissler, M.A. & Carey, S. (2005). The role of inferences about referential intent in word learning: Evidence from autism. *Cognition, 97,* B13-B23.

Pruden, S.M., Hirsh-Pasek, K., Golinkoff, R.M., & Hennon, E.A. (2006). The Birth of Words: Ten-Month-Olds Learn Words Through Perceptual Salience. *Child Development, 77*(2), 266-280.

Pruden, S. M., Hirsh-Pasek, K., Maguire, M. J., & Meyer, M. A. (2005). Foundations of verb learning: Infants form categories of path and manner in motion events. *Proceedings of the 28th annual Boston University Conference on Language Development,* 461-472. Somerville, MA: Cascadilla Press.

Pulverman, R. & Golinkoff, R.M. (2004). Seven-month-olds' attention to potential verb referents in nonlinguistic events. *Proceedings of the 28th Annual Boston University Conference on Language Development,* 473-480. Somerville, MA: Cascadilla Press.

Pulverman, R., Golinkoff, R. M., Hirsh-Pasek, K., & Sootsman Buresh, J. (2008). Infants discriminate manners and paths in non-linguistic dynamic events. Cognition, 108, 825–830.

Quinn, P.C. (1994). The categorization of above and below spatial relations by young infants. *Child Development, 65,* 58-69.

Riby, D.M., & Doherty, M.J. (2009). Tracking eye movements proves informative for the study of gaze direction detection in autism. *Research in Autism Spectrum Disorders, 3,* 723-733.

Riby, D.M., & Hancock, P.J.B. (2009). Do faces capture the attention of individuals with Williams syndrome or Autism? Evidence from tracking eye movements. *Journal of Autism and Developmental Disorders, 39,* 421-431.

Rice, C., et al. (2009). Prevalence of Autism Spectrum Disorders by the Autism and Developmental Disabilities Monitoring Network, United States, 2006. *Morbidity and Mortality Weekly Report, 58* (SS-10). CDC.

Rogers, S.J., Young, G.S., Cook, I.C., Giolzetti, A., & Ozonoff, S. (2008). Deferred and immediate imitation in regressive and early onset autism. *Journal of Child Psychology and Psychiatry, 49,* 449-457.

Roseberry, S. (2010). *Blicking* through video chats: The role of contingency in toddlers' ability to learn novel verbs. Dissertation, Temple University.

Salkind, S.J., Sootsman, J.L., Golinkoff, R.M., Hirsh-Pasek, K., & Maguire, M.J. (2002, April). *Lights, camera, action! Infants and toddlers create action categories*. Poster presented at the biennial meeting of the International Conference on Infant Studies, Toronto, Canada.

Sanchez-Marin, F.J., Padilla-Medina, J.A. (2007). A Psychophysical Test of the Visual Pathway of Children with Autism. *Journal of Autism and Developmental Disorders, 38,* 1270-1277.

Santos, A., Rondan, C., Rosset, D., Da Fonseca, D., & Deruelle, C. (2008). Mr. Grimace or Ms. Smile: Does categorization affect perceptual processing in autism? *Psychological Science, 19,* 70-76.

Sasson, N.J., Turner-Brown, L.M., Holtzclaw, T.N., Lam, K.S.L., & Bodfish, J.W. (2008). Children with autism demonstrate circumscribed attention during passive viewing of complex social and nonsocial picture arrays. *Autism Research, 1,* 31-42.

Scott, R.M., & Fisher, C. (2009). 2-year-olds use distributional cues to interpret transitivity-alternating verbs. *Language and Cognitive Processes*, *24*(6), 777-803.

Shah, A. & Frith, U. (1983). An Islet of Ability in Autistic Children: A Research Note. *Child Psychology and Psychiatry and Allied Disciplines, 24*(4), 613-620.

Shah, A. & Frith, U. (1993). Why Do Autistic Individuals Show Superior Performance on the Block Design Task? *Journal of Child Psychology & Psychiatry & Allied Disciplines, 34*(8), 1351-1364.

Shulman, C., & Guberman, A. (2007). Acquisition of verb meaning through syntactic cues: A comparison of children with autism, children with specific language impairment (SLI) and children with typical language development (TLD). *Journal of Child Language, 34,* 411-423.

Smiley, P., & Huttenlocher, J. (1995). Conceptual development and the child's early words for events, objects, and persons. In M. Tomasello, & W. E. Merriman

(Eds.), *Beyond names for things: Young children's acquisition of verbs.* (pp. 21-61). Lawrence Erlbaum Associates, Inc, Hillsdale, NJ: England.

Smith, H. & Milne, E. (2009). Reduced change blindness suggests enhanced attention to detail in individuals with autism. *Journal of Child Psychology & Psychiatry, 50*(3), 300-306.

Snedeker, J., & Gleitman, L.R. (2004). Why is it hard to label our concepts? In D.G. Hall & S.R. Waxman (Eds.), *Weaving a lexicon* (pp. 257-293). Cambridge, MA: The MIT Press.

Spencer, J.V. & O'Brien, J.M.D. (2006). Visual form-processing deficits in autism. *Perception, 35*(8), 1047-1055.

Spencer, J., O'Brien, J., & Riggs, K. (2000). Motion processing in autism: Evidence for a dorsal stream deficiency. *Neuroreport: For Rapid Communication of Neuroscience Research, 11*(12), 2765-2767.

Soulières, I., Dawson, M., Samson, F., Barbeau, E.B., Sahyoun, C.P., Strangman, G.E., Zeffiro, T.A., & Mottron, L. (2009). Enhanced visual processing contributes to matrix reasoning in autism. *Human Brain Mapping, 30*(12), 4082-4107.

Soulières, I., Mottron, L., Saumier, D., & Larochelle, S. (2007). Atypical categorical perception in autism: Autonomy of discrimination? *Journal of Autism and Developmental Disorders, 37,* 481-490.

Swensen, L., Kelley, E., Fein, D., & Naigles, L. (2007). Processes of language acquisition in children with autism: Evidence from preferential looking. *Child Development, 78,* 542-557.

Tager-Flusberg, H. (1985). Basic level and superordinate level categorization by autistic, mentally retarded, and normal children. *Journal of Experimental Child Psychology, 40,* 450-469.

Tager-Flusberg, H. (2006). Defining language phenotypes in autism. *Clinical Neuroscience Research, 6*(3/4), 219-224.

Takata, H. & Okuma, H. (1986). Building verbal behavior for one adolescent autistic boy: Some magnet movable equipments for teaching him many verbs. *Kyushu Neuro-psychiatry, 32*(3-4), 341-348.

Talmy, L. (1985). Lexicalization patterns: Semantic structure in lexical forms. In T. Shopen (Ed.), Language typology and syntactic description: Grammatical categories and the lexicon. Cambridge: Cambridge University Press.

Tek, S., Jaffery, G., Fein, D., & Naigles, L.R. (2008). Do children with autism spectrum disorders show a shape bias in word learning? *Autism Research, 1,* 208-222.

Tomasello, M. & Merriman, W.E. (1995). *Beyond names for things: Young children's acquisition of verbs.* Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Ungerer, J., & Sigman, M. (1987). Categorization skills and language comprehension in autistic children. *Journal of Autism and Developmental Disorders, 17,* 3-16.

Vandenbroucke, M.W., Scholte, H.S., van Engeland, H., Lamme, V.A., & Kemner, C. (2008). Coherent versus component motion perception in autism spectrum disorder. *Journal of Autism and Developmental Disorders, 38,* 941-949.

Vlamings, P.H.J.M., Jonkman, L.M., van Daalen, E., van der Gaag, R.J., & Kemner, C. (2010). Basic abnormalities in visual processing affect face processing at an early age in autism spectrum disorder. *Biological Psychiatry,* advance online print, Aug 20, 2010.

Wagner, L., & Lakusta, L. (2009). Using language to navigate the infant mind. *Perspectives on Psychological Science, 4*(2), 177-184.

Watake, S. (1996). A case study of an autistic boy who used finger writing for communication. *Japanese Journal of Special Education, 33*(5), 33-39.

Weismer, S.E., Lord C., & Esler A. (2010). Early language patterns of toddlers on the autism spectrum compared to toddlers with developmental delay. *Journal ofAutism and Developmental Disorders, 40*(10), pp. 1259-1273.

Wetherford, M.J., & Cohen, L.B. (1973). Developmental changes in infant visual preferences for novelty and familiarity. *Child Development, 44,* 416-424.

Williams, T.I. (1993). Vocabulary Development in an Autistic Boy. *Journal of Autism and Developmental Disorders, 23*(1), 185-91.

Williams, J.H.G., Whiten, A. and Singh, T. (2004). A systematic review of action imitation in autistic spectrum disorder. *Journal of Autism and Developmental Disorders, 34,* 285-299.

Wilson, A.D., Plumb, M., Williams J.H.G., & Mon-Williams M.A. (2006). ‘Sticky attention’ in autistic spectrum disorder--visual psychophysics and movement. Perception 35 ECVP Abstract Supplement.

Zimmerman, I.L., & Castilleja, N.F. (2005). The role of a language scale for infant and preschool assessment. *Mental Retardation & Developmental Disabilities Research Reviews, 11(3),* 238-246.

Zimmerman I.L., Steiner, V.G., & Pond, R.E. (2002). *Preschool Language Scale, 4th edition.* San Antonio, TX: The Psychological Corporation.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neuroscience, 23*(2/3), 143-152.

APPENDICES

APPENDIX A
Consent Forms

Subject # ___________ DOB ___________
Age ___________ Condition ________

CONSENT FORM

Project Title: Protocol (11204) / Discrimination and Categorization of Actions
Investigator: Kathy Hirsh-Pasek, PhD., Department of Psychology, 267-468-8610

Welcome to the Temple Infant Laboratories at Ambler. Please take a moment to fill out this consent form so that your child can participate in our research. This research study examines precursors to verb learning. In order for a child to be able to assign a word to a specific category of action, the child must be able to perceive similarities and differences in a wide range of actions. We will observe how your child perceives and categorizes a series of actions presented to them on a television screen. From your child's reponses, and those of other children's, we will try to piece together how it is that children discriminate and categorize action. Your child's responses and name will always be kept confidential. All results will be tallied at the group level rather than by individual response, so your child will not be individually identifiable. Subject data will be stored for three (3) years after the completion of the study. Three (3) years after the completion of the study, the videotape will be destroyed. If at any time, you or your child would like to stop the experiment, let us know. You are free to quit at any point during the experiment.

Let me take this moment to thank you and your child for joining us in the exciting process of scientific discovery. If you have any questions about language development or about this experiment in particular, please give me a call: (267) 468-8610. If you would like further information regarding the rights of a research subject, you may contact Richard Throm at (215) 707-8757.

I, __________________________(name), agree to let my child ____________________(child's name) participate in this study of language development with Dr. Kathy Hirsh-Pasek. As part of the research, I agree to allow my child to be videotaped and understand that the video tape will be used for research and educational purposes only. My name and my child's name will be kept confidential at all times.

Signature ____________________________ Date ________________

Thank you,

________________________________ ___________________
Principal Investigator Signature Date

________________________________ ___________________
Authorized Representative Date

Subject # ___________ DOB ___________
Age ___________ Condition ________

CONSENT TO VIDEOTAPE

Project Title: Protocol (11204) / Discrimination and Categorization of Actions
Investigator: Kathy Hirsh-Pasek, PhD., Department of Psychology, 267-468-8610

I give Kathy Hirsh-Pasek permission to videotape my child and I during my child's participation in this study. I understand that the videotape will be used as part of a research project at Temple University. I understand that the videotape will be used for data analysis and educational purposes only. Subject data will be stored for three (3) years after the completion of the study. I have already given written consent for my child's participation in this research project. At no time will my name or my child's name be used. I understand that I can withdraw my permission at any time. Upon my request, the videotape will no longer be used. I understand that I will not be paid for being videotaped or for the use of the videotape.

If you have further questions, please feel free to ask during your visit or contact me by phone (above) or by mail at: Temple University, Department of Psychology, Philadelphia, PA 19122. If you would like further information regarding the rights of a research subject, you may contact Richard Throm at (215) 707-8757.

I, _________________________(name), agree to let my child ______________________(child's name) participate in this study of language development with Dr. Kathy Hirsh-Pasek. As part of the research, I agree to allow my child to be videotaped and understand that the video tape will be used for research and educational purposes only. My name and my child's name will be kept confidential at all times.

Signature ____________________________ Date ________________

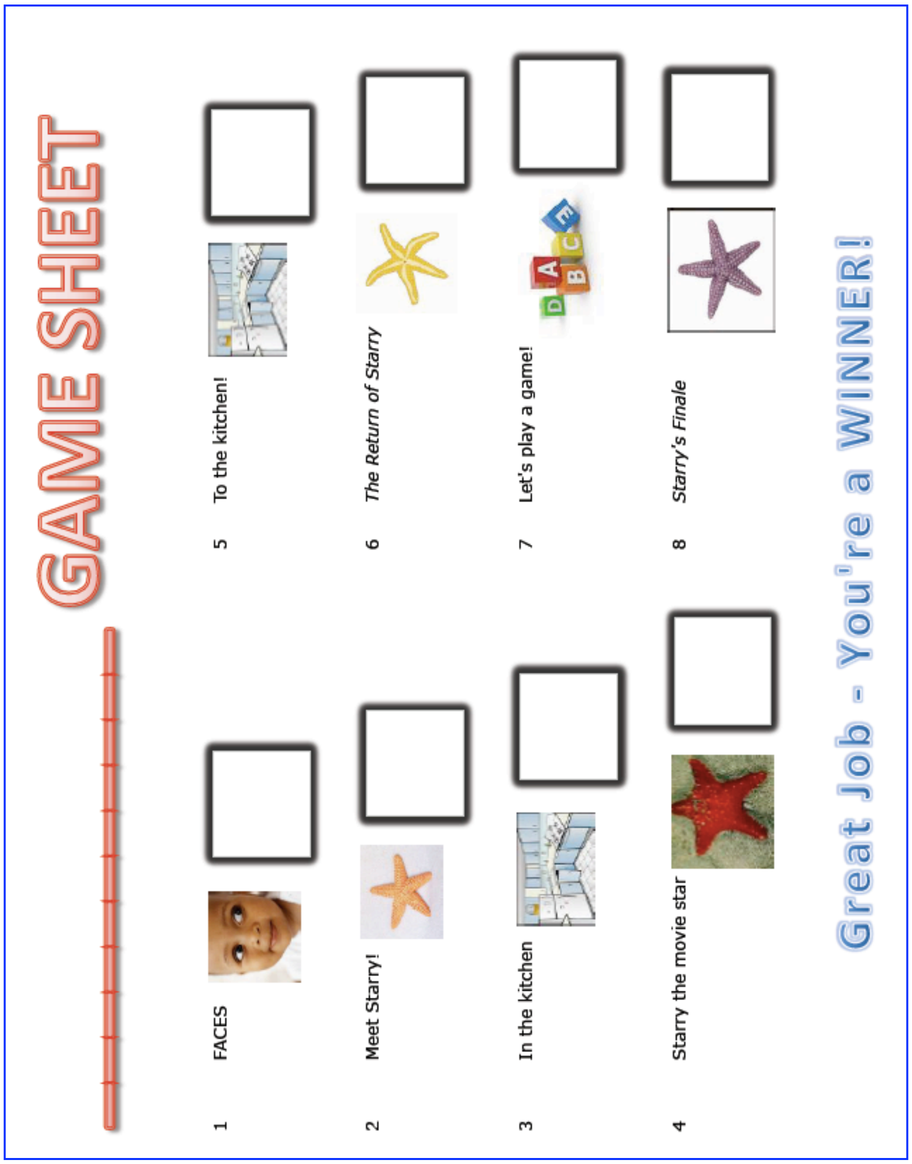
Thank you,

________________________________ ___________________
Principal Investigator Signature Date

________________________________ ___________________
Authorized Representative Date

APPENDIX B
Reward Sticker Chart

Children were offered a variety of age-appropriate stickers to choose from after they finished watching each video, and were encouraged to place the stickers in the box next to the video they completed. The actual size of the game sheet was approximately 8.5/11 inches, and it was matted on a stiff piece of colored card paper.



APPENDIX C
Video Order Counterbalancing and List of Paths/Manners

Participants were randomly assigned to one of four video orders. Videos were separated by an unrelated video or Study 3, and by putting stickers on the reward chart. Salience trials were used to gauge initial preference for either video.

Path Discrimination = PdiscA and PdiscB
Manner Discrimination = MdiscA and MdiscB
Path Categorization = PcatA and PcatB
Manner Categorization = McatA and McatB

Paths	Manners
Over	Side-bend
Under	Toe-touch
Around	Spin
Past	Flap
In front	Twist

Order 1	Salience	Familiarization	Test
PdiscA	twist under - twist over	twist under x 4	Novel: twist *over* = R
MdiscA	flap past - bend down past	flap past x 4	Novel: *bend down* past = R
PcatA	twist under - twist over	flap, side-bend, toe-touch, spin *over*	Out-of-category: twist *under* = L
McatA	flap past - bend down past	*bend down* over, around, under, in front	Out-of-category: *flap* past = L

Order 2	Salience	Familiarization	Test
MdiscA	flap past - bend down past	flap past x 4	Novel: *bend down* past = R
PdiscA	twist under - twist over	twist under x 4	Novel: twist *over* = R
McatA	flap past - bend down past	*bend down* over, around, under, in front	Out-of-category: *flap* past = L
PcatA	twist under - twist over	flap, side-bend, toe-touch, spin *over*	Out-of-category: twist *under* = L

Order 3	Salience	Familiarization	Test
PdiscB	flap around - flap past	flap around x 4	Novel: flap *past* = R
MdiscB	toe touch under - twist under	twist under x 4	Novel: *toe touch* under = L
PcatB	flap around - flap past	toe-touch, spin, twist, side-bend *past*	Out-of-category: flap *around* = L
McatB	toe touch under - twist under	*toe touch* past, in front, around, over	Out-of-category: *twist* under = R

Order 4	Salience	Familiarization	Test
MdiscB	toe touch under - twist under	twist under x 4	Novel: *toe touch* under = L
PdiscB	flap around - flap past	flap around x 4	Novel: flap *past* = R
McatB	toe touch under - twist under	*toe touch* past, in front, around, over	Out-of-category: *twist* under = R
PcatB	flap around - flap past	toe-touch, spin, twist, side-bend *past*	Out-of-category: flap *around* = L

APPENDIX D
Study 3 Protocol

<u>Canonical set</u>
Toys:
- Peg board (presented without peg in for free play, then with peg in *after* failed attempts)
- Hammer
- Peg
- Post
- Ring

Actions:
- Hammer peg into peg board
- Put ring on post

<u>Non-canonical set</u>
Toys:
- Train
- Train tracks
- Pot
- Pot lid

Actions:
- Put train in pot
- Balance tracks on inverted pot

<u>Procedure</u>

canonical toys always come first

1. Present a set of toys to the child. "Look at all these toys!"
2. Encourage the child to explore the toys for approximately 20-30 seconds (say things like, "Cool, huh? Look at these! What can you do with these?"). Note on the subject sheet what the child spontaneously does with the toys. If not exploring all toys, say, "Look at <u>all</u> these toys!" and gesture towards all of them. *Don't* say, "Try doing _________" or any other encouragement of specific actions. *Don't* encourage the child to play with any specific sets of toys – just encourage exploration in general.
3. Separate the toys into action pairs, leaving all toys within reach.
4. Say, "Okay, now I want you to watch me." Try (and fail) to perform an action with a set of toys (which pair comes first is determined by condition). Fail to accomplish the task in three different ways (e.g., hit the peg board, narrowly missing the peg, in three different places; in front and to either side of the peg). Say, "Oops!" or "Uh-oh" after each failure and indicate distress by appropriate intonation and facial expressions.
5. After trying (and failing) three times, say, "Can you help me? Can you do it for me?"
6. After the child does something, say "Thank you!" and move on to the next set of toys.

Note: At test, if the child does NOT complete the action or imitate exactly your failed attempts after you asked him/her to help or do it for you, then please write down what the child did.

<u>Watch and take notes during both the canonical and non-canonical conditions:</u>

What does the child do during *free play?* The canonical action with the toys? The non-canonical action? Another unrelated action? During free play, write down what the child did.