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Object Categorization in Children with Autism Spectrum Disorder (ASD)

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by

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Abstract

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The purpose of this study was to investigate hierarchical object categorization in children with autism spectrum disorder (ASD), examining three levels of category inclusiveness (superordinate, basic, subordinate) across three tasks (sequential touching task, generalized imitation task, sorting task) in three domains (animals, tools, kitchen utensils) in the same group of children with ASD. Previous research on the categorization abilities of children with ASD has shown mixed results. This study was designed to clarify past discrepancies in the literature.

Ten children with ASD participated in this study (mean CA = 4 years, 10 months; range 3 to 6 years; mean VMA = 3 years, 3 months; range 9 months to 6 years, 5 months). In the sequential touching task, children saw objects from two categories, and their spontaneous touching of those objects was recorded. Results showed no differences between category levels. Within level, participants differentiated between animate and inanimate domains on the superordinate level, and categorized basic level animate categories, having more difficulty with subordinate level categories. The generalized imitation task, in which the child must imitate the experimenter's modeled action with an appropriate exemplar, showed that participants generalized significantly better than chance on superordinate and basic level categories, but similar to chance on subordinate level categories. The sorting task, in which the child must sort eight objects (from two categories) into two separate boxes, also revealed no differences between level, but revealed sorting better than chance on the subordinate level only. The proportion of correct sorting was positively correlated with language. A positive correlation was found between the generalized imitation and sorting tasks, suggesting that the tasks may be tapping similar background knowledge. Overall, while children did not show significantly better performance on one level over another, two of the three tasks revealed lowest performance on the subordinate level, a finding that is consistent in typical development. The other task showed that it is possible that children with ASD are showing a different pattern of categorization. The results emphasize the importance of using multiple tasks, as well as multiple levels of category inclusiveness and domains, to study categorization in ASD.

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CHAPTER I. INTRODUCTION

Autism is a complex spectrum disorder that has continued to perplex researchers since its initial discovery over 70 years ago by Leo Kanner (1943). One question that has been repeatedly asked but that lacks a definitive answer is how children with autism understand their world. How do those with autism relate to objects around them and events that they experience in order to make sense of their environments? If autism is as heterogeneous as it is believed, then it is plausible that children with autism are learning in qualitatively different ways than typically developing (TD) children, resulting in an understanding of objects and events that differs considerably from their mental age matched counterparts. If children with autism have a categorization impairment, then further study and better understanding of the issue are necessary for developing appropriate interventions. First, however, it is necessary to define autism and to understand how the concept of autism has changed over time.

What is autism? Though earlier accounts of autism are debated, the groundbreaking description by Leo Kanner in 1943 is credited as the first official study of autism (Wolff, 2004). Kanner listed the crucial symptoms as an extreme autistic aloneness; abnormal speech with echolalia, pronomial reversal, literalness and inability to use language for communication; and monotonous, repetitive behaviors with an anxiously obsessive desire for the maintenance of sameness (Kanner, 1943). Only one year later, Viennese pediatrician Hans Asperger described four cases of autistic psychopathy of childhood. His descriptions, similar to those of Kanner, were of children often able, some with extraordinary gifts in mathematics or natural science with creative and original modes of thinking. Their social and emotional relationships were often poor, they were highly sensitive, they lacked feelings for others, had stereotypic behaviors as well as pervasive special interests, and were clumsy. Language acquisition was not usually delayed, but language use was idiosyncratic. Later work adjustment was often good but their social handicaps endured (Wolff, 2004).

Although the first descriptions of autism occurred in the early 1940's, the disorder appeared in both the DSM-I and II in the form of childhood schizophrenia, and not as a disorder of its own (Volkmar, Cohen, & Paul, 1986). Subsequently after the DSM-II was published in 1974, much progress was made in characterizing and defining infantile autism (IA). The DSM-III, published in 1980, incorporated many of these findings in its classificatory scheme for severe disorders of early onset. The phrase, pervasive developmental disorder (PDD) was created to encompass IA, childhood onset pervasive developmental disorder (COPDD), and atypical pervasive developmental disorder (APDD).

The DSM-III change represented a major advance in the diagnosis of childhood developmental disorders, making it possible to specify the related degree of intellectual disability and medical symptoms on different axes. Though at the time this change seemed like a great advance, the diagnostic categories and criteria for these disorders were not systematically studied. For example, the comparison of IA and COPDD revealed weaknesses of the diagnostic separation. IA was defined as an early onset disorder (prior to 30 months of age) characterized by pervasive lack of responsiveness to others; gross deficits in language development; peculiar speech patterns, if speech was present at all; bizarre responses to the environment; and an absence of delusions, hallucinations, loosening of associations, and incoherence as in schizophrenia. COPDD had an onset of after 30 months and before 12 years of age, and was characterized by impaired social relatedness, an absence of delusions or hallucinations, and at least three of the following: resistance to change; inappropriate or constricted affect; sudden, excessive anxiety; peculiar movements; abnormal speech patterns (although not abnormal language); under or oversensitivity to sensory stimuli; and self-mutilation.

When the DSM-IV was published in 1994, the diagnosis of autism changed yet again. According to this manual, the major features of autism were represented in three domains: failure to develop interpersonal relationships and a lack of responsiveness or interest in people, impairment in communication and imaginative activity, and a markedly restrictive repertoire of activities and interests (Tanguay, 2006). Because it is a categorical diagnosis, children had to show a number of specific criteria, displaying symptoms from all three domains to receive the diagnosis. In addition to changing infantile autism to autism, the DSM-IV also added Asperger’s Syndrome (AS), first described by Hans Asperger fifty years earlier in 1944. AS was not included in earlier manuals because it was not widely acknowledged until Lorna Wing's innovative paper in 1981 (Wolff, 2004). The criteria in the DSM-IV for AS specified a profound impairment in interpersonal relationships, but with normal language development. There has been extensive controversy over whether AS is a qualitatively distinct form of autism, or whether it is simply the upper boundary of the spectrum of autism (formally addressed in the latest manual).

The DSM-5 was published in 2013 and major changes were made to the disorder. Four previous disorders (Autistic Disorder, Asperger’s Disorder, Childhood Disintegrative Disorder, and Pervasive Developmental Disorder Not Otherwise Specified), were combined to create one new disorder, autism spectrum disorder (ASD). In addition to this overhaul, the latest manual changed the three impairments (social impairments, language impairments, and restricted, repetitive behaviors) to two domains; the primary impairment being social communicative, and the secondary impairment remaining the restricted, repetitive behaviors. The DSM-5 also specified three levels of severity for each of the two domains: level 1 (requiring very substantial support), level 2 (requiring substantial support) and level 3 (requiring support; APA, 2013).

For some time, clinicians have recognized that a problem in the classification of ASD is that the disorder does not seem to be a categorical, either/or disorder (Tanguay, 2006). Rather, autism is a spectrum disorder, which was finally acknowledged in the DSM-5, and which makes it extremely difficult to conduct research on this population. For instance, if one examines the joint attention behaviors of children with ASD, the results will vary greatly depending on the part of the autism spectrum from which one selects participants. If higher functioning children with ASD take part in the study, their cognitive profiles might differ radically from others on the spectrum. Likewise, if lower functioning children participate, intellectual disability often accompanies autistic symptoms, creating a basic confound in the research. The heterogeneity of ASD is one major reason why there are many confusing and inconsistent findings in this literature base.

Why is the history of the classification of ASD relevant? The early conceptualization of the disorder has influenced not only how it is that one studies the disorder, but also who it is that has been the focus of the study. Any empirical study with ASD as its focus must address its history since the literature documenting ASD has drastically changed in the last several decades. If, according to the DSM-I and DSM-II, children with ASD were grouped together with children with childhood schizophrenia, then it is difficult to look objectively at studies that were completed at that time, since "core" autistic symptoms were confounded with symptoms of other disorders. Although we have learned much about the nature of ASD since its first discovery, its turbulent and shifting history in the DSMs reminds us that there is still a great to deal to learn.

One area in which there is contradictory information in the literature is the study of categorization in ASD. Do children with ASD categorize the world as do TD children? Do they end up forming the same categories as others by using different processes? And is this categorical knowledge (or lack of knowledge) related to any of their other abilities or lack of abilities? Unfortunately, conclusions are mixed largely because the assumptions that researchers have made about how categorization skills develop in children, widely differ. A more detailed look into ASD and its many impairments will be presented later. First an analysis of categorization in typical development is offered.

Categorization is an important skill to have in this world and yet it is not often explicitly thought about in an everyday sense. Categorization is inextricably linked to our conceptual understanding of everything in the world around us. The world is comprised of lots of things. Aside from the billions of people who inhabit this planet, there are countless artifacts such as vehicles, buildings, tools, furniture, technological gadgets, not to mention the many natural kinds of animals, plants, and other living things with which we share the planet. Keeping track of all of these things is certainly daunting, and what helps one manage the complex environment is the ability to construct categories. These categories might not be exactly the same for all people everywhere, since the world is an enormous place, but creating categories helps to make sense of the environment. Even though there may be some differences from place to place, people generally use categories for the similar purpose of providing structure and organization in their representation of the world.

How do people come to categorize objects in the world? If one were to ask how it is that one comes to understand that a maple tree is a certain kind of a tree, which is a certain kind of living organism, realistically, it would be quite difficult to answer that question. And yet the question is central to how we develop knowledge. The underlying answers to this fundamental question can be addressed by studying how infants and young children develop knowledge of object categories.

Categorization: Traditional Views

In 1976, Eleanor Rosch and her colleagues were interested in how people carve up the world and find structure in the environment. They developed a theory of categorization that featured a hierarchical structure with three levels: superordinate, basic, and subordinate (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). These levels are structured such that a subordinate category is a member of a basic category, which is a member of a superordinate category. An example of a superordinate category is animal, an example of a basic category is cat, and an example of a subordinate category is Siamese cat. Rosch investigated which category best matches the correlational structure of the environment and concluded that it was the basic level category. Utilizing several experiments, Rosch and her colleagues found that basic level categories are at the level of abstraction for which cue validity is maximized. Cue validity is the validity of a given cue *x* as a predictor of a given category *y* which increases as the frequency with which cue *x* is associated with category *y* increases, and decreases as the frequency with which cue *x* is associated with other categories other than *y* increases (Rosch et al., 1976). According to Rosch, categories at higher levels of abstraction (superordinate categories) have lower cue validity since they have fewer attributes in common (e.g., cars and airplanes are not very similar) and categories at lower levels of abstraction (subordinate categories) have lower cue validity because they share most attributes with contrasting subordinate categories (e.g., electric guitars and acoustic guitars are very similar). In sum, basic level categories are the most inclusive categories which optimize the correlational structure of features of the world (Rosch et al., 1976). In this view, it is simply too much of a cognitive burden to consider cars, airplanes, trucks, and motorcycles as the same thing because they actually look quite different from one another, and have slightly different functions as well. Likewise, it would be quite burdensome to create separate categories for a 747 jet and a 727 jet, since the similarities between them far outweigh the differences.

This theory, which stressed the importance of basic level categories, claimed that the process of category formation is universal, occurring in the same way for people everywhere. Although universal, Rosch and her colleagues pointed out that expert knowledge might disrupt these basic taxonomies, with their example being an airplane mechanic (Rosch et al, 1976). For such a person, expert knowledge of airplanes will create a more differentiated taxonomy of airplanes than that of an ordinary person. A mechanic might possess extraordinary knowledge of different types and subtypes of airplanes, which would affect his categorical knowledge of airplanes. Therefore, a person with expert knowledge in any field disrupts the tenet of this theory. This example also demonstrates that defining the basic level can be difficult when applied universally. Most domains have never even been studied; therefore, it is not clear what the basic level may be for many categories, including artifacts such as buildings and toys (Mandler, Bauer & McDonough, 1991).

What is important for categorization according to this theory? In other words, how do people identify and categorize basic objects? Rosch and her colleagues asserted that people categorize objects based on perceptual similarity and shape (1976). For example, dogs are all perceptually similar, much more so than a dog is to a cat, bird, or rabbit. The first four experiments investigated the aspects of basic objects that make them the most inclusive category: the co-occurring attributes common to the category, sequences of motor movements common to the object, similarity in the shape of an object, and identifiability of an average shape in the category (Rosch et al., 1976). The conclusion of each of these four experiments was that basic objects form the categories which are optimally inclusive. The next eight experiments examined additional aspects of the concept of basic objects, with two experiments in this group studying 3–10-year-old children on their ability to sort both basic level and superordinate level categories. The authors, who employed both a simplified oddity problem format (which included the 3–4-year-olds), and a simple sorting format, found evidence for their hypothesis that the basic level categories were easier to sort than the superordinate level categories (Rosch et al., 1976). Success on these experiments by the youngest children (3–5-year-olds) led to the conclusion that children first develop knowledge of basic level objects, and then gradually come to understand broader, superordinate level objects.

Despite the fact that this view of categorization was widely accepted at the time, there were some weaknesses prevalent in Rosch's argument, as evident in her own footnote. Rosch stated that were the concept of cue validity a true probability, it would necessarily follow that the superordinate level category would be the most inclusive category, since superordinate level categories include basic level categories (Rosch et al., 1976). This important point, placed in a footnote, disrupts the entire tenet of the theory, which is that the basic level category is the most inclusive category. Also, in the latter eight experiments, the authors tested the hypothesis that object names at the basic level should be the names most generally used by both adults and children. These linguistic tasks were misleading, however, because one knows and expects a child's first learned words to be basic level nouns since they are present in adults' everyday language, particularly in child-directed speech (Anglin, 1977; Brown, 1958). For example, it is convenient to say that I need to go to the *car* wash, not the *vehicle* wash, and not the place that cleans my Jeep. Children often use first words that are spoken to them, a fact which does not necessarily reflect children's underlying conceptual knowledge of those words. Finally, the boundaries of basic level categories were often confounded with superordinate level categories (Rosch et al., 1976). For instance, to categorize cars and dogs into exclusive categories and claim such as evidence for basic level categorization is confounded because a car is a vehicle and a dog is an animal. Therefore, it is unclear whether the differences between dogs and cars represent boundaries between basic level or superordinate level categories. Actually, they represent both (Mandler & Bauer, 1988).

This categorization theory, which was accepted for some time, was tested on three-year-old children and older (Rosch et al., 1976). Within the last three decades, however, much research has shown that infants, some as young as three months, are capable of categorizing objects (Behl-Chadha, 1996; Eimas & Quinn, 1994; Mandler & McDonough, 1993, 2000). On what bases are infants categorizing? Several studies have shown that very young infants can categorize on perceptual bases, thus recognizing that two different kinds of mammals or pieces of furniture look differently (Behl-Chadha, 1996; Eimas & Quinn, 1994). Though these findings have departed greatly from earlier beliefs about infants' limited capabilities, they have not addressed what it is that infants understand about objects in the world. Just because three-month-olds differentially respond, indicating that a cat and dog are two different things (Quinn, Eimas, & Rosenkrantz, 1993), does that mean that they understand that cats and dogs are indeed different? At what point in development do infants and young children come to conceptually understand what makes objects belong to one category and not another? Studies that focus on perceptual differences are simply not sufficient in our understanding of infants' developing knowledge of objects, since they only reflect infants' ability to detect that two objects look differently.

Conceptual Categorization

Making the leap from noticing perceptual differences to understanding what makes up kinds of things, has been a question at the heart of how humans develop knowledge. Yet, studying the origin of knowledge in preverbal infants is not an easy task. By 3–4 years of age, it is known that children are able to verbally explain what kinds things are (Gelman & Markman, 1986; Massey & Gelman, 1988). But what fosters the transition between the infant that is capable of seeing differences among objects, and the toddler who can verbally explain why and how objects are different kinds? Whereas Eleanor Rosch and other psychologists focused on how and when young children and infants notice perceptual differences amongst objects and categories, Mandler and McDonough (1993, 1998a, 1998b, 2000) took a more expanded, developmentally-based approach because they were interested in determining when infants and young children come to conceptually understand categories. They investigated the origins of infants' conceptual knowledge by using a variety of different tasks that differ in structure, with the goal of providing a comprehensive picture of infants' developing conceptual knowledge.

One of the tasks used to answer this question was the object examining task (Mandler & McDonough, 1993, 1998), which was pioneered by Ruff (1986) and also used by Oakes, Madole, & Cohen (1991). In this task, infants are familiarized to a set of objects within a category. Following familiarization, they are given a new exemplar from the same category, followed by a new exemplar from a contrasting category. If the infants increase their examination time to the final test object compared to the exemplar from the same category, it can be assumed that the infants differentiated the two categories. This task is well-suited for use with infants, as there are no verbal demands on the infants, and the act of feeling, looking at, or mouthing objects seems to be a lot more engaging than merely observing pictures or slides (although examining time was the only measure used; Mandler & McDonough, 1993). Of course, it should be noted that examination time, defined as concentrating on and inspecting the object, does not necessarily imply a conceptual understanding of how two categories differ. If infants examine a novel dog after seeing a series of cats, it is unclear if infants are categorizing based on perceptual or conceptual differences. Mandler and McDonough (1993) found that both 9- and 11-month-old infants are capable of distinguishing airplanes from birds with outstretched wings, two conceptually different categories that are perceptually quite similar. They additionally found categorization of perceptually varied objects such as furniture vs. vehicles. These results shed light on how this task can be used to speculate on the beginnings of conceptual knowledge.

Another task that was used with slightly older infants (older than one-year-old) was the sequential touching task (also referred to as the object manipulation task; Mandler et al., 1991, Ricciuti, 1965; Sugarman, 1983). In this task, which is based loosely on a sorting task, the experimenter places a collection of objects in front of the child, allowing the child to touch, explore, and manipulate the objects. The eight objects consist of four objects from one category, and four objects from a contrasting category. If children are sensitive to the categorical distinction between the objects, they will tend to touch objects in the same category in sequence more frequently than would be expected by chance (Mandler et al., 1991). As with the object examination task, successively touching the objects within a category more frequently than the contrasting category could be perceptual or conceptual categorization; the key to interpreting the results lies in the contrasts used. Previous research by Mandler, Fivush, and Reznick (1987) studied the categorization of "bathroom things" and "kitchen things" using this technique with pictures rather than objects, and found that infants were able to differentiate these categories, despite the fact that there were no perceptually similar attributes within each category.

Finally, the last task used by Mandler and McDonough was the generalized imitation task (1996, 1998b, 2000). In this task, the experimenter models a simple event using small replicas of real-world objects and encourages the infants to imitate what they have observed. The interesting part of the task, however, is that the objects given to the infants are different than the ones used to model the event. For example, the experimenter might demonstrate the event of sleeping by showing a dog sleeping on a bed. The experimenter then takes away the dog, and gives the infant another animal, along with a vehicle. The question is if the infants will imitate the event by generalizing to the appropriate object. If the infants imitate that event with the animal but not with the vehicle, this is taken as evidence that they understand that a property of being an animal is sleeping, a property not shared by vehicles (Mandler & McDonough, 2000). This task highlights knowledge of what objects are and how they function.

Using these three tasks on infants ranging from 7–30 months of age, Mandler and McDonough uncovered a different developmental pattern of categorization than the one proposed by Rosch and her colleagues (1976). Rather than learning first about basic level categories, these studies revealed that infants from 7–18 months are categorizing between animal, vehicle, plant, and furniture domains, and only from 9–11 months are infants *starting* to categorize at the basic level, recognizing such distinctions as dog vs. cat and car vs. airplane (Mandler, et al., 1991; Mandler & McDonough, 1993, 1998b; Pauen, 2002; Trauble & Pauen, 2007). In addition, 18–30 month-old infants are generalizing properties of animals, vehicles, and household artifacts, and are becoming more successful at generalizing properties within basic level categories at 24 months and older (Mandler & McDonough, 1998b, 2000). This evidence, using more developmentally appropriate methods, has shown that infants are first distinguishing between superordinate level categories and over time, are becoming more knowledgeable about basic level domains within those categories. This developmental pattern is similar to patterns that are evident when one gains expertise in a domain; namely, a differentiation process.

Much of the work of Mandler and McDonough was based on ideas about early conceptual development as proposed by Katherine Nelson (1973, 1974). It should be noted that historically speaking, the work of Katherine Nelson followed that of Eleanor Rosch and her colleagues, followed by the work of Jean Mandler along with Laraine McDonough. The common interpretation at the time was that according to Rosch's theory, children were categorizing the basic level according to perceptual similarity and shape. To her credit, Rosch and her colleagues did include more varied aspects of categorization, but these studies were done primarily in adults (Rosch et al., 1976). Rosch's work on the functional basis of objects, was influential upon Katherine Nelson, whose work very much influenced Mandler and McDonough. For the purposes of the current study, Katherine Nelson is discussed after Mandler and McDonough, in order to highlight how their theory contrasted directly with that of Rosch.

Nelson, who was interested in the relation between the young child's acquisition of conceptual knowledge, learning of words, and production of first sentences, created a conceptual model around what she termed a Functional Core Concept (FCC; Nelson, 1974). This theory is based on the premise that children can categorize objects before they can name them, with the assumption that a child has a concept of "ball" before labeling it as "ball". The FCC theory states that a child develops the concept of an object by focusing attention on that object, identifying how this object relates to surrounding persons and/or objects, identifying those characteristics that are central to that object, and finally attaching a name to the object (Nelson, 1974). The obvious, critical feature of this theory is that the object has functional value, leading to the creation of the concept. Nelson's emphasis on the child's dynamic experiences with objects in the world corresponds with the theories of Mandler and McDonough, who stressed that it is the child's conceptual understanding of objects that is the basis of cognitive development. Furthermore, the generalized imitation task used by Mandler and McDonough, (1993, 1996, 1998) tested infants' knowledge of what objects in different categories are and how they function, and was based, in part, on the theoretical claims of Nelson and the FCC (Mandler & McDonough, 2000).

Nelson also stated that children's knowledge is contextualized. Simply put, pieces of reality are never experienced apart from their context, whether these pieces are concepts, words, or objects (Nelson, 1983). Within this framework, it becomes clear that in understanding conceptual development, it is necessary to not only analyze knowledge of objects, but to have knowledge of events as well. Why? Because objects are embedded in events and cannot be separated from them. For instance, a child develops the concept of ball by interacting with others in the context of a ball, and learning the functional attributes of that ball (e.g., throwing, rolling, bouncing, etc.).

One type of knowledge organization is a schema – a part-whole organization of elements – for example, the temporal-spatial organization of scenes and events (Lucariello & Nelson, 1985; Mandler, 1979, 1983). Scripts are a type of schema representing event structures and are organized in terms of temporal and causal relations between component acts (Nelson, 1978). Nelson has demonstrated that the basis of many, or perhaps all, early categories of objects lies in earlier acquisition of scripts, or representations of familiar routines (Lucariello & Nelson, 1985).

For example, a child learns the concept of food by figuring out that what happens at mealtime is that mommy puts me in a highchair, puts a bib on me, and then I eat cheerios (or apples, or carrots). Since a young child takes part of this mealtime event or activity, the child learns not only appropriate actions (eating, drinking) but also appropriate objects associated with those actions (cheerios, apples, or carrots). In this way, children learn these slot-filler categories, which contain objects that can be substituted for one another (at mealtime I can eat x, y, or z just as at the park, I can play with a, b, or c).

Nelson's theoretical framework for infant's concepts was based in part on explaining toddler's first words, many of which are labels for objects (e.g., ball or dog; Nelson, 2008). Though these objects differ for each child, their basis is functional within contexts. Nelson states that the child's first language constructions are assumed to come directly from primitive conceptual representations (Nelson, 1983). But how do language and the development of concepts proceed together? The question is a complicated one. For one, it cannot be assumed that infants are perceiving the world in the same way as are adults. McDonough and her colleagues showed that preverbal infants are adept at forming various spatial categories (McDonough, Choi, Mandler, & Bowerman 1999), and yet when the children are older (at around 20 months), the categories onto which they extend early linguistic terms are specific to the language they are learning (Choi, McDonough, Mandler, & Bowerman, 1999). Therefore, language can function as both strengthening the salience of categories already formed, but also decreasing the salience for those categories that are not present in the language being learned.

One idea about how children could be using rules to learn about objects and early words has been postulated by Nelson and Nelson (1978). In the first two stages, a child moves from idiosyncratic experiences to a few general rules. Often this is evidenced by children's early preverbal behaviors (such as gestures or grunts) and proceeds to children naming first objects. Children are using words to name those objects and describe the characteristics of those objects (Nelson & Nelson, 1978). The third stage is comprised of the child learning many rules about word names, all the while narrowing and acquiring more specific rules. It is at this stage where children come to realize that as balls are round and bounce, bowls are round and hold food. The fourth stage is integration and consolidation, such that a child has a basic, working vocabulary of about 500 or so words, and can name most of the important objects in the child's life (Nelson & Nelson, 1978). Finally, the fifth stage is characterized by appropriate but flexible application. Children in this stage are able to incorporate new words appropriately into their vocabularies. This sequentially outlined theory highlights the importance of the two developing systems, of learning words and objects, in the young child.

The link between language and conceptual development has been demonstrated elsewhere as well (Balaban & Waxman, 1997; Booth & Waxman, 2002; Booth, Waxman, & Huang, 2005; Gelman & Markman, 1987; Xu, 2002). This growing body of research has provided evidence that early word learning supports the early acquisition and organization of conceptual knowledge in infancy. Through three experiments, Booth and colleagues have shown that infants as young as 20-months make extensions of novel words that vary systematically as a function of the conceptual status of the named object (2005). For example, when objects were named as artifacts, infants extended novel words primarily on the basis of shape, and when objects were named as animate kinds, infants extended novel words on the basis of both shape and texture. Giving infants conceptual information about objects had an effect on their word learning, showing its importance as infants develop language. Perhaps a similar result could be elicited by giving nonverbal information to infants? Not so. Balaban and Waxman (1997) found that in nine-month-old infants, word phrases, but not tones, even those matched to the words for amplitude, frequency, and duration, influenced object categorization. Additionally, Xu (2002) found that in testing nine-month-olds on their ability to use labels to help establish a representation of two distinct objects, the presence of two distinct labels facilitated object individuation, while the presence of one label (for both objects), two tones, two sounds, or two emotional expressions did not. The consensus from these studies is that in toddlers and young children, conceptual knowledge and word-learning are two closely related and intertwined processes.

Categorization and ASD

Now that categorization in typical development is understood, categorization in ASD will be investigated. To start with, one needs to consider the possibility that people with ASD might be experiencing the world differently than TD individuals. Anecdotal evidence comes from two high-functioning individuals with ASD who have been successful at describing what it is like to develop with ASD. Temple Grandin is one such individual who is on the higher end of the spectrum. Not merely high-functioning, Grandin has a Ph.D. in animal science and has designed one third of all livestock facilities in the United States (Grandin, 1995). She articulates in great detail how she processes information, explaining that she is a "visual thinker" rather than a language-based thinker (although she points out that other people with ASD think in other sensory modalities besides vision).

Grandin states that her mind catalogs thoughts into visual images which she can remember quite accurately for a long time. When describing what happens when she sees a specific breed of dog, Grandin says that she accesses this catalog, remembering specific episodes that she has had over her lifetime with that breed of dog. She states that her thoughts move from specific visual images to generalization and concepts (Grandin, 1995). Contrasted with people without ASD, who are able to generate images and prototypes rather quickly without necessarily tapping episodes of memory, it is clear that this visual-based thought processing is quite taxing. Moreover, it would seem that even though Grandin understands that a poodle is a type of dog, which is a type of animal, her reflections reveal that perhaps *how* she obtained that information might differ from how others obtain that information.

Donna Williams is another influential individual with ASD. Williams is an author from Australia, who has written an autobiographical account of her life with ASD (1992). From a very young age, Williams describes a world that captivated her, not because it contained people or objects, but because it contained lights, colors, and sensations. In the first three years of her life, she learned to lose herself in patterns on the wallpaper or carpet, or in repeated sounds. Williams states that she heard the sounds of other people's voices, but did not actually listen to them, or have any desire to communicate with them. There were relatives with whom she had a close connection early on; however, those relationships were mediated through objects that she associated with such people. For example, when remembering her grandmother, Williams collected scraps of wool that were a reminder of her. She says, "For me, the people I liked *were* their things, and those things (or things like them) were my protection from the things I didn’t like–other people" (Williams, 1992, p.6).

These two accounts illustrate the firsthand experiences of an individual developing with ASD. What is striking is the preference for objects over people in general, as well as each person's experiences with those objects and concepts. Of course it should be noted that these are two individual, introspective accounts, which are not likely to be indicative of ASD as a whole. Nonetheless, these accounts are useful because they provide a window into the disorder, leading one to ask more questions. How have researchers attempted to answer the question of how children with ASD categorize objects and events? As stated before, due to both the complexity of autism as a spectrum disorder, and the shifting definition of the disorder throughout history, there is a great deal of contradictory evidence in the literature.

The earliest studies exploring concept formation revealed that children with ASD have difficulty with perceptual categories (Fay & Schuler, 1980; Noach, 1974). One study looked at how four children with ASD were able to classify blocks according to height and size, while ignoring the other aspects (e.g., color, shape, and nonsense syllable). Qualitative analysis revealed that the children with ASD showed an impairment, performing substantially lower as a group than TD children (Noach, 1974). Another study by Schuler and Bormann (1977) used a matching-to-sample paradigm and found that while children with ASD were able to match identical objects, and match broken parts with their whole counterparts, they were unable to match objects with their functional complements or equivalents. Also, some children had difficulty with matching similar but non-identical objects (such as a red plastic toy car to a brown metal car), as well as matching parts to wholes (such as the wheels of a car to the car), suggesting that most of the children were able to use perceptual cues to match, but not conceptual ones (see Fay & Schuler, 1980).

Three later studies examining categorization in ASD used control groups of children (TD children and children with mental retardation [MR] now referred to as intellectual disability [ID]) actually found no deficits at all in the group with ASD (Tager-Flusberg, 1985a, 1985b; Ungerer & Sigman, 1987). In a study by Tager-Flusberg, knowledge of basic level and superordinate level categories was assessed with a matching-to-sample task using pictures (1985a). The first experiment within this study testing basic level categories (e.g., car, chair, and dog), found no differences between children with ASD, children with MR, and TD children, who were all matched on mental age. A second experiment within this study, utilizing the same task with the same children, tested superordinate level concepts (e.g., vegetable, fruit, animal, clothing, furniture, and vehicle). Again, no differences were found amongst any of the groups on completion of the categorization tasks. However, as with the tasks that compared basic level and superordinate level categories in Rosch's study, there was a major confound embedded within these matching-to-sample tasks. When asked to point to the choice most like the target on each trial (e.g., rocking chair), children were shown a picture of either another chair (e.g., ottoman) or a category member from a different superordinate level category (e.g., an antique car). The fact that children can match one type of chair with another type of chair, when compared with either a car or a dog, does not provide specific information regarding their basic level categorization. A more appropriate comparison would include basic level objects from the same superordinate category (i.e., if the rocking chair is the target object, appropriate comparison objects might be an ottoman and a bed for example).

A second study investigated another aspect of categorization, the acquisition and organization of semantic concepts in the same three groups matched on verbal mental age (Tager-Flusberg, 1985b). Since other studies revealed that children with ASD have difficulty processing meaning in language and cognitive tasks (Hermelin & O'Connor, 1970; Tager-Flusberg, 1991), it was hypothesized that there would be difficulties in concept formation as well. The organization of both basic level (bird, boat) and superordinate level concepts (food, tool) was assessed by showing each child 48 pictures and asking, "Is this a____?" using the name of the category for which picture was selected. Each category had central members of the category, more peripheral members, related foils, and unrelated foils. Results indicated that there were no significant differences between the three groups. Furthermore, the overextension and underextension errors were comparable across groups as well, in that there were slightly higher false positive responses to the unrelated foils for the superordinate level categories as compared to the basic level categories (Tager-Flusberg, 1985b). In the second experiment, the child selected a picture (a nonverbal response) that belonged to the named category from an array of pictures, again using two basic level categories (house, fish) and two superordinate level categories (musical instruments, tools). Again, the results showed no significant differences across groups and a similar pattern of overextension and underextension errors. These results showed that children with ASD have concepts; the methodology does not allow one to answer the question of how or when these concepts were formed.

Finally, a third study assessed categorization skills on both functional and perceptual grounds in children with ASD (Ungerer & Sigman, 1987). The methodology included a spontaneous object sorting task, using stimuli that were geometric forms and miniatures of objects representing four color (red, yellow, blue, and green), three form (square, triangular, and circular shapes), and four function (animal, fruit, vehicle, and furniture) categories. Just as the aforementioned studies demonstrated, no significant difference emerged between the children with ASD, children with MR and TD children, who were all matched on mental age. There were some problems with the sample of children, though, questioning the accuracy of the results. The MR group was not homogenous (e.g., half of the sample had Down syndrome, others had organic dysfunctions) and therefore, not an appropriate control group because it is unclear if the results are attributable to intellectual disability or some other biological cause. In addition, it is not clear what comparisons were made in the sorting task. For instance, the authors stated that on each trial, the child was presented with two different sets of four objects (e.g., four red circles and four red squares), both from the same superordinate category (e.g., form). This contrast involves a change in one dimension with others held constant, therefore maximizing both high contrast between categories and high similarity within categories. In the task involving four red circles, it is not clear how discriminable one circle was from another. If they were not discriminable, one might question whether any categorization strategy was required at all.

Even as these three studies demonstrated a lack of a categorization impairment specific to children with ASD, there are some indications that a deeper look into categorization is necessary. As stated before, there were potential confounds in two of the studies, compromising the assertion that categorization skills are developing appropriately in children with ASD. Additionally, in the previous spontaneous sorting task study which focused on the relationship between categorization and receptive language, significant, positive correlations were found for both TD and children with MR, whereas there was no such link in children with ASD (Ungerer & Sigman, 1987). As a result, it is possible that children with ASD categorize by utilizing different processes, with language processes playing a rather uncertain role if any.

Although the earliest studies looking at categorization did not find an impairment specific to ASD, further studies looking at more complex aspects of categorization have shown mixed results (Klinger & Dawson, 1995; Minshew, Meyer & Goldstein, 2002; Shulman, Yirmiya & Greenbaum, 1995). One study by Shulman and colleagues tested children with ASD, children with MR and TD children (all matched on mental age) on several Piagetian classification tasks and found several group differences (1995). In this study, there were three different types of tasks: two free-sorting tasks testing geometric shapes and representational objects, a matrix task testing both perceptual and functional classification, and a class inclusion task. Results indicated that on the free-sorting tasks, children with ASD performed similarly to the other groups on sorting geometric shapes. However, children with ASD performed significantly worse than the other groups on representational sorting, or placing objects that go together from six categories (trees, beds, human figures, animals, tools, and vehicles). On the matrix task testing perceptual classification, which is classifying according to two perceptual criteria (color and form) simultaneously, those with ASD performed significantly better than those with MR and significantly worse than TD children. The matrix task testing functional classification (classifying things that fly, and things that give light) revealed that both children with ASD and children with MR performed significantly worse than TD children. Finally, the class inclusion task (testing color and shape) revealed that children with ASD performed significantly worse than the other groups (Shulman, et al., 1995). These results provided a glimpse into differences between perceptual and conceptual bases of categorizing. When utilizing individual perceptual attributes alone, children with ASD do not seem to differ from TD children. However, when more complex, functional attributes are tested, or when combinations of perceptual attributes are used, children with ASD perform significantly worse than TD children, as well as children with ID in certain contexts, suggesting that some aspect of the conceptual classification of objects may be uniquely impaired in ASD.

Since early studies revealed that individuals with ASD were capable of rule-based learning (Hermelin & O'Connor, 1986), several subsequent investigations focused on rule-based and prototype-based categorization in children with ASD. What is a prototype? It has been suggested that infants organize new information through the use of prototypes, or the best representative member of a category, so that they are not overly cognitively burdened. Posner and Keele (1968, 1970) have argued that a prototype is a mental representation created by averaging all previously experienced category members. By utilizing prototypes, infants and children are not constantly flipping through dozens of images of category members in order to determine what something is (similar to Temple Grandin's descriptions of her concept formation). Studies have shown that the ability to form a perceptually-based prototype is an automatic process developing in the first year of life (Younger, 1990).

In ASD, the picture is not quite so clear. A study comparing prototype-based and rule-based learning, found that children with ASD were just as accurate on rule-based categorization as children with Down syndrome (DS) and TD children. However, on a task where the participants had to select the category prototype, children with ASD and children with DS both underperformed as compared with TD children (Klinger & Dawson, 2001). Although this study and others have shown a possible prototype impairment in ASD (Klinger & Dawson, 1995, 2001; Plaisted, 2001), other studies have shown intact prototype formation in ASD (Molesworth, Bowler, & Hampton, 2005; 2008), and still another found intact prototype formation but impaired generalization (Froehlich, Anderson, Bigler, Miller, Lange, DuBray, Cooperrider, Cariello, Nielsen, & Lainhart, 2012). These conflicting results could be due to the differing functional levels of the participants, as well as methodological differences between the studies. When Molesworth and colleagues (2008) employed the same methodology as Klinger and Dawson (2001) but with higher functioning participants with ASD, they not only found overall support for their earlier finding of intact prototype formation in ASD, but they also found that there was great heterogeneity on task performance, with about a third of their participants failing to show any prototype effect at all. This finding alludes to the problem of conducting research within this population, since task performance depends on the functioning level of the participants.

Another study looking at concept formation found evidence that high-functioning individuals with ASD have difficulty abstracting information (Minshew et al., 2002). These authors included measures of concept formation (the Stanford-Binet Absurdities Test, the 20 Questions task, and the Goldstein-Scheerer Object Sorting Test), measures of concept identification (the Halstead Category Test and the Trail Making Test Part B) and a measure testing both concept formation and identification (the Wisconsin Card Sorting Test; WCST) and used factor analysis to find a dissociation between the concept formation and the concept identification components of abstraction. In the ASD group, a three factor solution was obtained; the first factor receiving salient loadings from the 20 Questions task, and the Stanford Binet Picture Absurdities and Verbal Absurdities subtests; the second factor receiving loadings from the WCST measures; and the third factor receiving high loadings from the Halstead Category Test and the Trail Making Test Part B. In the control group, however, only a two factor solution was obtained; the first factor including all of the tests except for the Halstead Category Test and the Trail Making Test Part B, which loaded onto the second factor. Therefore, the authors found evidence for their hypothesis that there is a dissociation between concept formation and concept identification abilities that accurately describes the abstraction deficit in ASD.

All of the findings from these studies that have focused on more complex aspects of categorization or concept formation point to the possibility that simple categorization tasks, assessing perceptual constructs such as form, color, and shape, by utilizing sorting and matching-to-sample methods are unable to capture the differences in how children with ASD are using categories differently than others. Merely testing category skills may not be getting at how children with ASD are processing this information differently.

It appears that the studies that have looked at categorization from one perspective only (e.g., sorting, matching-to-sample, etc.) have found no deficits in children with ASD, while those studies that have considered categorization as involving more than simple sorting or matching, have found some differences in the way in which children with ASD categorize (Klinger & Dawson, 1995, 2001; Shulman et al., 1995). Additional evidence that children with ASD may categorize differently than TD children comes from a developmental study which examined exemplar typicality on reaction time and accuracy of categorization (Gastgeb, Strauss, & Minshew, 2006). Children, adolescents, and adults with ASD were shown pictures of objects that were either the most typical, the least typical, or somewhat typical of their category. All of the age groups (along with matched, typical controls) were then tested on their knowledge of whether these objects did or did not belong to either natural (cat, dog) or artifact (couch, chair) categories. The results showed that children, adolescents, and adults with ASD all responded more slowly than typical controls to atypical category members, indicating slower processing of categories that seem to persist through adulthood.

Another area in which individuals must use knowledge of whether or not something fits into a typical category is in the perception of faces and facial expressions. Children and adults are quite adept at perceiving different kinds of faces and facial expressions. People are so proficient in this area that they can recognize faces and expressions in seconds, a skill that does not require any explicit teaching. There are three aspects of processing faces: perceiving the features that define faces (e.g., two eyes, a nose, and a mouth), assessing those features holistically, and processing the second-order relations, or spacing among those features (Maurer, Le Grand, & Mondloch, 2002). In this way, recognizing a face is more complex than one might think. Are children with ASD able to process faces as are others, and are they able to categorize expressions as happy, sad, or angry?

A study that focused on the second-order relations, or spacing of facial features, found a deficit in individuals with AS (Katsyri, Saalasti, Tiipana, von Wendt, & Sams, 2008). Any image can be broken down into spatial frequency components that represent different levels of details; higher spatial frequencies represent more local or individual features and lower spatial frequencies represent more global or holistic-level features. The authors evaluated the recognition of four static and dynamic basic emotions (anger, disgust, fear, and happiness) from varying levels of low-spatial frequencies (by using either slight, strong, or no filtering) in participants with AS and matched controls. The results revealed that participants with AS did not differ from the control group in identifying emotional expressions from the non-filtered or slightly filtered displays. Only in the strongly filtered condition, individuals with AS displayed a deficit in recognizing emotional expressions as compared with typically matched controls (Katsyri et al., 2008). As a result, preliminary evidence indicates that at least one aspect of processing faces may be impaired in individuals with ASD.

Another study assessed second-order processing and holistic processing in adults with ASD as compared with TD controls (Wallace, Coleman & Bailey, 2008). For the holistic processing task, 90 pictures of faces and 90 pictures of cars were flashed sequentially as pairs on a computer screen for either 40, 70, or 100 milliseconds, afterwards which the participant was asked whether the two images in the pair were the same or different. The second-order processing task had 20 pictures of faces and 20 pictures of houses, which were each altered in the same way; in the face pictures, alterations were made by both moving the eyes and cropping the mouth a certain distance, and in the pictures of houses, the upstairs and downstairs windows were shifted. The result was two test faces from one original face (and likewise for the house pictures). After participants were shown sequential pairs of faces or houses (half being the same and half being altered), they were asked again to identify whether the two images were the same or different. Both of these tasks had similar results: participants with ASD performed significantly worse than matched controls on the pictures of faces only (Wallace et al., 2008). Another study using fMRI to map activation in the visual ventral cortex of adults with ASD in response to faces, houses, and common objects, found group differences in adults with ASD only in response to faces (on both an experimental and a more naturalistic paradigm; Humphreys, Hasson, Avidan, Minshew, & Behrmann, 2008). Overall, these studies show an impairment of processing faces in ASD.

Although there is ample evidence that individuals with ASD differ from others in their perception of faces, what about facial expressions? Several studies assessing this ability found varying deficits in individuals with ASD (Hobson, Ouston, & Lee, 1988; Teunisse & de Gelder, 2001). One study tested emotional facial expressions (happy, unhappy, angry, and scared) by having participants with ASD match photographs of faces to the corresponding emotion, with full-face oval photographs, photographs in which the mouth had been blanked out, and photographs in which the mouth and forehead had been blanked out. The results suggested that as the emotional cues (the mouth, forehead) were taken away, the participants with ASD were less able (than matched controls) to infer emotion in the photographs, although they were just as likely to identify the same person among the photographs (Hobson et al., 1988). Therefore, the lack of the forehead and mouth had a detrimental effect on their ability to recognize emotion, but not identity. The second experiment utilized the same procedure, except the photographs of the faces were inverted (i.e., upside-down). The participants with ASD scored significantly better than matched controls, showing that they were able to match emotion and identity using photographs of inverted faces, while typical controls were not (Hobson et al., 1988). This finding is of interest because it shows that when one disrupts facial configurations enough (by inverting faces rather than blanking out certain features), typical individuals cannot use those emotional cues to interpret faces. In contrast, individuals with ASD appear to be focusing more on matching patterns of features, which is why they are more successful when faces are inverted, than when specific features are blacked out. In a more recent study, it was found that on both a discrimination and identification task using realistic photo stimuli of three expression continua, adults with ASD were unable to perceive facial expressions categorically (Teunisse & de Gelder, 2001). From these studies it is clear that there are striking differences in the way that individuals with ASD process and interpret or understand emotional facial expressions.

Is there any indication from the diagnostic criteria that there may be a categorization deficit that is unique to ASD? Put differently, if we analyze each of the two impairments of ASD, does it seem plausible that categorization may also be deficient, or at least developing differently as compared with TD individuals? To answer this question, let us examine the characteristics of ASD.

Autism Spectrum Disorder: Two Impairments

ASD is a pervasive developmental disorder that has two main impairments. The first core impairment is in social communication and social interaction across multiple contexts and is manifested by the following: deficits in social-emotional reciprocity, deficits in nonverbal communicative behaviors used for social interaction, and deficits in developing, maintaining, and understanding relationships. The second impairment is the presence of restricted, repetitive, and stereotyped patterns of behavior, interests, and activities as manifested by: stereotyped or repetitive motor movements, use of objects, or speech; insistence of sameness, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior; highly restricted, fixated interests that are abnormal in intensity or focus, and hyper- or hyporeactivity to sensory input or unusual interest in sensory aspects of environment (American Psychiatric Association, 2013).

If one were to break down each of these impairments, it is apparent that categorization impacts each of these abilities (or inabilities). The first impairment is a deficit in social behavior and social communication. How do children with ASD interact with others? And how may these behaviors affect categorization? Kanner stated that the fundamental disorder is the children's "*inability to relate themselves* in the ordinary way to people and situations from the beginning of life" (1943, p. 242). According to Kanner, the social impairment characterized the most significant impairment of autism.

Social interaction is crucial for development from birth onwards and is linked with various skills that one acquires throughout life. The few unfortunate examples of children who managed to develop without substantive social interaction from an early age have proven that the consequences of such an isolated life are dire. Arguably the most famous case documented was that of Victor, who emerged out of a forest in France in 1800 as a young child. One of the developmental outcomes of his early existence was an inability to develop communicative language (Lane, 1979). Victor's upbringing and subsequent development, which fascinated psychologists, philosophers, linguists, sociologists and countless others in many fields, illuminated the importance of social interaction, especially on language development. Even if Victor could not develop meaningful language, does this mean he could not categorize? Certainly not. To some extent, his survival depended on his ability to categorize his surroundings. For example, knowing what was edible was crucial. Had he been exposed to people and developed social relationships, then this would have had beneficial consequences on other aspects of his development. Unlike the circumstances of Victor and other feral children, children with ASD have ample opportunities for social interaction and yet, they do not normally interact with others either from a lack of desire or a lack of skills. What are the developmental precursors to these social impairments?

It is apparent that from a very early age, TD infants are social creatures. Social interactions influence categorization skills via observation, teaching, and cultural transmission. From birth to six weeks of age, infants show a sensitivity towards social stimuli (Rochat & Striano, 1999). Specifically, infants show an interest in people, looking at the features, movements, and sounds of the human face (Maurer & Salapatek, 1976). Young children with ASD are less likely (than both TD and developmentally delayed children) to orient to both social and nonsocial auditory stimuli and this orienting impairment is more severe for social stimuli (Dawson, Toth, Abbott, Osterling, Munson, Estes, & Liaw, 2004). If children with ASD do not naturally orient towards people and faces, then it would seem that they might also have difficulties using the gaze and attention of others to learn about objects and people in the world, that is, joint attention.

Joint attention is defined as the simultaneous engagement of two or more individuals in mental focus on the same external thing (Baldwin, 1995) and involves a number of social-communicative acts on behalf of the infant: being able to follow its mother's gaze and gestures to determine the mother's focus of attention, alternating gaze between an object or event and the mother's gaze, and pointing to and showing objects to capture its mother's interest. These early behaviors typically develop around 9–15 months of age and are an important social milestone in the infants' understanding of objects and people (Siller & Sigman, 2008). It has been well documented that children with ASD have significant deficits in joint attention, which in turn, adversely affects their understanding of objects and people (Charman, Swettenham, Baron-Cohen, Cox, Baird, & Drew, 2003; Dawson et al., 2003; Sigman & Ruskin, 1999).

There is a great deal of evidence that in addition to affecting knowledge of objects and other people, joint attention is also linked with another important skill, the development of communication. In typical development, it is through joint attention interactions that the infant begins to link words and sentences with objects and events (Baldwin, 1995). Also, it has been established that joint attention is a precursor to language development (Desrochers, Morissette, & Ricard, 1995; Sigman and Kasari, 1995). Is the link between joint attention and language as robust in ASD? Numerous studies have shown that in children with ASD, joint attention is predictive of both current language ability and future gains in expressive language skills (Charman, et al., 2003; Mundy, Sigman, Ungerer, & Sherman, 1987; Sigman & Ruskin, 1999).

How could these early social behaviors be linked with categorization? As stated earlier, infants naturally look towards people, and specifically towards faces, very early on in development. Orienting towards social beings is not only comforting for infants, but it is also important in teaching infants about the myriad objects and events in the world. If infants and young children with ASD are not inherently inclined to look towards others' faces, then they will not follow others' gaze, nor share gaze focused on other objects, nor share attention of those objects with others. And if they do not engage in these behaviors, then they are less likely to start labeling those objects, using language to communicate about those happenings.

The other part of the core impairment of ASD is a delay, or lack of, spoken language. Oftentimes, parents of children with ASD first become concerned about their children's development when their speech is either delayed or absent (Wetherby, Woods, Allen, Cleary, Dickinson & Lord, 2004). The picture is not so clear, however, across all children with ASD. There is great heterogeneity in the language of children with ASD ranging from a complete lack of verbal behaviors to idiosyncratic language use that can appear quite normal (Wetherby, 2006). The proportion of children with ASD without any spoken language has been estimated anywhere from 25% to 50% (Lord, Risi & Pickles, 2004). Yet those with ASD who are able to develop language often find difficulty with the symbolic and communicative aspects of language, expressing a range of problems including impaired or absent gesture-use, echolalia, and difficulty following pragmatic and grammatical rules (Wetherby, 2006).

It is a momentous occasion when an infant or toddler begins to speak. Before one utters one's first words, one engages in a number of communicative acts, including coordinating attention between people and objects, engaging in social exchanges, and communicating with others by using gestures, such as pointing, that have common meanings (Bates, O'Connell, & Shore, 1987). As stated earlier, these joint attention skills have been shown to be impaired in ASD. Moreover, a number of longitudinal studies have shown a relationship between joint attention abilities and later language outcomes, strongly suggesting that if a child is not looking towards others nor using gaze to interact, then it is unlikely that this child will use language to communicate as would a TD child.

What other early social-communicative behaviors are impaired in ASD? When a child needs or wants something, one often directs one's attention to others in order to relay this information to them. Children with ASD often use gestures to communicate their wants or needs (also called proto-imperative gestures), but they rarely use gestures to simply share information with others (also called proto-declarative gestures; Tager-Flusberg, 1996). When children with

ASD start using spoken language, it seems that they do not use language functions (or speech acts) in the same way as TD children. Children with ASD rarely use language to share information with other people, nor do they ask information from others (Tager-Flusberg, 1996). This link between social development and language development is strong in both typical and atypical populations.

Children with ASD who go on to develop spoken language often acquire expressive language between 2–6 years of age (Paul & Wilson, 2009). But even in this subgroup, there is considerable heterogeneity. Some children with ASD who develop language may be extremely delayed, with some cases of children developing language in adolescence (Paul & Wilson, 2009). Others may have profiles similar to that of children with specific language disorders who are not on the spectrum (Tager-Flusberg & Joseph, 2003), and still others may develop normal and even precocious language (Tager-Flusberg, Paul & Lord, 2005).

One of the most salient aspects of the language impairment in ASD affects pragmatics (Baltaxe, 1977), which are the rules for specifying how language is used appropriately in different social contexts. Although they may have above average skills in language form (i.e., sound production, grammar) and/or content (i.e., vocabulary), children with ASD may have difficulties with such pragmatic skills as taking turns, greeting others, and following along with conversational rules (Paul & Wilson, 2009). Children with ASD are often unresponsive to the conversational bids of others. When they do respond to others' initiations, they offer little to the ongoing discourse, have difficulty sustaining the conversational topic, or offer irrelevant comments (Tager-Flusberg & Anderson, 1991). The pragmatics impairment is useful in illuminating categorization because it reveals the social nature of language. If children with ASD have difficulty with joint attention, social-communication and pragmatics, then there could be an intertwined categorization impairment as well, since it would appear that much of categorization depends on social interactions and language.

How might the language impairment be related to categorization? If one does not have language, or is developing abnormal language, then being able to categorize the world effectively becomes a lot more difficult and tedious. As stated earlier, there is a link between language and conceptual development in typical development (Balaban & Waxman, 1997; Booth & Waxman, 2002; Booth, et al., 2005; Gelman & Markman, 1987; Xu, 2002), such that the two systems are intertwined. If there were a categorization impairment, it might go hand-in-hand with a language impairment. After all, one extends language to new situations based on categorization skills, whether the categories are object, action, or event based.

The second impairment of ASD is the presence of repetitive and stereotyped behaviors (RSBs). The first documented descriptions of these behaviors came from Kanner (1943), who described both object and body stereotypies, including spinning, jumping, and other rhythmic movements of the body. Despite the fact that RSBs are a core diagnostic feature of ASD, much less is known about them as compared with the social and communication areas (Lewis & Bodfish, 1998; Turner, 1999). There are several possible reasons for this lack of attention. First, RSBs are not unique to ASD, being prevalent in a wide variety of developmental disabilities, psychiatric disorders (e.g., schizophrenia), and neurological disorders (e.g., Parkinson's disease, Tourette's syndrome; Lewis & Bodfish, 1998). Second, there is considerable heterogeneity in RSBs in those with ASD, making it difficult to delineate how these behaviors function. Third, there lacks a single, uniform measure of RSBs in the field, making comparisons among studies complicated. Finally, there are few studies that explain how young, TD infants and children use these behaviors, which differs from how they are used in ASD (Cuccaro, Shao, Grubber, Slifer, Wolpert, Donnelly, Abramson, Ravan, Wright, DeLong, & Pericak-Vance, 2003; Turner, 1999).

Repetitive behaviors can vary widely in ASD and can include stereotypy, rituals, compulsions, obsessions, insistence on sameness, echolalia, self-injury, tics, dyskinesia, akathisia, and perseveration (Lewis & Bodfish, 1998). What are some possible implications for the use of repetitive or stereotyped behaviors in early childhood? TD infants in the first year of life engage in a number of repetitive behaviors including kicking, waving, banging, twirling, bouncing and rocking (Thelen, 1979), with many of these behaviors relating to objects. At around 3–4 months, TD infants begin to attend to, grasp, manipulate, and inspect distant objects (Trevarthen, 1979, 1988). Infants' exploration of objects tends to get more advanced by about six months, giving them information about the nature of different objects and the relationships between them (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). This object exploration is referred to as manipulative play, the first developmental step in children's play. Manipulative play is sensorimotor in nature, allowing infants to handle objects by feeling, licking, sniffing, turning them around, throwing them away, etc. (Williams, 2003). At 13–15 months, infants begin to engage in the second developmental play skill, functional play, defined as using an object in accordance with its socially designated function, for example, flying a toy airplane in the air (McDonough, Stahmer, Schreibman, & Thompson, 1997; Williams, 2003). At this age, the child understands what certain, common objects are and how they function, exhibiting this knowledge through play. Finally, at around 24 months, spontaneous symbolic play develops in which the child uses pretend play, for example, using a banana as a telephone. This advanced type of play has been considered important by many theorists, including Piaget (1962), who deemed pretend play (along with language and deferred imitation) the onset of children’s ability to represent objects, events, and behaviors that are required but not available—indicating their use of symbolic activity.

Due to the difficulty of testing very young infants with ASD, it is hard to assess play behaviors at a young age. However, one study, which examined atypical object use in a group of 12-month-old infants (later diagnosed with autism), found that the autism group displayed a number of atypical object use behaviors, especially unusual visual object exploration, defined as either engaging in prolonged visual inspection (>10 seconds), examining objects from odd angles or peripheral vision, or squinting/blinking repeatedly while examining the object (Ozonoff, Macari, Young, Goldring, Thompson, & Rogers, 2008). Also, several of these indicators of atypical object use at 12 months significantly predicted Autism Diagnostic Observation Schedule (ADOS) scores, and four subscales of the Mullen Scales of Early Learning (fine motor, visual reception, and expressive and receptive language) at 36 months, highlighting unusual visual exploration as an early diagnostic indicator of ASD (Ozonoff et al., 2008). Another study examined restricted object use, defined as action schemata and/or toy preferences that are restricted in range and make up a large portion of the child's differentiated intentional actions directed towards objects. The authors found that in children with ASD, the more time that is spent in restricted object use, the less aware that children with ASD are of adult attentional directives, adult prompts, and models to imitate (Bruckner & Yoder, 2007). These results show that children with ASD who are inappropriately focused on objects are less likely to attend to adults, thereby showing less coordinated attention between objects and people.

A number of studies have found deficits in the play behaviors of young children with ASD. There is a lot of disagreement about functional play; several studies have shown no deficit (Baron-Cohen, 1987; Charman & Baron-Cohen, 1997), while other studies have shown differences in the functional play of children with ASD (Lewis & Boucher, 1988; Sigman & Ungerer, 1984). Jarrold has reviewed the literature on symbolic play, concluding that abnormalities in symbolic play among children with ASD are not restricted to delays in the emergence of such play, nor can they be characterized as a straightforward inability to symbolize (2003). The developmental picture is complex because it appears that children with ASD can indeed demonstrate knowledge of pretend and symbolic events, even though they may rarely spontaneously do so (Charman & Baron-Cohen, 1997; Hobson, Lee, & Hobson, 2009; McDonough et al., 1997).

Overall, a presence of repetitive and stereotyped behaviors may be associated with an impairment in categorization. As stated earlier, some evidence has shown that infants and young children with ASD are interacting with objects differently than are TD children. Of course, all young children engage in repetition during their development. One needs only spend an afternoon with a toddler to appreciate how opening and closing a door over and over again is leading to the child's understanding of how objects, and more specifically, doors, move and how they function. Unfortunately, it seems that children with ASD get stuck in this developmental course, and their fascination with certain parts of objects takes an abnormal course. If children with ASD are busy spinning a top in the light of a window, flapping their hands at the sound of a school bell, or obsessing over the school bus' route to school, then it is a wonder how they learn about objects and how those objects function in the world. Being preoccupied with certain objects does not necessarily imply a categorization impairment. However, it does lend evidence that perhaps children with ASD are learning about objects and categorizing them quite differently than are others. As can be seen, each of the two impairments has implications for categorization.

A Theoretical Account of ASD: Weak Central Coherence Theory

Due to the heterogeneous nature of the disorder, it has been daunting for researchers to explain the underlying cause of ASD. Besides the two main impairments, there are a host of related impairments that are prevalent in ASD. There have been many psychological explanations, but only one, weak central coherence theory, best explains the entire picture of ASD. Central coherence is a term that Uta Frith first coined that describes how individuals process incoming information (1989; Happe, 1999). TD children and adults tend to look for meaning in global form, often at the expense of attention to or memory for details. Individuals with ASD are hypothesized to show weak central coherence, exhibiting a processing bias for featural and local information, along with a relative failure to see the big picture in everyday life. Weak central coherence theory posits that this global processing feature that is typical of people is disturbed in individuals with ASD, who show a more detailed-focused processing. This different processing style leads to children and adults with ASD to show a preoccupation with details and parts, while failing to extract the gist or meaning of a given situation. Kanner (1943) also noted this weak central coherence, stating that a universal feature of ASD is the "inability to experience wholes without full attention to the constituent parts" (p. 243).

How is this processing bias manifested in individuals with ASD? Children with ASD have processing differences in a number of perceptual modalities, in addition to spatial and verbal modalities (Happe, 1999; Happe & Frith, 2006). They perform faster than matched controls on the Embedded Figures Test, in which individual shapes have to be found within a larger pattern (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983). Additional strengths of children with ASD include relatively good performance on certain subtests of the Wechsler scales (Wechsler, 1974, 1981), such as Block Design and Object Assembly (Shah & Frith, 1993), and good performance on the Figure Ground and Form Completion subtests of the Leiter International Performance Scale-Revised (Kuschner, Bennetto, & Yost, 2007; Leiter-R; Roid & Miller, 1997). Furthermore, individuals with ASD display a failure to disambiguate homographs using surrounding word context (e.g., pronouncing tear in "In her eye/dress there was a big tear"; Happe, 1997), a difficulty in enumerating canonical patterns when counting (Jarrold & Russell, 1997), and a tendency not to perceive visual illusions (Happe, 1996). All of these cognitive strengths and weaknesses seem to be best explained by a preference for processing at the local level, at the expense of the larger, gestalt level. Weak central coherence theory also seems to best explain savant skills (occurring in approximately 1 in 10 individuals with ASD; Happe, 1999), in areas such as puzzles, music, art, calculation, and memory.

Other theories which attempt to explain the disorder include the theory of mind deficit (Baron-Cohen, 1995; Baron-Cohen, Leslie, & Frith, 1985), which claims that individuals with ASD are delayed in their ability to ascribe beliefs and desires to others in order to predict their behavior, and the executive dysfunction hypothesis (Normal & Shallice, 1986; Ozonoff, 1995) which states that people with ASD fail to guide their behavior with reference to internally specified goals, as opposed to external stimulation. Both of these theories have explanations for the main impairments, however, they fail to explain the various strengths of some individuals with ASD. The notion of weak central coherence in favor of more detailed-focusing processing is one of the only theoretical accounts accounting for strengths of those with ASD, and has been received with enthusiasm and immediate recognition by the ASD community (Happe & Frith, 2006).

To summarize, children with ASD are not focusing on the global context in their everyday lives, but on the smaller, more local details. This has been shown through various studies in both the visual and auditory domains, with individuals with ASD demonstrating the following: stable memory for exact pitches (Heaton, Hermelin, & Pring, 1998), enhanced local processing of music stimuli (Heaton, 2003), raised thresholds for perceiving coherent motion (Betrone, Mottron, Jelenic, & Faubert, 2003), and superior visual search (Plaisted, O'Riordan, & Baron-Cohen, 1998). As compared with these perceptual domains, there is evidence in the conceptual domain that children with ASD are less able to extract meaning from a given array of information. One example comes from Tager-Flusberg (1991), who found that children with ASD, as opposed to both TD and learning disabled children, were not facilitated in immediate free recall by the semantic similarity in a list of nouns. Another study utilized a between-groups analysis, concluding that children with ASD, as compared with TD and developmentally delayed children, displayed an emerging pattern of relative strengths on Figure and Ground and Form Completion and a relative weakness on the Repeated Patterns subtests of the Leiter-R (Kuschner et al., 2007). This last study points to the differences in nonverbal cognitive functioning of children with ASD, highlighting how certain perceptual tasks are a strength, while certain conceptual tasks are a weakness for children with ASD.

If children with ASD are not attending to the same objects and events as are others, then it may follow that they are not learning about object categories in the same way as are others. As discussed earlier, TD infants and young children learn from a variety of different experiences, constructing meaning along the way. They come to understand what constitutes food and what constitutes a toy from attending to these different things in their environment and their experiences with them. And yet, the evidence has shown that children with ASD have different experiences; socially, communicatively, and with a reliance on repetitive actions/events in their environment. It may be that in having these different experiences, they are relying more on perceptual processes in developing knowledge of object categories. Ironically, it is possible that Rosch's theory of category development may be more appropriate for children with ASD, with their primary focus on perceptual similarity that allow basic level categories to have the highest cue validity. If this were an accurate description of their categorization skills, then children with ASD might show a different developmental pattern of categorization (as compared with TD infants and children). In typical development, infants and young children first differentiate superordinate level categories, and later come to differentiate basic level domains within those categories, on the basis of conceptual knowledge. Perhaps children with ASD are so focused on details that they differentiate categories in a more bottom-up process, first differentiating basic level or even subordinate level categories, and later coming to differentiate more superordinate level categories, by focusing more on perceptual differences. As compared with children with ASD, TD infants and children have so many more advantages in their experiences with people and objects in the world, developing categories as they develop themselves.

Overall, there are limitations with our current knowledge of categorization in ASD. It is difficult to come to a consensus about how children with ASD form categories, since most studies tend to regard categorization as a one-dimensional concept. The results from early studies looking directly at categorization found no differences in ASD (Tager-Flusberg, 1985a, 1985b; Ungerer & Sigman, 1987). Later studies, testing more complex aspects of categorization found unique problems in children with ASD (with some problems shared with children with DS as well; Klinger & Dawson, 1995; Minshew et al., 2002; Shulman et al., 1995). And yet, the results seem to depend on which segment of the spectrum of autism is tested and which control groups are used. This is problematic in that there is far from definitive evidence of whether children with ASD have difficulty forming object categories. By considering categorization as a developing multidimensional process, affected by other developing systems (language, social development, repetitive behaviors), it appears that another look into categorization in ASD is warranted.

Another limitation with the current literature is that the vast majority of studies have utilized high-functioning children or adults with ASD at different developmental levels. What is troubling is that ASD is a heterogeneous disorder. It is unclear if there are any meaningful differences in the way in which different subgroups within ASD might be categorizing. Besides having high and low functioning distinctions (related to IQ or developmental level), there are also children who display a range of communicative abilities, from those that are nonverbal to fairly precocious language speakers.

In studying object categorization in typical development, Bornstein and Arteberry (2010) utilized the sequential touching methodology to assess superordinate, basic, and subordinate categories within four domains (animals, vehicles, fruit, and furniture) in TD children from 12- to 30-months of age. They found evidence of a clear developmental pattern of more inclusive categorization (i.e., superordinate) developing prior to less inclusive categorization (i.e., basic and subordinate). While not developmental in nature, the present research has a similar structure to Bornstein and Arteberry, except that the present study used multiple tasks or methods. Ultimately, this project will be expanded, mimicking the methodology of Bornstein and Arteberry in utilizing several ages to assess categorization developmentally.

Purpose of this Dissertation

The goal of this research was to examine categorization abilities of young children with ASD, across multiple levels, stimuli, and methods (or tasks). The pilot study was conducted first to confirm if these categorization tasks were indeed appropriate for the population with ASD. In the pilot study, only basic and superordinate level categorization were assessed in five participants utilizing four categorization tasks: object examining, sequential touching, generalized imitation, and sorting tasks. The object examining task was found to be inappropriate for children with ASD, so the main experiment was conducted with three tasks: sequential touching, generalized imitation, and sorting tasks. Within each task of the main experiment, superordinate, basic, and subordinate categorization were tested in three domains (animals, kitchen utensils, and tools) across children with ASD.

The main research question addressed in this research is how do children with ASD form categories? Do they form categories in a top-down progression as do TD children, using conceptual knowledge to distinguish superordinate level categories before basic level and subordinate level categories (Mandler & McDonough, 1993, 1998a, 1998b, 2000)? Or are children with ASD forming categories in a more bottom-up progression by using perceptual differences to distinguish basic level and subordinate level categories before superordinate level categories (Rosch et al., 1976)?

Another research question focuses on whether or not this categorization process differs by domain. Do children with ASD categorize natural kinds and artifacts differently? In the literature, there are mixed results concerning how children with ASD distinguish between animate and non-animate objects. Several studies have found that individuals with ASD fail to see social motion as do TD individuals (Blake, Turner, Smoski, Pozdol, & Stone, 2003; Klin, 2000; Moore, Hobson, & Lee, 1997). Other studies have found no difficulty in detecting animate motion (Johnson & Rakison, 2006; Murphy, Brady, Fitzgerald & Troje, 2009). One study testing whether children with ASD use motion to identify animacy found group differences (Rutherford, Pennington, & Rogers, 2006). Using a novel paradigm involving geometric figures, the authors found evidence only in the training phase that children with ASD take longer to consistently distinguish animate from non-animate moving geometric figures, as compared with TD children and children with developmental delay. In the testing phase, however, children with ASD performed similarly as the two control groups once criterion was reached, suggesting that either children with ASD are able to form quick, compensatory strategies, or that they need to be primed in order to use such information.

Besides those main research questions which were the focus of the current study, the role of language in developing categories was also assessed. Specifically, do language skills and categorization abilities positively correlate in children with ASD?

CHAPTER II. PILOT STUDY

Method

Participants

Five children (3 males and 2 females) with ASD were assessed in this pilot study. Their mean chronological age was 7.0 years, ranging from 5 to11 years. Having a wide range of ages and abilities was thought to be useful in this initial study as there had been no systematic or thorough analyses of categorization abilities in this population to date. The children attended a school that was started for ASD and other developmental disabilities. Written parental consent was obtained for each child. Due to experimenter error, one child's date of birth is missing, so age is approximated since only the birth year is known (see Tables 2 and 3).

Stimuli

In each task, 3-dimensional miniature replicas of real objects in each of the categories were used. The objects included animals, vehicles, musical instruments, tools, dogs, cats, cars, and trucks. Stimuli are listed in Appendix A.

Design and Procedure

In this pilot study, the goal was to ascertain whether four different categorization tasks were appropriate for children with ASD. Each task tested both a basic level and a superordinate level contrast. The superordinate contrasts were between animals and vehicles, and musical instruments and tools. The basic level contrasts were between cats and dogs, and cars and trucks. Testing occurred in several sessions over the course of six months. Each session occurred at the child's school, during the school day. At each session, the child received a combination of the object examining task, sequential touching task, generalized imitation task, and sorting task.

There were a total of eight tasks per child. Each session was videotaped for later scoring. During each testing session, the child was seated at a table opposite the experimenter.

Object examining task.

In the object examining task, participants were familiarized to four of the five exemplars from one category. Each of the four exemplars was placed on a table in front of the participant one at a time. The participant was allowed to touch, examine, and/or explore the object for 20 seconds. After 20 seconds, the experimenter simultaneously took away the object, trading it with another object from the same category for another 20 seconds. This pattern continued, with the child examining four separate objects from the same category. The experimenter then repeated this process, so that the child viewed the set of four objects twice (totaling eight trials). The experimenter then gave the child a first test object, which was the fifth previously unseen object from the familiarization category. Lastly, the second test object was presented, which was a previously unseen exemplar from a contrasting category. All of the objects were counterbalanced (as much as possible) across children.

The sequential touching task.

The sequential touching task was administered by placing eight objects in a random fashion on a tray, four objects from one category and four objects from a different category. The experimenter then pushed the tray in front of the child and said, “Play”. The child was then allowed to play with all of the objects freely for two minutes. If the child dropped an object onto the floor, the experimenter replaced the object within reach. After the two minutes elapsed, the experimenter ended the task by retrieving the objects. This was done by having the child sort the eight objects into two separate containers (see sorting task). The superordinate contrast was musical instruments vs. tools and the basic contrast was cars vs. trucks.

Sorting task.

The experimenter administered the sorting task directly after the two minutes of the sequential touching task had elapsed. The tray with eight objects (four from one category and four from another category) was on the table in front of the participant. The experimenter then placed two boxes on the table, one on either side of the tray, and then picked up an object from the tray from one category and showed it to the child saying, “See this? It goes here”, as the object was placed in one of the two boxes. The experimenter then showed the child another object from the tray from a different category, saying the same thing while placing the object in the second box. At this point the experimenter returned the objects to the tray, saying, “Your turn. Put the objects away”. The superordinate contrast was musical instruments vs. tools and the basic contrast was cars vs. trucks.

Generalized imitation task.

For the generalized imitation task, participants were first given a warm-up task, which was stacking three soft blocks, and then knocking them over. Participants were encouraged to imitate this action and were praised for doing so.

The experimenter then brought out a modeling exemplar and a prop and demonstrated an action. There were two actions demonstrated typical of animals (sleeping and drinking) and two actions performed typical of vehicles (keying and riding). For example, the action of sleeping was demonstrated using a dog (modeled exemplar) and a bed (prop), by placing the dog into the bed. The experimenter then patted the dog along with the appropriate vocalization of “night, night”. This action was repeated three times in three different positions around the table to ensure that the child was attending to the action. The experimenter then removed both objects from view and placed three objects in the middle of the table. One item was the prop used in the demonstration (bed) and it was placed in the middle of the table. The two new exemplars were placed on either side of the object (with side counterbalanced), one of which was from the same superordinate category as modeled (e.g., bird), and one from a different superordinate category (e.g., airplane). After the three objects were placed on the table, the experimenter said, “Your turn. Night, night”, in order to persuade the child to imitate the activity. In the example used, the bird is a better selection than the airplane because birds sleep (a quality of being an animal) but airplanes do not. In the basic level, a different kind of contrast was used. As before, the experimenter would model sleeping with a dog (for example) but the test items were from the same domain (e.g., a different dog and a cat). In this task, the focus was on if the child could imitate the action, and which item the child would select first to demonstrate that action. Since both dogs and cats sleep, either would be an appropriate choice. However, if the child noted the modeling exemplar, the child would be more likely to choose the different dog rather than the cat.

Scoring

Two coders coded data across all four tasks and reliability exceeded 90%. For the object examining task, the examining times were recorded for each of the objects. The dependent measure was the child’s examining time with the hypothesis that the child would examine the test item from the new category longer than the test item from the old category. It should be noted that examining is not the same as merely looking at an object. Ruff (1984, 1986) found different behavioral patterns between looking and examining that indicate different kinds of ‘attentive states.’ More recent research by Elsner, Pauen and Jeschonek (2006) showed that these different states are also marked by physiological differences in heart rate.

For the sequential touching task, every object that the child contacted, either by hand or with another object, and the order in which the objects were contacted, was coded. The dependent measure was the order in which the child selected each of the items to touch, examine, or manipulate. If the child noticed that there were items from two different categories, the child should selectively examine items from one category and then move on to items from the contrasting category in a sequential fashion (Ricciuti, 1965; Sugarman, 1983). The rationale (based on extensive research with TD children) is that if the children touch the objects from a given category in sequence more often than expected by chance, they must be doing this because of their relatedness. There are two measures for analyzing their sequential touching. The first measure of categorization was the mean run length (MRL), which was calculated by dividing the total number of touches a child exhibits by the number of runs. Runs are sequences of touches to objects from within one category; a run of three touches would indicate that the child touched three items from one of the categories and then began touching an item from the other category. The longest possible run is the total number of touches if a child touches items from only one category. The MRLs were compared to chance (1.75; see Mandler, Fivush, & Reznick, 1987) to establish whether the children responded to the category more than would be expected by chance. When children as a group touched objects from the same category at run lengths greater than chance, it follows that children as a group categorized.

The second measure is a more qualitative measure of individual categorization. To assess individual categorization, the percentage of children in a group who are categorizers was computed using a Monte Carlo program (Mandler et al., 1987). Individual children were considered categorizers if their run lengths included three or four different objects from one of the two domains presented. Because a run of touching multiple objects in a row can occur by chance, especially when a child makes a lot of touches, the Monte Carlo program determines the likelihood of such occurrences. The program computes how often categorizing runs occur in 10,000 random draws. Repetitions are allowed (excluding touches to the same item in immediate succession) as long as the run includes three or four unique objects. This technique estimates the probability of one or more categorizing runs occurring by chance, as a function of the total number of items the child touched (Mandler, et al., 1987).

For the sorting task, coding consisted of the participants' choice of stimuli to sort into the two separate boxes. The dependent measure was the choice of stimuli used to sort the objects. The results are expressed in terms of the proportion of correct sorting, out of eight trials.

For the generalized imitation task, coding included performance (or nonperformance) of the properties and the exemplar used (Mandler & McDonough, 1996; 1998). The dependent measure was the choice of stimuli used to imitate the properties that were demonstrated. First and second choices were noted but only first choices were considered in the results.

Results and Discussion

The data allowed for both quantitative and qualitative analyses and were analyzed both across and within participants. Since there were only five participants in this first study, the data were analyzed mostly qualitatively and each task was evaluated in terms of success and failure.

Object Examination Task

The object examining task was the easiest and most structured task. The structure was such that the first nine trials were composed of items from the same category and the tenth item was from a different category. Thus the child only needed to derive the relatedness of the first trials and note the novelty of the last. Success was measured as longer examining times at the novel category member. For the superordinate level contrast, animals vs. vehicles, one out of five children (20%) succeeded. After being shown a series of animals and then being shown a new animal and a vehicle, 1 out of the 5 children looked longer at the vehicle than the new animal. However, on this superordinate contrast, all five children performed close to ceiling. On the basic level, one child's data were not examined because of experimenter error. Two out of 4 children (50%) succeeded on the basic level contrast, dogs vs. cats. Therefore, after seeing several dogs and then being shown a brand new dog and a cat, 2 out of the 4 children looked longer at the cat than the brand new dog, with one child performing at ceiling (see Table 1).

This task, which is the simplest and most structured of the tasks, shows that children with ASD are slightly more sensitive to the basic boundaries than the superordinate ones. However, since this task has traditionally been used on TD infants (see Mandler & McDonough, 1993; 1998), and this population seems to be performing near ceiling, it appears that this task is not appropriate for older children. It could be that children's repetitive behaviors are interfering with this task, making them selectively attend to parts of the object. It also could be that this task is not appropriate for older children.

Table 1: Mean Amount of Time (in Seconds) Attending to Objects in Object Examining Task

Object	Basic	Superordinate
Object 4	15.6	19.0
Novel Object (from same category)	16.0	19.2
Novel Category	18.4	17.8

Sequential Touching Task

The sequential touching task is not as structured as the object examining task because the child is shown a collection of eight objects at once arranged randomly on a tray. In order to succeed on this task, the child must impose structure on the task, pulling out the differences between the two categories. To determine whether the participants responded to the category differences more than would be expected by chance, two-tailed *t*-tests were conducted, comparing MRLs to chance. Results of the Monte Carlo task were also calculated and are discussed below. Neither the superordinate level: $t(4)=1.02$, $p > .10$, n.s., nor the basic level: $t(4) = 0.37$, $p > .10$, n.s. were statistically significant. Therefore, the children did not systematically respond to the categories greater than would be expected by chance. Since there were only five participants, though, and this measure is used for group performance, this is not that surprising. The Monte Carlo analyses assessing individual categorization are shown in Table 2. As can be seen, on the superordinate level contrast, musical instruments vs. tools, four out of five children (80%) succeeded, while on the basic level contrast, cars vs. trucks, two out of five children (40%) succeeded (with one of those children categorizing at a marginally significant level). This result shows better performance on the superordinate level than on the basic level, a finding that replicates research with younger TD children.

Table 2: Mean Run Length (MRL), P-values Comparing MRLs to Chance on the Sequential Touching Task across the Superordinate and Basic Levels

Participant	Chronological Age (CA)	MRL (Super)	P (Super)	MRL (Basic)	P (Basic)
MM	6, 6	2.15	**p=.01**	2.83	**p=.00**
KB	7, 7	2.56	**p=.00**	1.50	p>.05
JC	6, 0	2.31	**p=.00**	1.76	**p=.06**
MB	6, 6*	1.76	**p=.05**	1.38	p>.05
BH	10, 7	1.18	p>.05	1.76	p>.05

*Approximation

Sorting Task

The sorting task has traditionally been considered a difficult task because it is relatively unstructured and requires the child to shift focus. And yet, it has been used with success in this population (Kaland, Smith, & Mortensen, 2008; Liss, Harel, Fein, Allen, Dun, Feinstein, Morris, Waterhouse & Rapin, 2001; Ropar & Peebles, 2007; Ungerer & Sigman, 1987). Success is measured by the placement of each of the two sets of objects in their correct, respective boxes. One reason why the sorting task is difficult is because play activities sometimes interfere. Children often ignore the instructions (that are both demonstrated and verbalized) to separate the objects into two piles because they merely want to play with all of the objects. In the superordinate level contrast, musical instruments vs. tools, two out of five children (40%) were able to categorize correctly and in the basic level contrast, cars vs. trucks, the same two out of the five children (40%) were able to categorize correctly. The other three children (60%) sorted according to chance levels (50%).

These results do not support or refute the hypothesis either way, as it is difficult to interpret the finding. Several of the children were unable to sort the objects because their repetitive and stereotyped behaviors were impeding on the task. It is tough to say that these children therefore lack knowledge of the two separate categories, just as it would be hard to say that TD children lack that knowledge because they are playing with the objects.

Generalized Imitation Task

The generalized imitation task tested four actions (sleeping, drinking, keying, and riding) for each of the superordinate and basic contrasts. For the superordinate level contrasts, all five children (100%) were able to generalize to the appropriate superordinate category (see Table 3).

For the basic level contrasts, every action was again demonstrated (on a different test day), but two different exemplars were presented to the child; one from the same basic category as modeled (e.g., another dog) and one from a different basic category but the same superordinate category (e.g., a horse). In this way, both objects would be appropriate since both exemplars are animals. For this basic level contrast, all five children (100%) were again able to generalize to both appropriate categories. Also, the order in which the objects were chosen was also analyzed. Four out of the five children (80%) did not show a preference to either the object from the same basic category or the object from the different basic category. One out of the five children (20%) chose the object from the different basic category for all four actions (see Table 3). This task shows that the children are all demonstrating conceptual knowledge of these objects. This finding should not be so surprising, since the ages of the participants were 5-11. Though the other tasks have not revealed this pattern, these children have shown the ability to imitate and generalize, just as TD children do.

Table 3: Results from the Generalized Imitation Task across the Superordinate and Basic Levels

Participant	CA	App. – Inapp.	Same – Different
MM	6, 6	100 – 0	50 – 50
KB	7, 7	100 – 0	50 – 50
JC	6, 0	100 – 0	0 – 100
MB	6, 6*	100 – 0	43 – 57
BH	10, 7	100 – 0	50 – 50

*Approximation

Overall, it appears from the data that the results are mixed across tasks. The participants show slightly more sensitivity to superordinate categories over basic ones, using knowledge of what the categories are over how perceptually similar they are. When breaking down each task, however, it is clear that this is not the whole story.

The object examining task revealed near ceiling performance, so this task was removed in the main experiment. In the sequential touching task, it appears that the children were showing more sensitivity to superordinate categories over basic categories. Why is there a discrepancy between the object examining and sequential touching tasks? The answer lies in the differences between the tasks. In the highly structured object examining task, the participants are focusing on the objects one at a time. In the sequential touching task, the child must impose the structure on the task, seeing all the items together. Here the children are more sensitive to the boundaries between domains. The results of this task do not support the traditional categorization view or weak central coherence theory (Happe & Frith, 2006).

The sorting task revealed that most of the children sorted according to chance. The generalized imitation task results revealed that children with ASD were able to generalize, and that they conceptually understood what the objects are and how they function. It is also interesting that for the basic level contrast, when both exemplars given to the child were appropriate, most of the children recognized this by generalizing to both exemplars. Traditionally it has been thought that children generalize based on similarity; therefore, based on this view, one would expect the participants to generalize to the different dog before generalizing to another kind of animal. But, if they are categorizing based on conceptual knowledge, then one would expect them to choose either exemplar about 50% of the time since they are both appropriate. This is exactly what the data reveal. But across tasks, the generalized imitation task showed that all five of the children possessed knowledge of the object categories, while in the sorting task, three of the children were unable to demonstrate that knowledge.

In conclusion, no single task tells the entire story. Importantly, results from this first experiment show that these tasks, with the exception of the object examining task, are appropriate for children with ASD. Additionally, the main experiment included younger children to determine the pattern of these emerging categories. Finally, in order to more clearly test the possibility that children may be categorizing in a bottom-up way, the main experiment also included the subordinate level.

CHAPTER III. MAIN EXPERIMENT

The purpose of the main experiment was to more systematically test the possibility that children with ASD may be categorizing in different way than are TD children. In order to get at differences between levels, the subordinate level was added to the research design of the main experiment. The pilot study showed that the object examining task may not be appropriate for children with ASD. Therefore, three categorization tasks (sequential touching, generalized imitation, sorting) were used in the main experiment. Also, younger children were used in the main experiment, and their language comprehension was assessed in order to delineate the relationship between children's categorization and their language comprehension.

Bornstein and Arteberry (2010) also analyzed three levels of categorization with the sequential touching task in TD children across ages 12-, 18-, 24-, and 30-months. One of the only studies to assess three levels of categorization across multiple domains (animals, vehicles, fruit, and furniture), they found that more inclusive levels of categorization emerged earlier than less inclusive levels. Using a similar structure, the present study assessed three levels of categorization in one group of children with ASD, using the sequential touching task in addition to the generalized imitation and sorting tasks. Previous studies of categorization in ASD have shown mixed results, with one reason being that a single measure of categorization was used in one group of children. Therefore, it was believed that using multiple levels, domains, and tasks in the same group would clarify how children with ASD learn object categories.

Method

Participants

Ten children with ASD (9 males and 1 female) participated in this main experiment. Their mean chronological age was 4.8 years, ranging from 3 to 6 years. This sample of children came from a different private school for children with ASD and other developmental disabilities. Written parental consent was obtained for each child. Since the goal of the study was to understand early categorization in children with ASD, testing children as young as possible was preferable (note that the earliest accurate diagnosis of ASD is from 2-3 years of age).

Each child was given the Peabody Picture Vocabulary Test, Third Edition (PPVT-III; Dunn & Dunn, 1997) or Fourth Edition (PPVT-IV; Dunn & Dunn, 2007). The PPVT was used to test language comprehension by showing the child a page with four pictures on it and asking the child to point to the correct item after a label was verbally presented. The number of correct responses was then scored. Both a norm score (standardized M = 100), and a developmental age-equivalent score were then derived from the raw score for each child. Mean age-equivalent PPVT scores were 3.3, ranging from 9 months to 6.5 years. It should be noted that one child had such low language abilities that he could not achieve a baseline score, and was therefore unable to get an accurate raw score on the PPVT. Therefore, his language comprehension was estimated (see Table 4). Each participant was also given three categorization tasks, each of which tested a superordinate level contrast, a basic level contrast, and a subordinate level contrast. The objective of this study was to assess categorization skills across a variety of tasks within each child. There have been no studies using different tasks to assess levels of categorization skills within the same group with ASD (but see Bornstein and Arteberry [2010], who used this approach with TD children).

The children selected for this experiment represented a spectrum of abilities. The school administrator did not allow use of a diagnostic instrument, such as the Autism Diagnostic Observation Schedule (ADOS) or the Autism Diagnostic Interview Revised (ADI-R). Records were kept by the school but were confidential. The school administrator selected classes with children on the spectrum for whom the study would be appropriate. Based on the experimenter's previous experience working with and studying children with ASD, it was confirmed that these children were appropriate for the study. Two children's data were removed from the study after it was thought that they had language delay rather than ASD. The participants represented a range of abilities; from low functioning to high functioning and from almost nonverbal language to sophisticated language abilities.

Table 4: Demographic Information and PPVT Scores

Participant	CA	PPVT raw score	PPVT standard score	Age-equivalent
1	6,1	42	66	3,4
2	5,2	*	*	0,9
3	5,0	52	89	4,1
4	4,5	24	72	1,1
5	4,11	40	81	3,2
6	3,7	51	98	3,6
7	3,4	32	85	2,7
8	3,4	60	108	3,10
9	6,3	65	77	4,1

10	6,6	106	99	6,5
MEAN	4,10	52.4	86.1	3,3
Range	(3,4 – 6,6)	(24 –106)*	(66 – 108)*	(1 – 6,5)

*Was not able to complete PPVT

Stimuli

Each task used 3-dimensional scale models of various animals, utensils, and tools in a variety of colors (see Appendix B and Appendix C). Table 5 lists the properties that were tested. It should be noted that the category contrasts in the main experiment are different than the ones used in the pilot study. These category contrasts are hierarchical in nature, such that the subordinate categories come from the basic categories, which come from the superordinate categories. See Appendix D for pictures of some of the stimuli.

The generalization properties are also listed in Table 5. For each property tested, the experimenter demonstrated the action with a modeled prop and the actions were accompanied by appropriate vocalizations (e.g., “night, night” to demonstrate animals sleeping in the bed). These actions were modeled using the test prop; for example, by placing the animals on the bed, while saying “night, night”. The test exemplars were the same for all children, with one exemplar being the appropriate one (e.g., another animal) and the other being the inappropriate one (e.g., tool). The order in which the properties were modeled and the placement of modeling and test exemplars were counterbalanced.

Table 5: Category Contrasts and Properties Tested

Superordinate	**Basic**	**Subordinate**
Typical animals vs. Kitchen utensils	Dogs vs. Birds Spatulas vs. Spoons	Dalmatians vs. Poodles Slotted spoons vs. Measuring spoons
Atypical animals vs. Tools	Insects vs. Frogs Levels vs. Brushes	Dragonflies vs. Butterflies Paint brushes vs. Cleaning brushes
Kitchen utensils vs. Tools **(same categories as above but different contrast)**	Spatulas vs. Spoons Levels vs. Brushes **(same as above)**	Slotted spoons vs. Measuring spoons Paint brushes vs. Cleaning brushes **(same as above)**

Generalization Properties

Superordinate	**Property**	**Vocalization**
Typical animals vs. Kitchen utensils	Sleeping in bed vs. Cooking	"Night, night" vs. "Cooking"
Atypical animals vs. Tools	Drinking from cup vs. Fix a broken tractor	"Mm, Mm" vs. "Fix it up"
Kitchen utensils vs. Tools	Cooking vs. Fix a broken tractor	"Cooking" vs. "Fix it up"
Basic		
Dogs vs. Birds	Chews a bone vs. Sits in a nest	"Yum, yum" vs. "Sitting in a nest"
Spatulas vs. Spoons	Flipping cookie vs. Stirring the cup	"Flip it over" vs. "Stir it up"

Insects vs. Frogs	Has antennae vs. Swimming underwater	“Antennae” vs. “Swimming”
Levels vs. Brushes	Make it straight vs. Wash out the bristles	“Hold it straight” vs. “Wash it out”
Subordinate		
Dalmatians vs. Poodles	Ride a fire truck vs. Uses clippers to trim fur	“Whee” vs. “Buzz, buzz”
Slotted spoons vs. Measuring spoons	Drain the veggies vs. Measure the veggies	“All cooked” vs. “Add water”
Dragonflies vs. Butterflies	Eats ants vs. Collects pollen	“Yummy ants” vs. “Getting the pollen”
Paint brushes vs. Cleaning brushes	Paint the picture vs. Scrub the tractor	“Clean it up” vs. “Make it pretty”

Design and Procedure

Testing occurred at the child’s school, during the school day and sessions were videotaped for later scoring. During each session, the child was seated at a table opposite the experimenter. Each child was seen for multiple sessions (six to seven) and given four to eight categorization tasks at each session. There were a total of 11 sequential touching tasks, 11 sorting tasks, and 22 generalization tasks for a grand total of 44 tasks per child. The sequential touching and sorting tasks were administered one after the other; after touching or playing with the items on the tray for two minutes, the participants were instructed to put away the toys in the two corresponding boxes.

The order of categorization tasks, hierarchical levels, and objects used were counterbalanced as much as possible. For example, at one session, a child might have been tested on the following tasks: Dalmatians ride on fire truck (subordinate generalization), wash out the bristles (basic generalization), atypical animals vs. tools (superordinate) sequential touching and sorting, paint brushes make a picture (basic generalization), animals drink (superordinate generalization), and spoons vs. spatulas (basic) sequential touching and sorting.

Sequential touching task.

Each participant was tested on 11 sequential touching tasks. Each task had eight objects, four from one category, and four from another category (see Pilot Study for procedural details). The order in which the child selected each of the items to touch, examine, or manipulate was measured. Two coders coded 95% of the data and agreement was based on each object touched. The percentage of agreement was calculated for each contrast for each child. The overall reliability between the two raters was 85%.

There were two dependent measures. The first measure of categorization was the MRL (sequentially touching three or four items from the same category in a row), which was calculated by dividing the total number of touches a child exhibits by the number of runs. The second measure was computed using the Monte Carlo program (the number of categorizing runs based on the total number of touches in the task), which calculated each individual's categorization (see page 50 for a description of the Monte Carlo program).

Sorting task.

Each participant was also tested on 11 sorting tasks, the same contrasts (and objects) used in the sequential touching task (see Pilot Study for procedural details). The dependent measure for this task was the proportion of correct sorting out of eight trials. For example, if the participant was sorting animals and tools, and placed all eight objects in the same container, then this would be scored as 4/8, or 50%. If the participant placed each of the four objects correctly into their respective boxes, then this would be scored as 8/8, or 100%. Two coders coded 95% of the data and mean agreement for percentage correct sorting was 99%.

Generalized imitation task.

Each participant was tested on 22 generalization tasks, six from the superordinate level, and eight from each of the basic and subordinate levels (see Pilot Study for procedural details). In the main experiment, all of the properties demonstrated across the three levels included an appropriate and inappropriate exemplar. Each session began with a warm-up task, in which the participant was encouraged to imitate the experimenter’s action of stacking three soft blocks and then knocking them over. Each child’s data were included as long as the child could show evidence of imitation. On the first testing session, one participant was unable to imitate the warm-up task, because he seemed to be having an off day, so his data on those four generalization tasks were not included in the study. On all subsequent sessions, his mood improved and he was able to imitate the experimenter in the warm-up task, so the rest of his data were included. In addition, due to experimenter error, five of the participants received the wrong text exemplars on two contrasts (tools fix it up and utensils cooking), so these contrasts were removed (see Appendix E).

All of the properties chosen by the experimenter were easy to imitate, with a simple action and an appropriate vocalization (see Table 5). All of the modeled actions were demonstrated three times, similar to the pilot study, and included vocalizations to ensure that the participants attended to the action. The child was only required to imitate the action, not the vocalization. Coding included performance (or nonperformance) of the properties and the exemplars used (Mandler & McDonough, 1996; 1998). Two coders coded 95% of the data and mean agreement on imitation of the actions and the exemplar used was 89%. When discrepancies arose, the data from the primary coder were used.

The dependent measure is the proportion of appropriate and the proportion of inappropriate generalizations at each level of contrast. Proportion scores were used because there were 6 superordinate and 8 basic and 8 subordinate level tasks. This was designed so that one could compare generalization within domains at all levels of contrast.

Results and Discussion

Results for each of the three tasks will be presented first, followed by a comparison between tasks, and finally the relationship of language to the categorization tasks will be discussed.

Sequential Touching Task: Mean Run Length (Group Analyses)

The dependent measure of the sequential touching task is the sequential touching of items from one of the two categories of objects. As stated in the methods section, there are two measures for analyzing the sequential touching. The first measure, a quantitative measure, is the MRL, which provides a measure of how children respond as a group. Based on previous research, the MRL of the group should be statistically above the chance level of 1.75. The second measure, a qualitative measure, used a Monte Carlo program to assess individual children's sequential touching (discussed in next section).

The main research question of this study concerned how children were categorizing across the three levels. In other words, do children with ASD categorize better at one level of categorization? Based on traditional categorization views, best performance is expected on basic level tasks; based on infant research, best performance is expected on superordinate tasks; and based on the view that children with ASD focus on specific details of objects that could be used to categorize, best performance is expected on subordinate tasks. A repeated measures analysis of variance was conducted with Category level (superordinate, basic, and subordinate) as the within-subjects factor. Results do not support or refute any of the views. Overall, one sees that superordinate ($M = 2.32$, $SE = 0.21$), basic ($M = 2.06$, $SE = 0.13$) and subordinate categorization runs ($M = 2.10$, $SE = 0.25$) do not significantly differ from each other, $F(2,8) = 0.48$, $p > .10$, n.s.

The next question concerned performance compared to chance. Are the means significantly greater than chance (1.75)? The means, their associated two-tailed *t*-values, and standard error are shown in Table 6. On the superordinate level, the means were significantly greater than chance: $t(9) = 2.74$, $p < .05$. On the basic level, the means were significantly greater than chance: $t(9) = 2.42$, $p < .05$. On the subordinate level, the means were not significantly greater than chance: $t(9) = 1.39$, $p > .05$, n.s. This suggests that overall categorization is solid at the superordinate and basic levels, but poor at the subordinate level.

Table 6: Mean Run Length (MRL), Standard Error, *t*-Test Values, and Percentage of Participants Exhibiting Sequential Touching Greater than Chance According to the Monte Carlo Program

Contrast	MRL	SE	*t*-test compared to chance (quantitative data)	Monte Carlo program compared to chance (qualitative data)
Superordinate-level				
OVERALL MEAN	**2.32**	**.21**	**2.74***	43%
Animate/Inanimate Mean	**2.64**	**.32**	**2.79***	65%
Inanimate/Inanimate Mean	1.70	.11	-0.45	0%
Basic-level				
OVERALL MEAN	**2.06**	**.13**	**2.42***	60%
Animate Mean	**2.08**	**.13**	**2.53***	75%
Inanimate Mean	2.03	.19	1.45	45%
Subordinate-level				
OVERALL MEAN	2.10	.32	1.39	33%
Animate Mean	2.40	.47	1.38	45%
Inanimate Mean	1.81	.11	0.56	20%

***p < .05**

The next question of interest was regarding the animate and inanimate MRLs within each of the three levels. Do the animate/inanimate MRLs show the same pattern within category level? The MRLs were analyzed according to their animate or inanimate domain. It should be noted that the superordinate level is different than the basic and subordinate levels, since two of the contrasts at this level involve both animate and inanimate categories. The following computations were made: the two superordinate animate/inanimate contrasts (typical animals vs. utensils and atypical animals vs. tools) were averaged together, and compared with tools vs. utensils, an inanimate contrast. At the basic level, spoons vs. spatulas and brushes vs. levels were averaged together (basic inanimate level), and compared with the average of the insects vs. frogs and dogs vs. birds (basic animate level). And finally, within the subordinate level, the average of measuring spoons vs. slotted spoons and paint brushes vs. cleaning brushes (subordinate inanimate level) was compared with the average of Dalmatians vs. poodles and dragonflies vs. butterflies (subordinate animate level). The dependent measure therefore is the MRL for the animate and inanimate categories, and these means and their associated two-tailed *t*-values are also shown in Table 6.

Separate repeated measures analyses of variance were conducted on each category level (superordinate, basic, and subordinate), comparing the MRL to chance. Results show that on the superordinate level, the means of the contrasts between animate and inanimate domains were significantly greater than chance: MRL = 2.64 (SE = 0.32), $t(9) = 2.79$, $p < .05$. The mean of the contrast within the inanimate domain (tools vs. utensils) did not differ significantly than chance: MRL = 1.70 (SE = 0.11), $t(9) = -0.45$, $p > .10$, n.s. On the basic level, the means of the contrasts within the animate categories were significantly greater than chance: MRL = 2.08 (SE = 0.13), $t(9) = 2.53$, $p < .05$. The means of the contrasts within the inanimate domain did not differ significantly from chance: MRL = 2.03 (SE = 0.19), $t(9) = 1.45$, $p > .10$, n.s. On the subordinate level, the means of the contrasts within the animate domain did not significantly differ from chance: MRL = 2.40 (SE = .47), $t(9) = 1.38$, $p > .10$, n.s. and the means of the contrasts within the inanimate domain also did not significantly differ from chance: MRL = 1.81 (SE = .11), $t(9) = .56$, $p > .10$, n.s. In conclusion, as a group, these children differentiated between animate and inanimate domains and they were able to categorize basic level animals. Inanimate (artifact) categories were more difficult.

Sequential Touching Task: Monte Carlo (Individual Analyses)

What percentage of children showed this pattern of categorization? To assess if each child's categorizing runs consisting of touches to three or four objects in succession from a category differed from chance, the Monte Carlo program was used. This categorical measure, revealing each child's performance as systematic (showing sequential touching at greater than chance levels) or random, is shown in the far right column of Table 6. The results indicate that 65% of children showed categorization of superordinate animate/inanimate contrasts and none of them showed categorization of tools vs. utensils. 75% of children showed categorization of basic level animal categories whereas only 45% showed categorization of basic level artifacts. Forty-five percent of children showed categorization of subordinate level animal categories whereas only 20% showed categorization of subordinate level artifact categories. In conclusion, the quantitative and qualitative measures show a consistent pattern in the data.

Also calculated was the percentage of children who were classified as either single categorizers (categorizing runs in only one category) or exhaustive categorizers (categorizing runs in both categories). Eighty percent of children were classified as single exhaustive categorizers on the subordinate inanimate level, whereas only 15% of the children were classified as exhaustive categorizers on the subordinate inanimate level. Therefore, it seems that on the subordinate level, some children became fixated on one category of objects. This will be discussed further in the discussion.

Overall, the sequential touching task is showing a pattern of better categorization on the superordinate and basic levels, compared to the subordinate level. What are some reasons for this pattern of results? One possibility is experience. It is likely that children with ASD are gaining experience with animals, which is guiding their increasing knowledge about what they are and how they move. This finding lends support to others who have shown that children with ASD attend to biological motion of animate beings (Johnson & Rakison, 2006; Murphy, et al., 2009). Why might some have difficulty with inanimate or artifact categories? What is particularly difficult about tools vs. utensils? There are several possibilities. One is that tools and utensils is not actually a superordinate contrast. It is possible to conceptualize tools as a superordinate category, with objects such as spoons and spatulas as cooking tools, and objects such as levels and brushes as workshop tools. If this were the case, it might follow that inexperience with tools in general might hinder children's performance on this contrast. This and other possibilities will be explored in the discussion.

It appears from the data that children with ASD are categorizing objects in a similar fashion as somewhat younger, TD children. Mandler, Bauer, and McDonough (1991) used the sequential touching task in TD children and found that very young children (18 months) have formed conceptions of many of the objects in the superordinate categories of animals, vehicles, plants, furniture, and kitchen utensils. By 30 months, most children also make conceptual distinctions within those domains at the basic level showing a developmental pattern of emerging conceptual knowledge. They also found that most 22- to 24-month-olds differentiated animals from plants and kitchen utensils from furniture, but that fewer than half of the children could differentiate musical instruments and tools. The authors surmised that it is not necessarily that children at this age lack knowledge of instruments and tools. Rather it would seem that at this stage in development, children do not see the overall relatedness of one instrument to another or one tool to another, based on their lack of experiences with those objects. While the present study did not test those exact categories, a similar result was found with kitchen utensils vs. tools. It may be that expertise with different objects is influencing perception of what objects are and how they belong together. As has already been described, children with ASD are having vastly different experiences than TD children with objects and people. It appears that this expertise is popping up in different ways across different objects, thus creating a somewhat mixed picture of categorization.

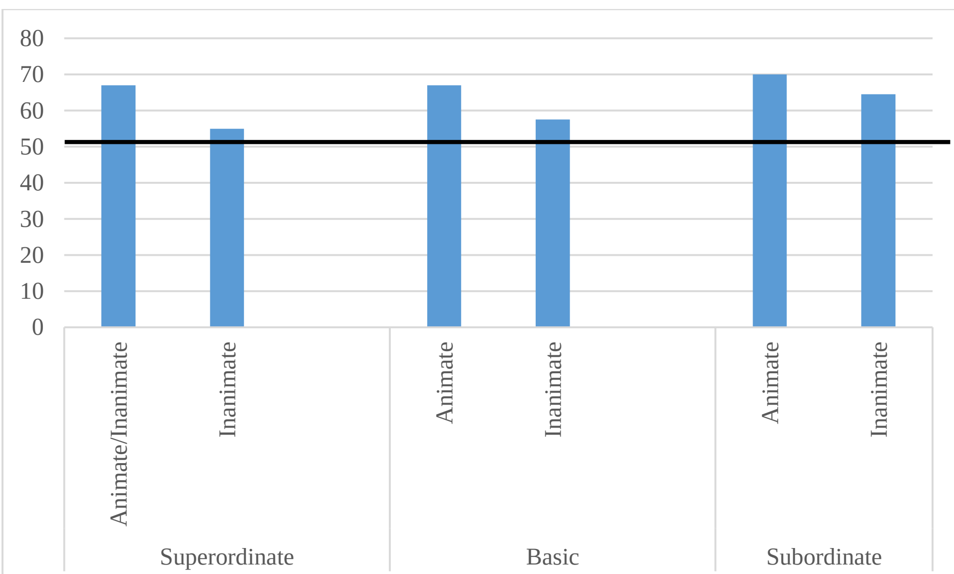
Sorting Task

The next task was the sorting task. The dependent measure was the proportion of correct sorting out of 8 trials, since there were 8 objects (four from each category) to be sorted into two containers. This task was challenging because the children were asked to mimic the experimenter, but in a very different way than the generalized imitation task. The children must understand the differences between the object categories, and also must understand the directions given by the experimenter. Additionally, the directions are arbitrary and need to be interpreted by the participant. Being told that objects of one kind go in one box, which is unmarked and has no cues, is understandably challenging. Since the sequential touching task places few verbal demands on the children, and the generalization task places minimal demands on the children, it was thought that the children would have the most difficulty with this task. It is not even until 24 months that TD children can sort objects into two containers (Gopnik & Meltzoff, 1987; Nelson, 1973).

The first question of interest concerned performance across levels. Were children better at sorting on one category level? The dependent measure was the proportion of correct sorting. A repeated measures analysis of variance was conducted with Level (superordinate, basic, subordinate) as the within-subjects factor. Just as with the sequential touching task, this task also did not find a significant result: F(2,18) = 1.43, p > .05, n.s. Therefore, the proportion of correct sorting across levels was similar.

The second question of interest concerned performance compared to chance. Even though children were not better at sorting on one level, were they sorting correctly more often than would be expected by chance (50%)? The means of each level were computed, and a *t*-test was conducted comparing each of these means to chance (50%). On the superordinate level, proportion of correct sorting did not differ significantly from chance: $t(9) = 1.45$, $p > .05$, n.s. On the basic level, proportion of correct sorting did not differ significantly from chance*:* $t(9) = 1.44$, $p > .05$, n.s. On the subordinate level, proportion of correct sorting was significantly greater than chance: $t(9) = 2.44$, $p < .05$. Therefore, children sorted best on the subordinate level (Figure 1).

Figure 1: Proportion of Correct Sorting Across Animate and Inanimate Categories



The next question concerned performance within levels. Were children better at sorting the animate and inanimate domains within each level? Similar to the sequential touching task, computations were made on each level, averaging the animate contrasts and comparing them with the averaged inanimate contrasts. The dependent measure was the proportion of correct sorting of the animate and inanimate domains. Separate repeated measures analysis of variance were conducted with the Proportion of correct animate and inanimate sorting (within each category level) as the within-subjects factor. On the superordinate level, the proportion of sorting the animate/inanimate contrasts ($M = .67$; $SE = .09$) was significantly greater than proportion of sorting the inanimate contrast ($M = .55$; $SE = .08$); $F(1,9) = 7.58$, $p < .05$. On the basic level, there was no statistically significant difference between the animate and inanimate categories: $F(1,9) = 2.48$, $p > .05$, n.s. On the subordinate level there was no statistically significant difference between the animate and inanimate categories: $F(1,9) = 0.78$, $p > .05$, n.s. In conclusion, children sorted significantly better on the animate/inanimate contrasts than on the inanimate contrast on the superordinate level. This result mirrors the findings from the sequential touching task. And yet, the sequential touching task did not have explicit instructions, while the sorting task did.

So far, with two of the three tasks analyzed, a picture is emerging than is different than the one suggested in the main introduction. It was believed that since children with ASD are attending to objects and people differently than are TD children, then they might be categorizing in a more bottom-up fashion, by showing more success on basic and subordinate levels as compared with the superordinate level. The results thus far show that children with ASD are performing similarly as TD children, as evidenced by the sequential touching task, but the sorting task is showing better performance on the subordinate level. There is no clear pattern emerging thus far.

Generalized Imitation Task

The generalized imitation task demonstrates how children are making generalizations about the relations among various objects in their world (see Mandler & McDonough, 1996; 1998). This task is based on elicited imitation, and as was shown earlier, children with ASD are capable of this ability (see Pilot Study).The dependent measure is the proportion of appropriate and inappropriate generalizations at each level of contrast. Proportion scores were used because there were 6 superordinate and 8 basic and 8 subordinate level tasks (totaling 22 tasks). This was designed so that one could compare generalization within domains at all levels of contrast. Note that the mere selection of one of the two objects presented was not sufficient. The child had to imitate the modeled activity with the appropriate object for the generalization to be scored. Children had three choices; use the appropriate object to demonstrate the modeled activity, use the inappropriate object to demonstrate the modeled activity, or choose not to imitate the activity at all by doing something else with the objects or ignoring them. The first object on which the activity was imitated was recorded. Although children occasionally demonstrated activities on both objects (for approximately one third of the tasks), the second choices were not analyzed.

The first question concerned responses at the three levels of contrast. Do children generalize better at one level of categorization? A repeated measures analysis of variance was conducted with Choice (appropriate, inappropriate) and Level (superordinate, basic, and subordinate) as the within-subjects factors. A main effect for choice was found: $F(1,9) = 37.9$, $p < .001$ (mean appropriate = .63, SE = .05; mean inappropriate = .31, SE = .04), such that children chose the appropriate exemplar significantly more often than the inappropriate exemplar for their generalizations. There was no main effect for level and no qualifying interaction between choice and level. That is, children generalized more often to appropriate than inappropriate objects regardless of level of contrast; superordinate, basic, and subordinate generalization did not differ.

The second question concerned performance compared to chance. It is known that the appropriate exemplar was used more often than the inappropriate exemplar, but was it chosen more often than would be expected by chance (0.50)? *T*-tests were conducted comparing each of the means to chance (0.50). On the superordinate level, performance was significantly better than chance: $t(9) = 3.18$, $p < .05$. On the basic level, performance was significantly better than chance: $t(9) = 2.26$, $p = .05$. On the subordinate level, performance was not significantly better than chance: $t(9) = 1.87$, $p = .10$, n.s. This shows that children had the most difficulty choosing the appropriate exemplar on the subordinate level, a similar finding from the sequential touching task. The difference between their appropriate and inappropriate generalizations was smaller in the subordinate than on the superordinate or basic levels, showing overgeneralization in this level. For example, the mean percentage inappropriate generalization in the subordinate level was 39.6% (compared with 30.4% in the superordinate level and 23.3% in the basic level). Therefore, some children had a more difficult time choosing the appropriate exemplar in the subordinate level, than in either the superordinate or basic levels.

The next question concerned animate and inanimate domains. Do the data suggest differences in generalization patterns between animate and inanimate domains? The dependent measure is the proportion of appropriate choices. A repeated measure analysis of variance was conducted with Level (superordinate, basic, subordinate) and Domain (animate, inanimate) as the within-subjects factors. The main effect for level was not significant: $F(2,8) = .66$, $p > .05$ n.s. Neither the main effect for domain, nor the interaction between them was statistically significant (see Table 7). Therefore, there were no differences in children's appropriate generalizations across domain or level.

Table 7: Mean Percentage of Children Imitating the Demonstrated Property using the Appropriate Exemplar across the Animate and Inanimate Categories

Level	Animate	Inanimate
Superordinate level	73	65
Basic level	68	59
Subordinate level	61	60

After all three tasks have been analyzed, the results are interesting because there are some similarities and differences between the tasks. The sorting task is more difficult than the other two tasks, as more demands are placed on the participants, who must impose the structure on this task. Interestingly, children were able to sort well on the subordinate contrasts, while their performance was not as high on the basic and superordinate levels. This singular finding, which actually lends evidence to the proposed hypothesis before testing began, goes against the other two tasks, which point to lowest performance on the subordinate level. What is it that differentiates the sorting task? These points will be considered in the discussion.

Across Tasks

After all of the tasks were analyzed, the links among the tasks were then explored. Are the tasks tapping similar constructs, or are they unrelated? If the tasks are unrelated, then it would assume that these tasks are measuring different skills, and that a child's performance on one of the tasks has no relationship to performance on another task. In this way, it would follow that children are not categorizing across the tasks based on conceptual knowledge but on some other basis, perceptual or otherwise. If, however, the tasks are related, then it would mean that there is significance between these tasks, as they are tapping into similar abilities. One may think of this question as one of paradigmatic vs. syntagmatic processing. If the tasks are related, then this is evidence of the shift to paradigmatic processing, in which the child is demonstrating knowledge not just of what this thing is, but also what it is not, as well as what it does.

The correlation between the MRL of the sequential touching task and percentage of actions correctly imitated in the generalized imitation task was found not to be statistically significant ($r = .21$, $p = .54$). Nor was the correlation between the MRL of the sequential touching task and the proportion of correct sorting of the sorting task found to be statistically significant ($r = .39$, $p = .24$). However, the correlation between the sorting task and the generalized imitation task was found to be statistically significant: ($r = .62$, $p = .04$). What this suggests is that the sorting and generalized imitation tasks are tapping similar underlying abilities. When children demonstrate knowledge of what certain objects are and how they function (in the generalized imitation task), they also tend to show their knowledge of the boundaries between object categories (in the sorting task). It is curious as to why the sequential touching task does not correlate with either of these two tasks. This point will be considered in the discussion.

Language and Categorization

A final research question considers language and its relationship to categorization. Specifically, does language comprehension correlate with categorization abilities as it does in TD children (Samuelson & Smith, 1999)? Surprisingly, yes and no. Analyses were conducted for each task. For the sequential touching task, PPVT age-equivalents (in months) were compared with the MRL for each of the 11 contrasts to see if language was playing a role in performance within this task. There were no significant correlations; therefore children's language comprehension was not related to their success on the sequential touching task. The same comparison was made with the generalized imitation task, and again found that there were no significant results, so there was no link between language comprehension and success on each of the 22 generalized actions. One might have thought that language comprehension would correlate with generalized imitation, given that modeling was accompanied by linguistic cues. And yet, regardless of their language level, participants fared well on the generalized imitation task. How does one explain a lack of correlation between these categorization tasks and language scores? One possible explanation used is that the language measure used in this study is not sensitive enough to children's actual language (see Siller, Swanson, Serlin & Teachworth, 2014).

Finally, language scores were compared with the proportion of correct sorting on the animate and inanimate contrasts of the sorting task. Results showed that every contrast was significantly related to language comprehension. As can be seen from Table 8, the correlations were positive, meaning that the higher the language comprehension, the better the sorting abilities. This is exactly what one would expect, since this task is mediated by language (Gopnik & Meltzoff, 1987). In other words, the ability to understand that objects that are similar go together, develops in conjunction with the ability to name those objects. Those children with better language comprehension performed significantly better on this task, which highlights the intertwined nature of language and categorization. This finding also stresses the need to use tasks that are sensitive to the variation in children's language abilities in ASD.

Table 8: Correlations between Sorting Task and PPVT Scores

Level	Domain	Correlation	p-value
Superordinate	Animate/Inanimate	0.76	0.01
	Inanimate	0.83	0.00
Basic	Animate	0.72	0.02
	Inanimate	0.68	0.03
Subordinate	Animate	0.72	0.02
	Inanimate	0.75	0.01

CHAPTER IV. GENERAL DISCUSSION

The present study tested three levels of categorization (superordinate, basic, subordinate) in three domains (animals, tools, kitchen utensils) across three different categorization tasks (sequential touching, generalized imitation, sorting) in the same group of children with ASD. The findings confirm the need to use a multifaceted approach in studying autism, a complex, heterogeneous, developmental disorder. Utilizing different measures in the same group of participants revealed similarities across tasks, but also unexpected differences. Such an approach is necessary and vital to understanding the cognitive capabilities, as well as deficits, of those with ASD. No other study has examined and illuminated construct validity across different measures of categorization abilities. Additionally, no other study has tested three levels of categorization, each within the same domains, in children with ASD.

TD infants and children begin to make broad inferences about the world, and with experience, make more and more narrow distinctions within those domains. Mandler, McDonough and their colleagues used these measures and others to show a clear developmental pattern of more broad understanding of objects and categories before less inclusive, more differentiated objects and categories (1993, 1998a, 1998b, 2000). Since autism is a disorder defined by abnormal social communication, it follows that children with ASD would have vastly different experiences constructing categories. The first studies examining categorization tested children with ASD and found no impairments (Tager-Flusberg, 1985a, 1985b; Ungerer & Sigman, 1987). Further studies examining varied aspects of categorization offered mixed results, depending on the task used and the type of categorization tested (Klinger & Dawson, 1995; Minshew et al., 2002; Shulman et al., 1995). The present study sought to bridge some of the gaps in the literature.

Addressing the larger question of how children with ASD first learn object categories, the data revealed no significant differences between levels. Therefore, when one examines the overall data, children with ASD performed similarly on each of the three category levels. It is important to note, however, that the pilot study was not conclusive, and also, there were only ten participants in the main experiment of this study. Even though the main hypothesis (that an ASD disorder would alter the processes involved in categorization by showing superior skills on the subordinate level) was not supported, when one looks closely at each individual categorization task, it is evident that differences did surface among category levels.

The sequential touching task, which, overall, is well-suited for children with ASD because of few demands placed on the participants, allowed for separate analyses on group (quantitative) and individual (qualitative) data. Group analyses showed better performance on the superordinate and basic levels, as compared with the subordinate level. Results also showed that children differentiated between animate and inanimate categories on the superordinate level, and categorized basic level animate categories. Individual analyses confirmed the group analyses, showing that most children categorized the superordinate and basic levels, with fewer children able to categorize the subordinate level. This task also highlighted the fact that children with ASD have difficulty categorizing certain contrasts, such as tools vs. utensils. Possible explanations for this difficulty will be discussed later.

The sorting task was the most difficult as this task explicitly required the participants to follow verbal and somewhat arbitrary instructions. Again no differences were found between levels; children's sorting was comparable across levels. However, performance was significantly better than chance on the subordinate level only. This result contrasts directly with the sequential touching task, which found the opposite pattern of results. Within levels, only the superordinate level showed differences: the proportion of sorting the animate/inanimate contrasts was significantly higher than the proportion of sorting the inanimate contrast, tools vs. utensils. Also, the proportion of correct sorting in each of the animate and inanimate domains across the three levels was positively correlated with language comprehension scores. Therefore, the higher the language comprehension, the better one's percentage of sorting, which is exactly what one would expect and which corresponds with typical development (e.g., Booth & Waxman, 2002; Samuelson & Smith, 1999), showing that language can refine perceptual skills towards sorting items by overall shapes and functions. This finding reveals that in ASD, just as in typical development, the developing systems of language and cognition are intertwined and influencing one another.

How can one explain best performance on the subordinate level? There was more consistency in the sorting on the subordinate level. It could be that this is a straightforward task, tapping into more bottom-up categorization. Sequential touching is a task where play behaviors and fixation might obfuscate categorization. Generalized imitation is a more straightforward task, and tellingly, most of the children could successfully imitate most of the actions, regardless of domain or level. The sorting task, however, could be providing evidence for the proposed hypothesis. If children with ASD are attending to these objects in a different way than are TD children, then it may be easier for them to see the differences between two more inclusive subordinate categories, then to see the coherence of the broader superordinate category. This proposal needs testing in TD children, as this pattern has not yet been examined.

The third task, the generalized imitation task, provided a window into how children with ASD understand objects and their roles in everyday events. Results showed that children with ASD were capable of imitating the actions demonstrated by the experimenter, using the appropriate over the inappropriate exemplar in most of the tasks. There were no statistically significant differences found between levels; superordinate, basic and subordinate generalizations did not differ. Similar to the sequential touching task, superordinate and basic level generalizations were significantly greater than chance, while subordinate generalizations were similar to chance. Children demonstrated overgeneralizing on subordinate properties, showing less competence on this level. There were no differences between generalizations of animate and inmate categories across levels.

As shown in Appendix E, only 50% of the children generalized “fixing it up” to tools when they were compared with utensils, while 80% generalized “fixing it up” to tools when they were compared with animals. This is the second task to show more difficulty with tools vs. utensils than other contrasts. Yet, another inanimate contrast, paint vs. cleaning brushes, which none of the participants could differentiate on the sequential touching task (see Appendix F), was quite easy for participants on the generalized imitation task. The vast majority of participants (89%) could generalize “making a picture” to paint brushes, while most (60%) could also generalize “scrubbing it clean” to cleaning brushes. Why such different performance on the same comparison across two tasks?

One reason is the structure of the tasks. The sequential touching task is based on systematic touching of objects. When shown eight brushes on a tray, participants did not selectively respond to the brushes as if they were different from one another. It is not that they are all perceptually so similar to one another (see Appendix G for a picture of the brushes used). Another possible reason is an intense focus on certain objects. Upon seeing brushes, participants often picked one up and start painting with it, often repeating that action. Since a hallmark feature of ASD is repetitive behaviors, this may have led them to ignore the other brushes. In fact, the higher percentage of single (80%) vs. exhaustive categorizers (15%) on the subordinate inanimate level of the sequential touching task supports this conclusion. On the two subordinate inanimate contrasts (paint brushes vs. cleaning brushes and measuring spoons vs. slotted spoons), children's categorizations tended to be more one-sided, with a greater focus on one of the two categories. If children are focusing more on one set of objects, this focus may be influencing their categorizing on the sequential touching task.

One consistency across the three tasks was difficulty with tools vs. utensils. What is so difficult about this contrast? As previously stated, there are some possible reasons for this. It could be that tools vs. utensils is not actually a superordinate level contrast. It is possible that tools is the overarching category, and that kitchen utensils are a certain group of tools. If this were the case, children's lack of experience with these inanimate objects could be preventing them from constructing the boundaries between the categories. Tools are not exactly safe for children to play with, and neither are kitchen utensils. Participants performed much better on typical animals vs. utensils and atypical animals vs. tools across all three tasks, so it is possible that the comparison between inanimate and animate objects facilitates categorization of these domains. Children with ASD might not have a lot of experience with or knowledge of tools, but when compared to animals, those boundaries were highly salient.

Another explanation for difficulty with this contrast is that there is a lot of perceptual variability within these categories, and similarity between the categories. Tools contain objects such as brushes, screws, wrenches, levels, etc., which do not look a lot alike, and which do not share the same functions as well. And yet some tools such as brushes and wrenches share certain perceptual attributes with utensils such as spoons and spatulas. If children with ASD are categorizing these objects based on perceptual similarity alone, then it might be easier to differentiate different types of brushes and levels then it would be to differentiate tools from kitchen utensils. A priori, each level is difficult to determine. After all, Rosch and her colleagues tested maple trees as a basic level category when they realized their participants were more likely to view maple trees as subordinate to trees, a basic level category of plants. Also, as stated earlier, Rosch stated in a footnote that were the concept of cue validity a true probability, it would necessarily follow that the superordinate level category would be the most inclusive category, since superordinate level categories include basic level categories (Rosch et al., 1976).

What is the role of perceptual similarity in children's categorizations? As was stated earlier, TD infants can categorize objects on perceptual bases as young as three months of age (Behl-Chadha, 1996; Eimas & Quinn, 1994). The tasks used in those studies habituated infants to pictures of objects, and the results showed that very young infants can indeed perceptually discriminate pictures. The tasks used in the present study, however, have been used with TD children to study how and when children develop conceptual knowledge (Mandler & McDonough, 1993, 1998a, 1998b, 2000). This led to the main research question, would using these tasks in children with ASD reveal a pattern of top-down categorization, based more on what kinds of objects these categories are? Or more bottom-up categorization, based on perceptual similarity? The results across tasks suggest that the answer depends on the domain tested and what children know about the domain. Two of the three tasks seem to show that children with ASD are categorizing in a more top-down progression, showing more success on the superordinate and basic levels than on the subordinate level. One task, the sorting task, seems to show more success on the subordinate level than on the basic or superordinate levels.

Overall, did participants perform better on the animate level than the inanimate level? The sequential touching task revealed performance greater than chance ($p < .05$) on the two animate/inanimate distinctions on the superordinate level, and also on the animate categories on the basic level ($p < .05$). The sorting task mirrored the sequential touching task in finding better performance on the two animate/inanimate distinctions ($p = .02$) than on tools vs. utensils. The generalized imitation task did not show any differences between the animate and inanimate categories, and the. Overall, participants showed better performance on animate categorization, but this may simply be due to poor performance on tools vs. utensils.

Where does this fit in the literature? It makes sense that children's experiences with animals is guiding their understanding of animals as a category, distinct from other inanimate beings. Some studies have reported that children with ASD have difficulty attending to biological or social motion (Blake et al., 2003; Moore et al., 1997), however, these studies have revealed the difficulty that children with ASD have with point-light-walker displays, in which a moving human or animal figure is represented by points of light on its joints (Rutherford & Troje, 2012). In these displays, participants must determine if the points of light that are moving are a person or not. In order to detect biological motion, one needs to put all of the moving parts together, which children with ASD have difficulty with, and which corresponds with weak central coherence theory. For the purposes of the current study, it seems that children with ASD are aware of the distinctions in the animate domain on both the superordinate and basic levels and that this knowledge is guiding their categorization of those objects. The extent to which their success relies on biological motion was not tested.

The last main finding was the correlation between tasks. Specifically, the generalized imitation and sorting tasks were positively correlated ($r = .62$, $p = .04$), such that as performance on one task increased, so did performance on the other task. This finding makes sense, as these tasks were chosen to represent various aspects of categorizing objects, or demonstrating knowledge of what these objects are. What is curious, though, is the lack of a statistically significant correlation between the sequential touching task and either of the two other tasks. What does this mean about the sequential touching task? Is it tapping separate knowledge? As can be seen from Appendix H, the sequential touching task is not that far off from the other two tasks. It is possible that with more participants, the link between these tasks would become more evident. Additionally, participants' performance on tools vs. utensils was so poor on the sequential touching task that it appears to have affected the correlation. In sum, a statistically significant correlation between two of the three tasks validates the use of these tasks in studying categorization.

Are children with ASD learning in qualitatively different ways than are TD children? The results from this study are inconclusive; however, the findings from the sorting task suggest that this is a possibility and would need to be explored further. Overall, this study confirms that the pattern of categorization is not so obvious in ASD, and one possible explanation is experience. If children with ASD are having such different experiences with objects and people than are TD children, it follows that they will have more success on certain contrasts over others. In typical development, experience also guides developing categorization (and language) but experiences are so much more varied in ASD that categorizations are also more varied. This is what the data reveal.

Limitations and Future Research

One of the limitations of this study was the number of participants. The goal was to include more participants, however, due to many constraints getting access to schools, as well as obtaining parental consent, the present study was completed after 10 participants were tested. There were a total of 44 tasks per child, which made data collection a long and arduous process.

The school that the children attended did not allow use of a diagnostic instrument, the ADOS or the ADI-R. Diagnosing the participants using one of these instruments would have allowed systematic testing, which would have also permitted comparison of autistic symptoms among the participants. Unfortunately, the participants' diagnosis could not be confirmed in this way. Instead, the experimenters had to rely on what the school administrators knew about the backgrounds of their students. Records were kept confidential by the school and were not accessible.

Another limitation was the age of the participants. A main goal of the present study was to assess how children with ASD learn object categories. Since research on TD children using the sequential touching task has found early conceptual categorization starting as young as one year of age (Bornstein & Arteberry, 2010), one goal of the present study was to test children with ASD as young as possible to get at emerging category formation. However, it is not standard to diagnose children until the second or third year, making it difficult to test very young children with ASD. One reason for this delay in diagnosis concerns doubts about validity and the long-term stability of early diagnoses (Kleinman, Ventola, Pandey, Verbalis, Barton, Hodgson, Green, Dumont-Mathieu, Robins & Fein, 2008). Many of the results, especially on the generalized imitation task, found that performance was comparable across category level, and already sophisticated. It would have been ideal to test children from 12 to 36 months in order to see more successes and failures. An interesting insight from Uta Frith is that in autism, learning is possible. Not only is it possible, but it enables explicit mentalizing, even though implicit mentalizing might be developing differently (2012). This observation highlights the fact that while children with ASD may have similar cognitive abilities as TD children, they often need to be taught explicit strategies to do so. It is possible that despite seeing the end product of many formed categories, this study missed the process of how those categories were formed.

Another limitation was the lack of a control group. The goal was to use either a control group of developmentally delayed children, or language delayed children to control for intellectual disability or language level. However, as stated earlier, the data collection process was much longer and more difficult than anticipated.

Besides testing more (and younger) children, future research on this topic should include multiple age groups to test categorization in a more developmental fashion. By comparing several different age groups, one would be able to see not only how categories emerge, but when they emerge. And finally, another long-term goal of this research is to test categorization longitudinally. By testing the same group of children with ASD over time, one would be able to see their developing conceptual knowledge. This is the ultimate goal of this research.

Another direction for this study is to vary the contrasts studied. One weakness of the design was that the superordinate level did not have an animate/animate distinction that could be compared directly with the inanimate/inanimate distinction. How would children perform when asked to categorize different animals? Would they categorize land and sea animals, for example? A result of using only animals in the animate domain had certain limitations. Future studies should include other animate beings (natural kinds) such as plants. Would children show sensitivities to plants, even though they move a lot more slowly than other animate beings? It should be noted that vehicles were not included in the main experiment because children with ASD have a tendency to focus on parts of the vehicles (e.g., wheels) repetitively and the main experiment was designed to test immobile artifacts only. Future studies should assess how children with ASD categorize vehicles and if repetitive behaviors influence categorization. It would be interesting to test not only how children with ASD learn to categorize animate and inanimate domains, but also how motion plays a role in their categorization.

Finally, future studies should also focus more on repetitive behaviors. It is well understood that these behaviors are present in ASD and that they are greatly affecting development. An abnormal focus on objects has a detrimental effect on interactions with people (Bruckner & Yoder, 2007; Ozonoff et al., 2008), which is a part of how one forms categories. If children with ASD are learning to categorize via repetitive behaviors, then it is possible that repetitive behaviors are interfering. For example, as stated above, vehicles were not included in the present study because one anticipated result was a focus on parts of the vehicles, rather than the whole vehicle. These behaviors should be studied further.

Summary and Conclusions

Overall, this study adds to our understanding of children with ASD, showing more developed categorization skills than was initially hypothesized. The findings confirm earlier studies showing intact categorization in children with ASD (Tager-Flusberg, 1985a, 1985b; Ungerer & Sigman, 1987), and yet also reveal that there may be differences from TD children (Klinger & Dawson, 1995).

The pilot study tested five children with ASD on four categorization tasks and found that 3 of the 4 tasks were appropriate for children with ASD. The results from the pilot study were somewhat confirmed with the findings from the main experiment. While different categories were used in the main experiment, the sequential touching task in the pilot study (which examined musical instruments vs. tools and cars vs. trucks) found that 4 of the 5 participants categorized the superordinate level contrast, while only 2 out of 5 participants categorized the basic level contrast. The sorting task in the pilot study (which tested musical instruments vs.

tools and cars vs. trucks) found that only 2 of the 5 children could sort correctly, while 3 of the 5 sorted according to chance, although no subordinate contrasts were tested. The main experiment also showed a pattern of sorting according to chance on most of the contrasts. Finally, the generalized imitation task (which tested sleeping and drinking of animals, and keying and riding of vehicles) found overwhelming success on both the superordinate and basic levels, which is similar to the results in the main experiment.

If children with ASD are developing categories in a different way than are TD children, this would reveal a great deal not just about how they view objects in the world, but also about other cognitive abilities. While this study did not show which category level is differentiated first, the results have revealed that in order to understand how children with ASD categorize objects and clarify discrepancies in previous research, one needs to utilize multiple levels of inclusiveness across multiple methods and contrasts.

APPENDIX A: List of Objects used and Appropriate Vocalizations in Object Examining, Sequential Touching, Generalized Imitation, and Sorting Tasks of Pilot Study

Task	Contrast	Objects	Vocalization
Object Examining	Basic	grey terrier, Spot, big terrier, Maltese, beagle Siamese cat, black cat, gray cat, brown cat, white cat	none
	Superordinate	fish, rabbit, elephant, horse, bird truck, motorcycle, school bus, sedan, airplane	none
Sequential Touching	Basic	old-fashioned car, racecar, green car, beetle, station wagon cement truck, green truck, red pick-up truck, backless truck, green pick-up truck	none
	Superordinate	piano, cello, trumpet, French horn, guitar wrench, screw, hammer, saw, screwdriver	none
Generalized Imitation	Superordinate	Drinking: cup (prop), German Shepherd (modeled); rabbit, motorcycle, Tabby, plane, fish, school bus, bird, pick-up truck Sleeping: bed (prop), Spot (modeled); rabbit, motorcycle, Tabby, plane, fish, school bus, bird, pick-up truck Keying: key (prop), racecar (modeled); rabbit, motorcycle, Tabby, plane, fish, school bus, bird, pick-up truck Riding: person (prop), station wagon (modeled); rabbit, motorcycle, Tabby, plane, fish, school bus, bird, pick-up truck	"Yum, yum" "Night, night" "Vroom, vroom" "Whee!"
	Basic	Drinking: cup (prop), poodle (modeled); German Shepherd, bird,	"Yum, yum"

		horse, grey terrier, rabbit, Spot, elephant, big Terrier Sleeping: cup (prop), poodle (modeled); big Terrier, bird, horse, grey terrier, rabbit, Spot, elephant, German Shepherd Keying: key (prop), sedan (modeled; VW bug, racecar, station wagon, green car, motorcycle, school bus, pick-up truck, plane Riding: person (prop), old-fashioned car (modeled); VW bug, racecar, station wagon, green car, motorcycle, school bus, pick-up truck, plane	"Night, night" "Vroom, vroom" "Whee!"
Sorting	Basic	old-fashioned car, racecar, green car, beetle, station wagon cement truck, green truck, red pick-up truck, backless truck, green pick-up truck	none (instructions only)
	Superordinate	piano, cello, trumpet, French horn, guitar wrench, screw, hammer, saw, screwdriver	none (instructions only)

APPENDIX B: List of Objects used in Sequential Touching and Sorting Tasks across all 11 Contrasts

Contrast	Category 1	Category 2
Dalmatians vs. Poodles	Brown poodle, gray poodle, classic white Poodle (red on chest), LM poodle	blue Dalmatian, Angry red Dalmatian, Happy Dalmatian, laying down Dalmatian
Dragonflies vs. Butterflies	Brown dragonfly, clear wings, Blue/green dragonfly, brown wings dragonfly	red butterfly, green butterfly, blue butterfly, Monarch
Dogs vs. birds	LM poodle, laying down Dalmatian, German Shepherd, Dachshund	cardinal, crane, yellow parakeet, bird with wings outstretched
Frogs vs. Insects	darker spots frog, purple feet frog, lighter leopard spots frog, green bug eyed frog	Monarch, ladybug, cicada, Brown wings dragonfly
Atypical animals vs. Tools	Cicada, Billy goat, Anteater, green bug eyed frog	Classic mayes gray level, skinny paintbrush, screw, wrench
Typical animals vs. Utensils	German Shepherd, fish, rabbit, yellow parakeet	green spatula, rolling pin, fat spoon, whisk
Spoons vs. Spatulas	LM Tablespoon, white slotted spoon, plastic spoon, soup spoon	yellow flipper, red flipper, yellow spatula, green spatula
Slotted spoons vs. Measuring spoons	Rose spoon, white slotted spoon, red slotted spoon, LM round slotted spoon	JV 1/8 measuring spoon, JV ¼ measuring spoon, tiny gray teaspoon, LM black Tablespoon
Levels vs. Brushes	Gray level, blue level, green level, brown level	blue hand/nail brush, soap brush, fat paint brush, angled paint brush

Paint brushes vs. Cleaning brushes	fan paint brush, artists paint brush, angled paint brush, skinny paint brush	Leather brush, blue hand/nail brush, soap brush, yellow scrub brush
Tools vs. Utensils	Green spatula, rolling pin, whisk, fat measuring spoon	Gray level, skinny paint brush, wrench, screw

APPENDIX C: List of Objects used in Generalized Imitation Task

Contrast	Action	Test object	Other within-category objects	Other props
Dalmatians vs. Poodles	Ride on fire truck	Happy red Dalmatian	Laying down Dalmatian, LM poodle	Fire truck
	Fur clipped	Classic white poodle	Laying down Dalmatian, LM poodle	Razor
Dragonflies vs. Butterflies	Eats ants	Blue/green dragonfly	Brown wings dragonfly, Monarch	Ants
	Collects pollen	Blue butterfly	Brown wings dragonfly, Monarch	Flower
Dogs vs. Birds	Dog chews bone	German Shepherd	Dachshund, yellow parakeet	Bone
	Bird sits on nest	Wings outstretched cockatoo	Dachshund, yellow parakeet	Nest
Insects vs. Frogs/Amphibians	Insect has antennae	Brown wings dragonfly	Cicada, bug eyes frog	Antennae
	Frog swims underwater	Lighter leopard spots	Cicada, bug eyes frog	Cup
Animals vs. Tools	Animal sleeps	Anteater	Bug eyes, screw	Bed

	Tools fix it up	Wrench	Bug eyes, screw	Tractor
Animals vs. Utensils	Animal drinks	rabbit	Whisk, yellow parakeet	Flower Cup
	Cooking	Fat spoon	Whisk, yellow parakeet	Orange cup
Spoons vs. Spatulas	Stir it up	Plastic spoon	Soup spoon/ladle, yellow spatula	Blue cup
	Flip it over	Green spatula	Soup spoon/ladle, yellow spatula	Cookie
Slotted spoons vs. Measuring spoons	Drain the veggies	LM slotted	LM Tablespoon, red slotted spoon	Veggies, cup
	Measure the veggies	Tiny gray teaspoon	LM Tablespoon, red slotted spoon	Veggies, cup
Brushes vs. Levels	Wash out the bristles	Fat paint brush	Angled brush and blue level	Blue cup
	Hold the board straight	Gray mayes	Angled brush and blue level	Board

Paint brushes vs. Cleaning brushes	Make a picture	Skinny paint	Blue hand/nail, angled brush	Board
	Scrub it clean	Classic leather brush	Blue hand/nail, angled brush	Tractor
Kitchen utensils vs. Tools	Fix it up	Wrench	Screw, whisk	Tractor
	Cooking	Fat measuring spoon	Screw, whisk	Orange cup

APPENDIX D: Examples of Stimuli: Dogs vs. Birds

Tools vs. Kitchen Utensils

APPENDIX E: Percentage of Participants Imitating Action with Appropriate Exemplar across all 22 Contrasts in Generalized Imitation Task

Contrast	Level	Percentage of Participants Imitating Action
Animals sleep	Superordinate	90
Tools fix it up	Superordinate	80
Insects have antennae	Basic	50
Frogs swim underwater	Basic	90
Brushes - wash out the bristles	Basic	67
Levels hold the board straight	Basic	60
Butterflies collect pollen	Subordinate	40
Dragonflies eat ants	Subordinate	70
Paint brushes make a picture	Subordinate	89
Cleaning brushes scrub it clean	Subordinate	60
Animals drink	Superordinate	56
Utensils cooking	Superordinate	60
Dogs chew on bones	Basic	50
Birds sit on nest	Basic	80
Spoons stir it up	Basic	70
Spatulas flip it over	Basic	40
Dalmatians ride on fire truck	Subordinate	44
Poodles get fur clipped	Subordinate	90

Measuring spoons measure veggies	Subordinate	40
Slotted spoons drain the veggies	Subordinate	50
Tools fix it up (opposed to utensils)	Superordinate	50
Utensils cooking (opposed to tools)	Superordinate	70

APPENDIX F**:** Mean Run Length (MRL), *t*-Test Values, Standard Error, and Percentage of Participants Exhibiting Sequential Touching Greater than Chance across all Contrasts

Contrast	MRL	SE	*t*-test compared to chance (quantitative data)	Monte Carlo program compared to chance (qualitative data)
Superordinate-level				
Atypical Animals vs. Tools	**2.68**	**.31**	**3.03****	70%
Typical Animals vs. Utensils	2.59	.44	1.91	60%
Tools vs. Utensils	1.70	.11	-0.45	0%
OVERALL MEAN	**2.32**	**.21**	**2.74***	43%
Animate/Inanimate Mean	**2.64**	**.32**	**2.79***	65%
Inanimate/Inanimate Mean	1.70	.11	-0.45	0%
Basic-level				
Spoons vs. Spatulas	1.72	.07	-0.41	20%
Insects vs. Frogs	**2.30**	**.23**	**2.41***	80%
Dogs vs. Birds	1.86	.19	0.59	70%
Brushes vs. Levels	2.34	.35	1.67	70%
OVERALL MEAN	**2.06**	**.13**	**2.42***	60%
Animate Mean	**2.08**	**.13**	**2.53***	75%
Inanimate Mean	2.03	**.**19	1.45	45%
Subordinate-level				
Measuring Spoons vs. Slotted Spoons	1.88	.25	0.98	40%

Dalmatians vs. Poodles	2.52	.74	1.05	40%
Dragonflies vs. Butterflies	2.27	.27	1.90	50%
Paint Brushes vs. Cleaning Brushes	1.74	.14	-0.08	0%
OVERALL MEAN	2.10	.32	1.39	33%
Animate Mean	2.40	.47	1.38	45%
Inanimate Mean	1.81	.11	0.56	20%

***p < .05**
****p < .01**

APPENDIX G: Pictures of Brushes used in Sequential Touching and Sorting Tasks

APPENDIX H: Percentage of Participants Categorizing 11 Contrasts across the Sequential Touching, Generalized Imitation and Sorting Tasks

Contrast	Sequential Touching	Generalized Imitation	Sorting
Atypical Animals vs. Tools	70	80	74
Typical Animals vs. Utensils	80	58	60
Tools vs. Utensils	10	60	55
Spoons vs. Spatulas	30	55	60
Brushes vs. Levels	70	64	55
Insects vs. Frogs	90	70	68
Dogs vs. Birds	70	65	66
Paint vs. Cleaning Brushes	20	75	70
Measuring vs. Slotted Spoons	40	45	59
Dalmatians vs. Poodles	50	67	71
Dragonflies vs. Butterflies	50	55	69

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