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The Effect of Word-Learning Biases on Early Vocabulary Acquisition in Young Children on the Autism Spectrum

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THE EFFECT OF WORD-LEARNING BIASES ON EARLY VOCABULARY ACQUISITION IN YOUNG CHILDREN ON THE AUTISM SPECTRUM

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ABBREVIATIONS

ASD	Autism Spectrum Disorder
LT	Late Talker
CDI	Communicative Development Inventory
CDI-WG	Communicative Development Inventory—Words & Gestures
CDI-WS	Communicative Development Inventory—Words & Sentences

ABSTRACT

Background: Vocabulary composition and word-learning biases are closely interrelated in typical development. Such word-learning biases are influenced by perceptually and conceptually salient word features, including imageability, concreteness, iconicity, and attention to shape. Autistic children often have delayed language acquisition, but there is currently little research examining the underlying mechanisms autistic children use to acquire words. The current study aimed to examine the noun composition of autistic children across a range of vocabulary sizes by examining associations between expressive noun vocabulary size and imageability, iconicity, concreteness and evidence for the shape bias, and to examine whether these patterns differ from their non-autistic peers. **Methods:** Participants for the word features analyses included 246 autistic children who were reported to produce between 5-312 nouns, and 940 expressive-vocabulary non-autistic children. Participants in the shape bias analyses included 272 autistic children who were reported to produce between 1-312 nouns, and 1,021 expressive-vocabulary and non-autistic children. Expressive vocabulary knowledge was measured using the MacArthur-Bates Communicative Development Inventory (Fenson et al., 2007). **Results:** Each analysis indicated that imageability, iconicity, and concreteness were associated with noun vocabulary size for both groups. Both groups displayed nonlinear change across vocabulary size, and group differences were found for each perceptual feature except imageability The pattern of the associations differed slightly for concreteness and iconicity for the autistic group, primarily at the very earliest points in noun vocabulary learning. Across the three word features, both autistic and non-autistic children learn highly imageable, iconic, and concrete words during the earliest stages of noun learning. Both groups also demonstrated evidence for the shape bias system, but the trajectory of growth of evidence for the system differed between the two groups.

Conclusions: Imageability, iconicity, and concreteness were identified as significant lexicosemantic features for describing expressive noun vocabulary size in autistic children. Although slight differences across word features were observed, autistic children seem to have broadly similar noun vocabularies to their non-autistic peers. Furthermore, autistic children with smaller vocabularies produced more words that are highly imageable, iconic, and concrete, whereas children with larger vocabularies produced words that are less perceptually salient, indicating a potential shift away from reliance on perceptual-based language processing. We report unique information about nonlinear growth patterns associated with each word feature, with evidence for the shape system, and distinctions in these growth patterns between groups. Future studies should explore word-learning and lexical growth patterns involving early verb acquisition in autistic children.

CHAPTER 1. INTRODUCTION

Autism spectrum disorder (ASD) refers to a neurological disorder characterized by deficits in social communication and social interaction, as well as restricted interests and repetitive patterns of behavior (American Psychiatric Association, 2013). The characteristics of ASD differ from person to person in a great variety of severities and subtypes (Schaefer & Mendelsohn, 2013). Although it is not a part of the diagnostic criteria of ASD, many autistic individuals[1] have language deficits, which can include a complete lack of spoken language to language delays, poor language comprehension, echoed speech, or typical language skills with marked difficulties engaging in social interactions (American Psychiatric Association, 2013; Pickles et al., 2014; Tek et al., 2008). Importantly, atypical language development is one of the first reasons parents seek out an autism evaluation for their child (Dahlgren & Gillberg, 1989; De Giacomo & Fombonne, 1998). The cause of the highly varied language differences found in autistic children has been debated in current literature, with some researchers suggesting that autistic children have deviant language development that may be associated with neurological processing differences, while others suggest that language development is delayed but follows a similar pattern as language development in non-autistic children (Eigsti et al., 2011; Jiménez, Haebig, & Hills, 2021).

Although there has been extensive research on the language abilities of autistic children, the processes by which they acquire language are not yet well understood. It is known that non-autistic children rely on specific word-learning mechanisms to process and store the meanings of novel words that they learn (Eigsti et al., 2011; Tek & Naigles, 2017). Some of these word-

[1] In the current study, I will use identity-first language (autistic child) instead of person-first language (child with autism) because autistic individuals have indicated a preference for this (Kenny et al., 2016).

learning strategies include attending to the shape of objects, and attending more to words with high imageability, iconicity, and concreteness. The shape bias is exhibited when a child extends the name of an object to new objects of the same shape rather than other characteristics such as color or texture (Tek & Naigles, 2017). Imageability refers to how easily a mental image is evoked when hearing or reading a word (Lin et al., 2022). Iconicity in vocal communication is characterized by a high correspondence or resemblance between the form and meaning that a word expresses (Perlman et al., 2015). Concrete words are those that can be learned on the bias of direct experiences, and they activate both verbal cues and perceptual memory cues (Brysbaert et al., 2014). The purpose of this research study is to examine word-learning biases in autistic children and compare the similarities and differences to word-learning biases utilized by toddlers with typical language development.

Language Profile of Non-Autistic Children vs. Autistic Children

The developmental milestone of the onset of language in non-autistic children generally follows a uniform pattern. While there is generally a much smaller range of individual differences within the typical course of language development, research suggests that the course of language acquisition in autistic children is highly heterogeneous (Kover et al., 2016; Pickles et al., 2014). Given this heterogeneity, it is important to examine whether autistic children utilize word learning strategies that children without autism have been found to use when developing their lexicons.

The study of developmental impairments due to the presence of language delays or deficits can help clarify the nature of language acquisition in children with different developmental disorders. Furthermore, it is important to investigate both the typical developmental course of language acquisition and the atypical course of language acquisition found in non-autistic and autistic children, respectively (Charman et al., 2003; Eigsti et al., 2011). Data from existing research has shown that language deficits are present in almost all autistic children, and a significant percentage of those children never acquire functional language (Eigsti et al., 2011). Furthermore, it is known that language acquisition in autistic children is characterized by significant delays in several language domains. For example, non-autistic children usually produce their first words around 8-12 months, while autistic children generally don't produce their first words until 23-38 months, on average (Howlin, 2003; Mayo, Chelbowski, Fein, & Eigsti, 2013). Also, some studies have found that autistic children produce less syntactically complex sentences than their non-autistic peers (see Eigsti et al., 2007). Identifying patterns of deficits within each language domain can elucidate the social and cognitive processes by which autistic children acquire language.

Charman et al. (2003) highlighted notable differences between the language profiles of non-autistic toddlers and autistic children. They collected data from 134 preschool-aged autistic children using parent reports measured on the MacArthur Communicative Development Inventory (CDI, Fenson et al., 2007) and compared these data to the published CDI normative data. The results of the study provided more insight into how the vast majority of autistic children experience extensive early lexical delays. As a group, the autistic participants were severely delayed in their early language comprehension and production compared to the typical course, and individuals within the group exhibited highly varied results. For example, early signs of language understanding (i.e., response to name) that are seen in most non-autistic children before 12 months of age were not present in 50% of the sample of autistic children until they reached a non-verbal mental age of 2.5 years. However, some autistic children had language competence within the normal range, highlighting the heterogeneity between autistic children (Charman et al., 2003).

Despite these differences in autistic toddlers' early language patterns, Charman and colleagues (2003) documented that other aspects of language development were similar to those in non-autistic children, specifically the pattern of acquisition of different word categories and word types. For example, word comprehension was more advanced than word production in absolute terms (though some autistic children have a reduced receptive advantage). Results of the study demonstrated that some patterns of language acquisition in autistic children differed from those found in non-autistic children, while most did not (for similar results, see Jiménez et al., 2021). Therefore, when studying early word learning biases, it is likely that autistic children may show evidence of some of the word learning biases that non-autistic children display.

The previously mentioned studies provide insight into just how prevalent early lexical delays in autistic children are, and how there is a considerable variation in language skills within this population. The findings shed light on the importance of examining the possible mechanisms of language acquisition in autistic children to inform our understanding of why these early language delays occur and why autistic children may vary in their subsequent language trajectories. Furthermore, intervention strategies could possibly be tailored to address the under use of certain word learning strategies, if identified. However, the fact that both non-autistic children and autistic children seem to know similar types of words suggest both groups may be relying on the same types of learning mechanisms to acquire these words, but possibly less efficiently in children with early language delays (Arunachalam & Luyster, 2016; Charman et al., 2003). It could be that autistic children are just on an extremely delayed trajectory for language acquisition, which causes learning biases to become functional later in life (Eigsti et al., 2011; but see Colunga & Sims, 2017). Specific word-learning mechanisms that have been well-documented in current literature include attending to features of imageability, iconicity, concreteness, and shape to process and store the meanings of novel words.

Word-Learning Features

In typical language development, learning new words involves attending to certain object properties in order to rapidly form individual categories of words, which leads to an accelerated rate of object name learning (Smith et al., 2002). As language learning progresses, non-autistic children become more skilled at learning object names. Adding new words to children's vocabulary first proceeds slowly, then more rapidly around the age of 2 years. By the age of 3 years, non-autistic children should be highly skilled word-learners (Gershkoff-Stowe & Smith, 2004; Smith et al., 2002). They learn new words quickly by relying on specific word-learning mechanisms to successfully map words onto objects and entities (Tek & Naigles, 2017). Children who have the prerequisite syntactic and lexical skills often show mastery of these word-learning mechanisms; however, these skills are generally delayed in autistic children (Arunachalam & Luyster, 2016).

Imageability

It has been said that throughout typical development, non-autistic children rely on perceptual, social, and linguistic cues to foster word learning (Hollich et al., 2000). Early learned words are usually perceptually salient and highly imageable, which is why imageability is another strong predictor for word acquisition in non-autistic children (Fenson et al., 1994; Gentner, 1977). Imageability quantifies the perceptual salience of a word by rating how easily it evokes a mental image (McDonough et al., 2011). Words differ in their capacity to induce mental images of things or events. Some words evoke a sensory experience, such as a mental picture or sound, very quickly and easily whereas other words may do so only with difficulty or not at all (Cortese & Fugett, 2004). There has been much speculation in current literature as to whether or not imageability plays a role in word acquisition, if imageability and Age of Acquisition are related, and if imageability is one reason why nouns are typically learned more easily than verbs.

Age of acquisition (AoA) is a term used to refer to the age at which a word is typically learned (Morrison & Ellis, 2000). Masterson and Druks (1998) examined the relationship between AoA and imageability by providing a list of words to adults and asking them to provide hindsight age of acquisition ratings of the words on a 7-point scale with each point representing a 2-year age band. For example, ‘1’ meant that the word was acquired from 0 to 2 years of age, while ‘7’ meant that the word was acquired after age 12. Their results showed a negative correlation between imageability and AoA for both nouns and verbs, meaning that more imageable words were acquired earlier in development. This suggests that if highly imageable words, regardless of word class, are easier to identify than less imageable words, then perhaps highly imageable words are also easier to learn (McDonough et al., 2011).

Recent experimental studies have provided evidence that highly imageable words actually are easier to learn and play a role in word acquisition. More specifically, nouns tend to appear before verbs and to dominate the lexicons of English-speaking children, and imageability may be one of the reasons nouns are learned more easily than verbs in non-autistic children (Fenson et al., 1994; McDonough et al., 2011). Specifically, the concepts behind nouns tend to generally be more imageable and easier to see than the concepts represented for verbs. Therefore, it is possible that nouns and verbs are distinguished from each other by a conceptual distinction between what each word class tends to label (McDonough et al., 2011). A way to affirm this distinction is by being able to measure a word's imageability.

For example, Gillette et al. (1999) asked 84 adults to guess 24 nouns and 24 verbs spoken in silent videos of a mother interacting with her child, which simulated the word learning process children experience. In a second experiment, the adults were asked to rate the imageability of each word. Gillette and colleagues (1999) found that adults were more successful at guessing the nouns than the verbs, and they rated nouns as significantly more imageable than the verbs. Similarly, Masterson and Druks (1998) provided a list of words to adults and asked them to rate the imageability of hundreds of nouns and verbs; they also found in their results that nouns were rated as significantly more imageable than verbs.

Other studies have also found that imageability can have an effect on word-naming and lexical decision. Ellis and Morrison (1998) measured AoA in a regression study of adult naming reaction times for 220 object pictures. Word AoA showed a high correlation with word naming speed ($r = .626$). They also found that imageability and AoA were predictors of naming performance with the correlation between the two almost as high as -.58 (Ellis & Morrison, 1998). Masterson et al. (2008) conducted a similar study by asking 3- and 5-year-old children to name 100 object pictures and 100 action pictures. Results showed that imageability was a significant predictor of action and object naming among the 3-year-olds and of object naming among the 5-year-olds. In regards to lexical decision, Morrison and Ellis (2000) found that imageability affected lexical decision but not word naming in adults. If it is to be assumed that imageability activates word meanings in a task, then semantics would play an important role in lexical decision. Therefore, Morrison and Ellis (2000) suggested that the more imageable a word is, the faster the meaning becomes available. Participants in a later study conducted by Cortese &

Fugett (2004) individually rated words according to the ease or difficulty with which they evoke mental images, and results indicated that the more imageable the referent of the word was, the shorter the reaction time was.

However, some limitations to these studies include unreliable adult reports of when they first started to produce a word. This could make some results questionable, since it is hard to remember the exact time they acquired a word. Additionally, the scale provided to adults to estimate AoA spans a long period of time, and each level of the scale represents a period of several years. This makes it almost impossible to examine the precise age of acquisition of words learned during the first two years of life (McDonough et al., 2011).

Therefore, McDonough et al. (2011) tested whether there is a relationship between imageability and children's age of acquisition of words as assessed by parental report, and whether imageability accounts for a word's age of acquisition above and beyond syntactic class. McDonough and colleagues found that the noun class had a significantly younger age of acquisition and a significantly higher imageability rating than the verb class. They also examined the relationship between AoA and imageability within each form class. Results indicated that for all nouns and verbs, CDI AoA was highly correlated with imageability. Therefore, their results reveal a significant relationship between imageability and parent reported age of acquisition. That is, words with higher imageability ratings (more imageable) tend to be acquired earlier than words with lower imageability ratings in non-autistic children (McDonough et al., 2011).

Although the evidence has shown that highly imageable words are more easily learned in non-autistic children, there is less research in the current literature showing the effects of imageability on word-learning in autistic children. It has been shown that autistic individuals have difficulties comprehending words with several, vague conceptual units, and they have an abnormally increased reliance on perceptually-based processing for words even with low-imageability (Arunachalam & Luyster, 2016; Gaffrey et al., 2007; Kana et al., 2006). Therefore, current literature, although sparse, has examined the extent to which imageability predicts early noun acquisition or noun processing in non-autistic children and autistic children.

Lin et al. (2022) investigated whether imageability predicts early noun and verb acquisition in autistic children to the same extent as vocabulary-matched children without autism, after controlling for word. This study conducted secondary data analyses using data from the National Database for Autism Research and a previous longitudinal study (Lord, Luyster, Guthrie & Pickles, 2012). The expressive vocabularies of autistic children with a mean age of 59 months and a mean vocabulary size of 339.0 words were measured using the CDI Words and Sentences Form (Fenson et al., 2007). The non-autistic group were matched on gender and expressive vocabulary size and included children with a mean age of 24 months and a mean vocabulary size of 340.0 words. Their results showed that the first acquired words in autistic children are highly imageable, which is consistent with the literature concerning non-autistic children. Additionally, the average imageability of nouns had a stronger correlation to expressive vocabulary size than the average imageability of verbs, though they were both correlated. The findings in Lin et al. (2022) demonstrated that imageability significantly predicted expressive vocabulary size for both groups even after controlling for word frequency. By controlling for word frequency, they found that word imageability explained unique variance in predicting expressive vocabulary size in both groups. Furthermore, smaller vocabulary sizes were associated with higher imageability and as total vocabulary size increases, the average imageability decreases in both non-autistic children and autistic children. Importantly, there were no significant interactions between imageability and group. Therefore, Lin and colleagues (2022) suggest that autistic children rely on similar word-learning strategies as their non-autistic peers, which supports previous hypotheses that language acquisition might not be deviant in autistic children, but just delayed in comparison to non-autistic peers (i.e., dimensional account, Arunachalam & Luyster, 2016; Charman et al., 2003; Eigsti et al., 2011).

Since autistic children are more reliant on visualization to support language comprehension (Kana et al., 2006), other word features that also are observable may also influence word learning. As such, additional research exploring other multisensory language features will help to support or reject the claims that autistic children use the same word-learning mechanisms as their non-autistic peers.

Iconicity

Iconicity refers to the perceptual similarity between a symbol and its referent, and studies have shown that non-autistic children are increasingly likely to contextualize highly iconic pictures, gestures, and words rather than less iconic symbols. Therefore, iconicity facilitates the acquisition of novel words by allowing the learner to easily access meaning from highly iconic words (Perry et al., 2015, 2021; Perlman et al., 2015). Through infancy and early childhood, non-autistic children begin learning how symbols relate to their real-world referents, and before 3 years of age, children's ability to contextualize pictures is influenced by iconicity, language, and intentionality (Hartley & Allen, 2015b; Kirkham et al. 2012). This phenomenon is important because iconicity is said to facilitate word learning in children; children tend to learn more iconic words earlier (Perry et al., 2015, 2021).

It has also been said that, across languages, certain types of words tend to be more iconic than other types (Perry et al., 2015). Perry et al. (2015) conducted a study to determine which types of words are most iconic in the English language and to determine if iconicity and age of acquisition are related. In three experiments with English words, Perry and colleagues asked native speakers to rate the iconicity of about 600 words from the CDI. They found that the ratings did vary by lexical category; from most to least iconic were onomatopoeia (moo), interjections (ouch), adjectives (sticky), verbs (stop), nouns (jeans), and function words (here). They also found that age of acquisition was a strong predictor of iconicity, even after removing the contribution of onomatopoeia and interjections. Words learned earlier in development tended to be more iconic, suggesting that iconicity in early vocabulary may aid word learning. Furthermore, words learned earliest by children were words that participants thought sounded like what they meant (e.g., "slurp" sounds like the noise made when you perform this kind of drinking action). Perry et al.'s (2015) findings provide compelling evidence that iconicity is an important property in the English language. To further explore this, Perry et al. (2021) investigated whether iconicity in caregiver speech facilitated word-learning in 34 non-autistic toddlers aged 1.5- to 2-years-old. They found that the toddlers were more likely to map novel words onto objects and retain these word-referent mappings when caregiver utterances had higher average iconicity (Perry et al., 2021).

Although it is suggested that iconicity can support word-learning in non-autistic children, current research proposes that autistic children can have trouble understanding symbolic relationships between words, pictures, and objects because of the difficulty in comprehending the dual nature of symbols-referents (Carter & Hartley, 2020; Hartley & Allen, 2014, 2015a). For example, the "dual nature" of pictures refers to the fact that pictures are both symbolic representations of independently existing referents and 3-D objects in their own right.

To assess understanding of symbolic relationships between words, pictures, and objects, Preissler (2008) taught minimally verbal autistic children the word "whisk" in association with a black-and-white line drawing of a whisk. Results showed that the majority of autistic children thought the word “whisk” only applied to the picture, and they did not extend the label to the symbolized object. This suggests that minimally verbal autistic children have difficulty understanding symbolic word-picture-object relationships (Preissler, 2008). However, the low iconicity of the pictorial stimuli could have negatively affected their performances.

Hartley and Allen (2015) tested this possibility by investigating the ability of 16 minimally verbal autistic children and 16 language-matched non-autistic children to contextualize pictorial symbols in a search task. Participants were tasked with finding a toy in a hidden location that was communicated to the children via pictures varying in iconicity. Researchers found that both groups made significantly more accurate retrievals when the pictures provided were more iconic (e.g., they were more likely to find the item if they were given a photograph rather than a line drawing). Additionally, they found that non-autistic children and autistic children with higher receptive language skills produced more accurate retrievals than their peers with low receptive language. Therefore, Hartley and colleagues (2015) suggest that iconicity and receptive language abilities play a role in children’s ability to conceptualize pictures (Hartley & Allen, 2015a).

Similarly, Hartley and Allen (2013) found in their study that autistic children generalized labels more frequently in color picture conditions. Their findings revealed that participants extended words to objects more accurately when taught using color photographs (i.e., high iconicity) rather than black-and-white photographs (i.e., low iconicity), indicating that iconicity has an important impact on symbolic understanding of pictures for autistic children.

More recently, Carter and Hartley (2020) investigated how ASD impacts children’s ability to learn and retain words from pictures that vary on the dimension of iconicity. They found that both non-autistic and autistic children achieved significantly greater accuracy on the referent selection trials for the photographs (deemed as having high iconicity) than for the cartoons (low iconicity). Also, autistic children had greater retention for the photograph trials than for the cartoon trials. Interestingly, autistic children responded with greater accuracy in the photograph condition than the non-autistic children did. These findings demonstrate that word learning in autistic children is facilitated by greater iconicity. With the ability to retain the iconic information and generalize it to new objects, autistic children could possibly learn words faster and easier.

Concreteness

Concrete words are those that can be learned on the bias of direct experiences; you can have immediate experience of a concrete entity through any or all of your senses and the actions you complete (Brysbaert et al., 2014). Therefore, concrete words tend to be easier to process and remember than abstract words, which cannot be directly experienced through senses or actions. Furthermore, to describe the meaning of abstract words, you usually have to use other words to capture parts of its meaning. On the other hand, concrete words refer to easily perceptible entities, which allows children to have access to both verbal systems and perceptual systems to help them understand and retain the meaning of a word (Brysbaert et al., 2014).

Hanley et al. (2012) examined how concreteness influences the processes of word production in non-autistic individuals. In this study, 56 non-autistic undergraduate students were presented with dictionary definitions of concrete and abstract words, and they attempted to recall the word that fits the definition. Generating words from dictionary definitions involves accessing a target word's semantic representation in memory, activating the word's lexical representation, and activating the word's phonological features (Hanley et al., 2012). Results found that significantly more concrete words than abstract words were correctly named in response to the provided definitions. Also, definitions of abstract words elicited more erroneous responses or failures to respond than the definitions of concrete words did. This shows that semantic-lexical weights are weaker for abstract than for concrete words. If concrete words have richer semantic representations than abstract words do, then the semantic representations of concrete words are more easily accessed in response to their definitions.

McGregor et al. (2011) demonstrated that through word definition and word association tasks, autistic children with language impairments (ASD+LI) showed less knowledge of abstract words than concrete words when compared to age-matched non-autistic peers and autistic children who had no language deficits (ASD-LI). Specifically, 12 of the 20 abstract words conveyed emotion, mental activity, or communication. Such words can be difficult for autistic individuals who also have syntactic deficits to understand and contextualize due to their diagnoses (McGregor et al., 2012).

Another perceptible feature of words is a referent's shape. Another word-learning bias that has proved beneficial in literature regarding non-autistic children is the shape bias. The next section will discuss the shape bias.

Shape Bias

The shape bias is a learning bias that toddlers develop, which facilitates their ability to rapidly learn new nouns. This shape bias is exhibited when a child extends the name of an object to new objects of the same shape rather than other characteristics such as color or texture. That is, when presented with a solid object with multiple parts and constructed shape, children extend its name broadly to all things that match it in shape. When shape is not a reliable source of information, such as for a nonsolid substance, children extend its name by other surface properties, especially material (Colunga & Sims, 2017; Landau et al., 1988). Importantly, the shape bias doesn't automatically exist—it tends to develop over time in children who have learned 50-150 count nouns in their expressive vocabulary (Samuelson & Smith, 1999; Smith et al., 2002), which is a milestone that autistic children are delayed in attaining. Furthermore, it is also important that children develop a noun bias to aid in the development of the shape bias.

The noun bias is a feature of early vocabulary composition in which a child is more likely to map a novel word onto an un-named object rather than the color, texture, or associated action of that object (Swensen et al., 2007). The previous literature has demonstrated that nouns tend to develop earlier in non-autistic children's lexicons than words in other syntactic classes (McDonough et al., 2011). According to Tager-Flusberg et al. (1990) and Charman et al. (2003), the noun bias may also appear in autistic children because nouns are more concrete than other word types. Jiménez, Haebig, and Hills (2020) also demonstrated that autistic children exhibited a noun bias in their vocabularies; however, it was weaker compared to the noun bias found in non-autistic children. Swenson et al. (2007) also indicated that both the non-autistic comparison group and the autistic children were more likely to map a novel word onto an object rather than an action. Thus, once a child learns 50-150 count nouns in their expressive vocabulary, they should then be able to use the shape bias to acquire even more words in their lexicon.

However, when developing the shape bias, the exact size of a child's noun vocabulary may not be as important as the relative proportion of words in their vocabulary that are classified as shape words instead of material words (or even combinations like chalk that have both shape and material features, which would not support the development of a shape bias; i.e., evidence that goes against the system; Perry & Samuelson, 2011). Furthermore, attentional differences may lead to differences in the types of words the child learns. However, it is debated in current literature as to whether or not autistic children utilize the true shape bias to acquire new words. To further understand whether the shape bias is utilized in autistic children, it must first be understood how the shape bias develops in children.

Theoretical Accounts of the Shape Bias

Despite disputes in the existing literature regarding whether or not the shape bias exists in autistic children, it is commonly accepted that the shape bias is present in almost all non-autistic children (Landau et al., 1988; Samuelson & Smith, 1999; Smith et al., 2002). Theorists also agree that the shape bias is an important strategy for successful vocabulary growth, and that it is a potential sign of the categorical organization of the lexicon (Abdelaziz et al., 2018). However, there is much disagreement as to whether the shape bias develops from perceptually based associations or by conceptual knowledge (Booth & Waxman, 2008; Colunga & Smith, 2008). Tek and Naigles (2017) provided an excellent review of both theories.

Attention Learning Account (ALA). According to the Attention Learning Account (ALA), the shape bias develops out of perceptual mechanisms whereby simple learning processes guide children's attention to pick out relations between perceptual features of objects, language, and category structures (Smith et al., 2002; Tek & Naigles, 2017). The main idea is that attentional learning is a continuous and ongoing process that tunes children's attention in the moment to properties and features known to be relevant to the task context (Colunga & Smith, 2008). The ALA suggests that the shape bias develops in a naming context because words act as a guide to directing children's attention to the specific perceptually salient property of shape (Landau et al., 1988). In Smith et al.'s (2002) study, they found that training children to attend to shape in the context of naming caused them to learn object names more rapidly. Furthermore, the tuning of attention to an object's shape will then indicate category membership through the organization of visually similar objects around the same label. ALA proposes that children's attention is automatically directed, without purposeful thought, to similarities that have been relevant in those linguistic and perceptual contexts in the child's past (Colunga & Smith, 2008). In other words, generalizing a novel name to a new instance occurs because of learned associations that cause contextually cued dynamic shifts in attention.

Smith and colleagues (2002) taught non-autistic children specific names for artificial objects organized by shape over a 7-week period. They used this training to test if children would generalize these names to new instances and categories of objects, and to examine whether or not knowledge of higher-level associations would result in accelerated object name acquisitions. Even though the objects presented were artificial, the study found that the children showed a significant increase in their production of count nouns for real objects. Tek and Naigles (2017) added that using simple artifacts, such as those utilized in Smith et al. (2002), might have heightened the perceptual salience of objects for young children and tuned their attention to the shared similarity of shape between the objects. This would make the category-relevant generalizations easier for them (Son et al., 2008).

The Smith et al. (2002) study supported a key claim to the ALA account—children not only learn first-order correlations, but they also learn higher order correlations. These higher (second, third) order correlations reflect statistical correlations across systems of categories, which is consequently highly useful in learning new object names (Colunga & Smith, 2008). The ALA suggests that conceptual knowledge does not precede or guide vocabulary learning, but that these higher order cognitive structures can emerge out of dynamic relations between perceptual and linguistic processes and an entire system of acquired categories (Colunga & Smith, 2008; Smith et al., 2002; Tek & Naigles, 2017). Furthermore, Landau, Smith, Jones, and their colleagues have argued that word learning “primarily engages the perceptual systems and is immune to influences from general world-knowledge” (Landau, Smith, & Jones, 1998, p. 20; also see Jones & Smith, 2002; Jones, Smith, & Landau, 1991; Landau, Smith, & Jones, 1988; Samuelson, 2002; Smith, 1995, 1999; Smith, Jones, & Landau, 1996; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002).

Moreover, word learning can provide an infant with a source of inductive reasoning (Booth et al., 2005). Graham, Kilbreath, and Welder (2004) demonstrated a nonobvious property on a novel target object to 13-month-old infants. They then gave the children other objects that varied in perceptual similarity to the target in an attempt to see if they would elicit the nonobvious property on any of the test objects. It wasn’t until the researchers labeled the target and test objects that the infants used categorical induction to attend to the property. This study provides evidence that word learning supports the foundations of conceptual structure at a young age.

Since the shape bias develops out of a naming context—according to the ALA—children must learn a sufficient number of count nouns (e.g., 50) before they can generalize names across object categories (Smith et al., 2002). To further elaborate on this argument, children must first learn basic names for *solid* objects during the early stages of language acquisition. They can then start identifying similarities shared by different objects with the same label (e.g., all balls are round). This leads to children learning to generalize the labels across object categories—in this instance, by shape (Tek & Naigles, 2017).

Moreover, children who do not have enough words for objects in their expressive vocabularies will have difficulties with the shape bias. This can be seen in Tek et al. (2008), where the non-autistic children did not show a shape bias at Visit 1 because over half of them had less than 50 count nouns in their expressive vocabulary. Therefore, children must have acquired a suitable lexicon before they can apply what they've learned to generalize a name to new instances (Colunga & Smith, 2008).

Conceptual Knowledge. On the other hand, some researchers believe the shape bias is influenced not only by perceptual information, but by conceptual information as well. According to this theory, the shape bias doesn't develop out of attentional learning mechanisms, but is an indication of children's knowledge that words refer to categories or hidden qualities of objects (Gelman, 2003). For example, if different animals are named "cat," children will know that all these animals fall under the same category of cat and will share the same characteristics (Tek & Naigles, 2017). It is known that children have an impressive capacity for conceptual knowledge, and that they acquire new words at a rapid rate (Booth et al., 2005). Therefore, this account assumes that conceptual and lexical development are closely entwined at birth, and difficulties with the shape bias may underlie difficulties with conceptual development (Tek & Naigles, 2017).

(Booth et al., 2005)Many studies have shown that shape is a good indicator of object kind, and children are able to use their conceptual knowledge before they produce words (Booth et al., 2005; Booth & Waxman, 2008; Diesendruck & Bloom, 2003; Gelman, 2003). If this is true, then it would challenge one of the main claims of the ALA, which is that the shape bias develops out of a naming context only after children have acquired 50 count nouns. Furthermore, infants as young as 1-year old can generalize new instances of objects by shape and demonstrate knowledge of what certain word classes refer to (Booth et al., 2005; Booth & Waxman, 2008). Evidence in recent studies indicates that the shape bias appears in children earlier than the ALA claims it does. Booth, Waxman, and Huang (2005) found in their study that infants with an average of 18 count nouns in their expressive vocabularies demonstrated a shape bias for both artifacts and animate kinds. The infants in the study were also able to exhibit distinct patterns of novel-name extension for animate objects and artifacts that cannot be attributed to the ALA's theory of perceptual properties alone.

Some studies have challenged the ALA's assumption that the shape bias is only observed in the presence of names and have even suggested that conceptual knowledge can guide early word learning. Diesendruck, Markson, and Bloom (2003) showed that children as young as 3 years can demonstrate knowledge of what certain word classes refer to (ex. object function). When an experimenter provided the children with information about the target object's intended function, the participants extended a novel word to the test object that was perceptually different but shared the same function. When asked to extend the target object's name onto a novel object, the children revealed a tendency to select a shape match to a target object in a similar manner when asked to select an object of the same kind as the target; and this tendency was specific to cases in which children were asked to generalize kind information.

They concluded that 2- and 3-year-olds extended novel names to novel objects by shape. More interestingly, the children also chose shape over color and texture when asked to find an object that was "of the same kind" as the target. Therefore, toddlers use the shape of an object as a cue to its conceptual status without hearing the object's label (Booth & Waxman, 2008). Therefore, Diesendruck et al., (2003) suggested that children's ability to learn the meanings of words might be the result of more general capacities that children possess such as the ability to form concepts, to reason about the intentions of other people, and to acknowledge mappings between syntax and semantics (Booth & Waxman, 2008).

Shape Bias in Late-Talking Toddlers Without ASD

The current literature indicates that the shape bias might be delayed and/or impaired in not only autistic children, but in late-talkers. Late-talkers (LT) are defined as children who fall significantly behind their peers in expressive vocabulary for their age (Perry & Kucker, 2019). Importantly though, LT children exhibit this vocabulary delay without any sensory, cognitive, or neurological deficits (Colunga & Sims, 2017). As is the case with autistic children, there is a lot of variability in the developmental trajectories of late-talking children. Some LT children catch up to their non-autistic peers around the time they reach school-age, others continue to fall in the lower range of language skill norms, and some remain significantly delayed (Colunga & Sims, 2017; Perry & Kucker, 2019). It should be noted that even within these listed deficits, there is heterogeneity in skills for individual LT children. Similarly to autistic children, these individual differences predict future individual language growth (Perry & Kucker, 2019).

More specifically, differences in LT children's individual vocabulary compositions can predict novel noun generalizations (Perry & Samuelson, 2011). For example, children who know several names for objects categorized by shape will usually extend novel names by similarity in shape. On the other hand, children who know more names categorized by material will generally extend a name to a novel object by material. Colunga and Sims (2017) suggest that there is a developmental feedback loop of learning new nouns, developing biases to attend to relevant object and substance properties, and learning more nouns. While non-autistic children generally exhibit this developmental feedback loop, several current studies suggest it is impaired or delayed in LT children.

Jones (2003) conducted a study to determine whether 2- to 3-year-old LT children have or have not acquired a shape bias. Twelve LT children, who were below the 30th percentile for age-normed expressive vocabulary, and 12 non-autistic children participated in the study. Jones

(2003) found that, as a group, the LT children used the shape bias to a lesser extent than the typically developing children did; late talkers were less likely to extend the name of a novel solid object to other objects that match it in shape. Interestingly, almost half of the LT children instead showed a bias to attend to texture (material) rather than shape. The study concluded that, while LT children are not utilizing the shape bias to learn novel names, some of them are utilizing other word-learning mechanisms such as the material bias.

Colunga and Sims (2017) hypothesized that there is a disassociation between vocabulary production and word-learning biases in LT children, which causes both a limited production of object names and a deficiency in word-learning processes. They conducted two experiments to see if noun vocabulary composition differs between non-autistic children, LT children, and neural networks trained to have a similar vocabulary composition to these children; and if these differences are related to corresponding differences in word-learning biases. They characterized words in the children's vocabularies on whether they refer to solid or nonsolid things that are alike in shape, material, or both. They found that early talkers' vocabularies contained more words for solids than for non-solids and more words for shape-based categories than any other type. Further analysis confirmed that early talkers showed a robust shape bias for solids and a robust material bias for nonsolids. Compared with the noun vocabularies of early talkers, late-talkers' vocabularies showed more variance and had fewer words for solids organized by shape and material. Therefore, while the LT children showed a shape bias for solids, more than half of them showed an overgeneralized shape bias for nonsolids. In the current study, we aim to make a similar group comparison of the noun vocabulary composition in non-autistic children and autistic children.

The results of Colunga & Sims (2017) add to the growing evidence that late talkers and typically developing children's vocabularies differ in their structure, which can therefore result in differences in attentional biases. Specifically, they showed that late talkers and early talkers know different sorts of nouns (i.e., late talkers are more likely to know nonsolids). Critically, then, both Jones (2003), who found that, as a group, LT children did not show a shape bias, and Colunga and Sims (2017), who found that, as a group, they did, reveal a great deal of heterogeneity among LT children's generalization abilities (Perry & Kucker, 2019). It is to be noted that the children in the study by Jones (2003) were nearly a year older than the children in the study by Colunga & Sims (2017), indicating that use of the shape bias may change throughout the stages of language development. By taking this into account, researchers can gain a more accurate description of children's individual language abilities at different points in their development and therefore make more informed conclusions about intervention strategies.

Similarly, Perry and Kucker (2019) used a variety of statistical methods to examine novel noun generalizations in LT children and the heterogeneity of word-learning biases used by them. Participants included 32 LT children whose expressive vocabularies were below the 30th percentile and 32 non-autistic children whose expressive vocabularies were above the 30th percentile. They found that both groups demonstrate a shape bias, but LT children on average were less likely to choose shape than the non-autistic children. These results are consistent with the results of Colunga and Sims (2017), in which LT children as a group generalized novel names by similarity in shape less than non-autistic children do. Upon removing 2 LT outliers from the regression analysis, they found a main effect of vocabulary, suggesting that, for the majority of LT children, vocabulary structure is a reliable predictor of their ability to generalize labels based on shape. This is important because individual differences in vocabulary composition can predict individual differences in word-learning biases (Perry & Samuelson, 2011). Perry & Samuleson (2011) demonstrated that, when examining vocabulary structure, words that are a part of the dominant segment of vocabulary statistics are said to be “for the system” (shape+solid and nonsolid+material) and therefore affect the biases that emerge. On the other hand, words that do not fall into these two categories are said to be “against the system.” Therefore, if a child has more words in their vocabulary that are “for the system,” they are more likely to utilize the shape bias to learn more words (Perry & Samuelson, 2011).

The material bias in LT children demonstrated in Jones (2003) and Colunga & Sims (2017) could possibly lead to frequent errors in extending the names of categories organized by shape because most solid objects learned at a young age are organized by shape (Jones, 2003). Moreover, vocabulary acquisition in LT children could be doubly disadvantaged because they lack a helpful shape bias and instead have a material bias that will lead them to error and confusion in solid-object naming. Jones & Smith (2005) demonstrated that late talkers have difficulty in recognizing highly familiar objects from abstract shape caricatures, which is a critical precursor to developing a shape bias. This finding suggests that the differences between LT and non-autistic children’s generalization might be connected to vocabulary growth *and* the ability to process and categorize shape information (Jones & Smith, 2005).

The research completed by the aforementioned studies adds to a growing literature on the differences in word-learning biases in late talkers and early talkers. Even before they turn two, children who excel in vocabulary acquisition show very consistent word-learning biases. On the other hand, the late-talking toddlers in these studies show a different and less consistent pattern of novel noun generalizations. To our knowledge, there are currently no longitudinal studies that can show the developmental outcomes of LT children in relation to their individual learning performance based on the shape bias. If a study like that were to be conducted, it could potentially point to if and how novel noun generalizations and the shape bias affect vocabulary development in individual LT children.

Shape Bias in Autistic Children

According to Tek and Naigles (2017), shape as a salient object property is one of the earliest categories that children use to organize different instances of objects under one label. Even so, autistic children have difficulty correctly extending word meanings and organizing words/concepts in semantic networks (Arunachalam & Luyster, 2016). Colunga and Sims (2017) suggests that noun vocabulary composition and word-learning biases are closely interrelated in typical development. This specific shape-bias evaluation of vocabulary composition has not yet been applied to vocabulary data from autistic children, which is one aspect we will examine in our study.

As previously noted, children's tendency to attend to shape in the context of naming solid objects booms when they have close to 50 to 100 count nouns in their expressive vocabulary. While autistic children can be similar to non-autistic children in acquiring a sizeable expressive vocabulary (albeit at a slower rate), they seem to have difficulty organizing words around the same conceptual units, such as similarity in shape (Naigles & Tek, 2017). A lack of shape bias therefore cannot be attributed to a limited number of words, as shown in Tek et al.'s 2008 study. Tek et al. (2008) explored the shape bias in autistic children across 4 different time points within one year of development using the intermodal preferential looking paradigm (IPL; Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987). Participants included 15 non-autistic children and 14 autistic children who ranged from 18 to 37 months at the beginning of the study. Both groups watched a noun bias video and a shape bias video, and participated in a pointing task and standardized testing. The stimuli for the shape bias video were presented in two consecutive sets of trials. The first set was the “NoName” condition, in which the objects were introduced without labels, and the second trial was the “Name” condition, in which the target objects were presented with novel names. Results of the study showed that all children preferred to map the novel noun onto an object rather than an action, therefore exhibiting the noun bias.

Despite this noun bias finding, results on the shape bias showed more variability (Tek et al., 2008). The non-autistic children did not show a shape bias at Visit 1, but they did show a significant shape bias during Visits 2, 3, and 4. This could be attributed to the increase in count nouns within their expressive vocabulary across visits, as the non-autistic children were only 20-months old at Visit 1. In contrast, the autistic children did not show a significant shape bias as a group at any visit, even when including the high vocabulary children (producing more than 50-100 count nouns). The autistic children’s absence of a shape bias in the IPL videos was not due to an inability to notice the shape similarities across the match-to-sample format because, even as early as Visit 1, they consistently favored the shape match over the color match in the pointing task. Interestingly, higher language scores on standardized tests were associated with better shape bias performance in autistic children (Tek et al., 2008). However, the autistic children were not using the true shape bias in novel word learning because they did not show a preference for object shape for labeled objects.

Potrzeba et al. (2015) conducted a follow-up study where they doubled the size of the samples from Tek et al. (2008). Even with more than 30 children in each group, they reported similar findings. Non-autistic children showed a shape bias at 20 months of age, but most of the autistic children did not show a significant preference for shape at any visit. They did not look significantly longer at the shape match rather than the color match during the “Name” trials in relation to the “NoName” trials. In contrast to the non-autistic children, the autistic children did not preferentially extend the novel word in the “NoName” trials to objects of the same shape in the “Name” trials. Even though the children in both groups had a similarly sized lexicon, they didn’t organize their words around the same conceptual units (such as similarity in shape). The results of both studies demonstrate that lexical use and lexical organization might be dissociated in autistic children, resulting in the shape bias not being utilized (Naigles & Tek, 2017; Potrzeba et al., 2015; Tek et al., 2008).

As discussed in Tek et al. (2008), the autistic group did not demonstrate a shape bias even with a mean vocabulary of 132 count nouns at Visit 4, nor did researchers find evidence for a shape bias in just those autistic children whose count-noun vocabulary exceeded 100. However, Potrzeba et al. (2015) noted that autistic children who had larger vocabularies demonstrated a slightly stronger shape bias. They found that within the autistic group, the children producing more words on the CDI at visit 1 showed a stronger shape bias at visits 2 and 6, controlling for their degree of shape bias at visit 1. The prevalence of a stronger shape bias in autistic children with larger vocabularies could be attributed to individual vocabulary structures within the group, which is another factor we will analyze in our study. According to Perry & Samuelson (2011), what may matter most for the acquisition of the shape bias is the relative proportion of words that fall into classifications that either support the shape system (i.e., shape + solid and material + nonsolid) or “go against the system” (i.e., solid + material).

In the previously discussed studies, there is evidence of autistic children not utilizing the true shape bias even though they have acquired a sizeable lexicon (Potrzeba et al., 2015; Tek et al., 2008). There are several theories in literature that propose the ways in which some autistic children can still acquire words without the use of the shape bias. First, they possibly rely on different mechanisms, and different brain areas that underlie these mechanisms, when learning new words. Specifically, brain mechanisms that process language in autistic individuals can be under-connected, with an increased reliance on alternative networks when processing language (Kana et al., 2006). Kana and colleagues (2006) examined brain activity in 12 autistic participants and 13 age-matched non-autistic children while they processed high-imagery and low-imagery sentences. In order to comprehend these imageable sentences, the linguistic content must be processed first to elicit a mental image, and then the mental image must be evaluated and related back to the sentence. It was found that the functional connectivity among cortical regions in the autistic participants was less connected than for the controls, and that visual input from the brain was activated for both high and low imagery sentences in autistic children. This provides evidence that language and imagery are under-connected in autism, and autistic individuals are more likely to rely on visual cues to comprehend language (Kana et al., 2006).

Also, autistic children may be relying on other categories of object features when extending novel words to similar objects. For example, Field et al. (2016) found in their study that autistic children map words onto novel objects by function rather than shape when acquiring their lexicon. Diesendruck et al. (2003) also suggested that non-autistic children extend object labels based on function, creator's intent, or other deeper properties instead of by shape. Tek and Naigles (2017) suggested these studies support their belief that autistic children rely on different word learning mechanisms than non-autistic children to build their lexicon.

Another theory is that autistic children have enhanced visual processing abilities that make it harder for them to filter out irrelevant visual information (Tek & Naigles, 2017). Early in development, children's use of the shape bias is influenced by visual properties of the objects themselves (Potrzeba et al., 2015). Even though shape as a salient object property is found in infants, extracting shape similarities across a variety of objects is not a simple task for every child. For example, Son et al. (2008) demonstrated that non-autistic toddlers show a stronger shape bias with perceptually simple objects (e.g., with a smooth shape and a single color) compared with more complex ones (e.g., with more edges and more than one color). Tek et al. (2012) also found that non-autistic toddlers extended labels to new objects more often if these objects matched the original only and exactly in shape. Children in this study were more likely to choose a material bias if the test objects shared both color and shape. It is also possible that due to their sensory hypersensitivity and restricted interests, autistic children could be less willing to include newer objects into a known category unless the visual match between the objects is most satisfactory (Gilston, 2014; Tek & Naigles, 2017). Therefore, effects of perceptual detail could be even stronger in autistic children because of their weak central coherence and preference for details of component parts rather than the object as a whole (Happé & Frith, 2006).

These points support the conceptual method of learning in autistic children (Tek & Naigles, 2017). Since conceptual and word learning development are said to be closely tied together at birth, autistic children may have trouble with shape bias because of the conceptual part, not the ability to acquire a sizeable lexicon (Gelman, 2003). This is contradictory to the ALA assumption that the shape bias develops in a naming context after children have a expressive vocabulary of at least 50 count nouns (Perry & Samuelson, 2011; Samuelson & Smith, 1999).

In alignment with Potrzeba et al.'s (2015) proposal that the shape bias requires more conceptual knowledge, Naigles and Tek (2017) proposed their "form is easy, meaning is hard" theory. In a nutshell, this theory states that the social difficulties generally found in autistic children cause the meaning-related components of language (e.g., pragmatics and semantics) to be more impaired than the form-related components of language (e.g., syntax). More specifically, children who have difficulties discerning the mental states and emotions of others will also find it difficult to learn words that refer to emotions and mental states; and lower-functioning children with greater difficulties comprehending the social and cognitive worlds may "over-rely on words that are essentially 'bleached' of specific lexical content" (Naigles & Tek, 2017, p. 94-103).

Furthermore, the presence or absence of a shape bias during early language acquisition may indicate a delay or impairment in categorizing words and/or comprehending the meaning of words (Tek et al., 2008). Tek and colleagues concluded in their study that the absence of a shape bias in autistic children cannot be attributed to any overall difficulty with word learning, nor with obvious difficulty in participating in the IPL paradigm (Tek et al., 2008). The reasoning behind this conclusion is that (1) the autistic children's increasing vocabulary size across visits shows their ability to learn words, (2) they had the ability to perform well on the Noun Bias video they saw at Visit 1, (3) they demonstrated successful mapping of novel verbs onto the appropriate actions at Visit 4, and (4) the children's successful performance on the noun bias video shows their difficulty with the shape bias is not because of the IPL task itself. Therefore, the specific word-learning strategy of the shape bias seems to be what is challenging to autistic children.

Gasteb et al. (2006) suggests that lack of a shape bias in children might be consistent with difficulties in categorization and lexical organization. This is because the shape bias requires children to use words as indicators of category structure—that is, different objects are models of the same category—and research has shown that older autistic children exhibit weaknesses and inconsistencies with category structure (Potrzeba et al., 2015). Gasteb and colleagues (2006) explored how autistic individuals process categories that varied from those found in non-autistic individuals and how these skills change with development. They found that even though autistic children improved over time in their categorization ability, they never reached the same proficiency as age-matched non-autistic peers. Therefore, autistic children might develop a shape bias that is weaker and/or later-developed than non-autistic children (Potrzeba et al., 2015).

The idea that the shape bias might only be delayed in autistic children, and it can emerge when they are older, has not been significantly researched in the current literature. This hypothesis seems plausible considering autistic children often show delays in the onset of language development and display impairments in pragmatic and grammatical abilities (American Psychiatric Association, 2013; Eigsti et al., 2007; Tek et al., 2014). Despite the gaps and differing theories in existing literature, it is generally accepted that many autistic children acquire a sizeable vocabulary and demonstrate a noun bias when presented with novel words (Eigsti et al., 2007; Smith et al., 2002; Swensen et al., 2007; Tek et al., 2014). Therefore, it is possible that at least some autistic children have developed a shape bias to use when learning new words. Expanding on this information and answering existing questions on the shape bias could lead to formulating shape bias interventions for autistic children who show significant delays in word learning (Tek & Naigles, 2017).

Current Study

Because autistic children have been suggested to have a processing style that demonstrates an attentional bias for low-level perceptual features, we aim to examine the association between noun vocabulary knowledge and perceptual word features. We will also examine the same relationships derived from vocabularies from non-autistic toddlers to determine if autistic children's expressive vocabularies show similar relationships to our variables of interest. Our specific research questions are:

1. Are word features of imageability, iconicity, and concreteness associated with noun vocabulary size in autistic children and non-autistic children, and do associations differ by group?
2. Do the noun vocabulary compositions associated with shape and material features differ between autistic children and non-autistic children?

Based on current literature, we hypothesize that the word features of imageability, iconicity, and concreteness could help facilitate early vocabulary acquisition in autistic children. Therefore, we predict that words that have high iconicity ratings, imageability ratings, and concreteness ratings will be learned earlier. The current literature demonstrates that iconicity is associated with word age of acquisition in toddlers with typical language development (Perry et al., 2015). Within the ASD literature, using iconic color pictures has been found to promote the extension of information from pictures to objects in autistic children, providing initial support for our hypothesis that iconicity may be associated with early vocabulary size in young autistic children (Carter & Hartley, 2020; Hartley & Allen, 2014, 2015a). As for imageability, there is one recently published study that demonstrates that the first acquired words in autistic children are highly imageable (Lin et al., 2022). In regards to concreteness, McGregor et al. (2012) showed that certain types of abstract words (e.g. emotion) can be more difficult for non-autistic school-age children to understand than concrete words. Consequently, words with higher concreteness ratings also may be easier for autistic children to learn. Therefore, we predict that words with high imageability ratings, iconicity ratings, and concreteness ratings will be learned earlier in vocabulary development in both autistic and non-autistic toddlers (Carter & Hartley, 2020; Hartley & Allen, 2014, 2015; Lin et al, 2022; McGregor et al., 2012). Specifically, children with small noun vocabulary sizes are predicted to have high average imageability scores, iconicity scores, and concreteness scores. Conversely, because we anticipate that children with larger vocabulary sizes will be more skilled in learning less imageable, iconic and concrete words, we predict that larger vocabulary sizes will be associated with overall lower imageability, iconicity, and concreteness average scores.

For our second research question, we hypothesize that autistic children will use the shape bias to a lesser extent than non-autistic children, and they may even use other word-learning mechanisms such as the material bias (Potezeba et al., 2015; Tek & Naigles, 2017). Therefore, we predict that, as a group, autistic children may know more words that go against the shape bias system relative to their vocabulary-matched non-autistic peers (Perry & Samuelson, 2011). As such, we would expect a significant main effect of group when comparing the proportion of words that support the system. However, individual differences may show that autistic children with larger expressive vocabularies may yield more evidence for the shape bias system versus evidence against the shape bias system (Perry & Samuelson, 2011; Potrzeba et al., 2015).

CHAPTER 2. METHODS

Imageability, Iconicity, and Concreteness

Word Features Participants

We examined early expressive vocabularies of 246 autistic children (56 females, 190 males), and then compared their expressive vocabularies to 940 children with typical language development (263 females, 677 males) using word-level data collected from the CDI-WG and CDI-WS forms. If children had multiple CDIs that were completed across time, only one CDI measurement was used for each participant.

The autistic participants were obtained from the NIH-supported National Database for Autism Research (NDAR; National Institute of Mental Health, n.d., Tifforrd & Ungar 2016). All autistic children had a diagnosis of ASD from the ADOS (Lord et al., 1999, 2012) or CARS (Schopler et al., 2010). The non-autistic comparison group was obtained from Wordbank (Frank, Baginsky, Yurovsky, and Marchman, 2017). WordBank is a publicly available database comprised of data from various studies; study protocols differed and did not always include developmental assessments to ensure that children had typical development. As a minimal method to ensure that the toddlers in the non-autistic group did not have developmental deficits, we required that each non-autistic toddler score in the 15th percentile or higher according to the CDI expressive normative data (Heilmann, Ellis Weismer, & Evans, 2005). After ensuring that the non-autistic toddlers did not have a language delay (using the CDI normative percentile scores), we individually selected non-autistic toddlers to match each child in the autistic group. When possible, we matched children according to expressive vocabulary size and gender. As such, the non-autistic and autistic groups are well-matched on expressive noun vocabulary size

(p = .601); the groups did not statistically differ by gender (χ^2 (1, N = 1,185) = 2.70, p = 0.101). Participant characteristics for our first research question can be found in Table 1.

Vocabulary Assessment Tool

The CDIs are a parent-completed checklist designed to evaluate the communicative skills of young children, and it is composed of two forms: CDI-Words and Gestures and CDI-Words and Sentences. The CDI-WG evaluates both receptive and expressive language, and it includes 396 words that are organized into 19 semantic categories (e.g., animal names, food and drink, toys, clothing, action words, etc.). For each word, the parent must indicate whether the child "understands" or "understands and says" the target word. The CDI-WS evaluates expressive language only, and it includes 680 words divided into 22 semantic categories similar to those on the CDI-WG. For this form, the parent or caregiver must indicate only whether or not the child says the target word. All of the 396 words that appear on the CDI-WG form also appear on the CDI-WS form. The current study focuses on nouns only. Nouns consisted of 312 words that appeared on the CDI; these words appeared in the following CDI semantic categories: animals, vehicles, toys, food and drink words, clothing, body parts, small household items, furniture, and outside words.

The participants that were included in addressing the first research question were required to have an expressive vocabulary size of at least five nouns to avoid spurious findings for the smallest vocabulary sizes and have a completed CDI Words and Gestures and/or Words and Sentences form. The ages for the autistic children ranged from 11 months to 173 months (M = 50.08), and the ages for the non-autistic children ranged from 10 months to 30 months (M = 21.59). Vocabulary sizes for the autistic group ranged between 5 and 312 nouns (M = 142.91); for the non-autistic group, vocabulary size was also between 5 and 312 nouns (M = 146.76). Age and vocabulary sizes for autistic children and non-autistic children whose vocabularies were used in this study are summarized in Table 2.1. Out of the 246 autistic children included in our analyses, 89 of them provided data from the CDI-WG form and 157 provided data from the CDI-WS form. For the non-autistic group (*n* = 940), 171 participants were from the CDI-WG form and 769 were from the CDI-WS form. Table 2.3 displays the number of participants organized by group and CDI form for both of our research questions.

Table 2.1. Participant Characteristics for Imageability, Iconicity, and Concreteness

	Autistic Children (*n* = 246; 56 females)			**Expressive Vocabulary-Matched Toddlers (*n* = 940; 263 females)**		
	M	*SD*	Range	*M*	*SD*	Range
Chronological Age (months)	50.08	29.66	11 - 173	21.59	5.39	10 - 30
Nouns Produced	142.91	100.22	5 - 312	146.76	103.58	5 - 312

Average Word Feature Scores

We gathered average word-feature scores from existing databases to determine the level of imageability, iconicity, and concreteness of words. Brysbaert et al. (2014) collected a list of concreteness ratings for 63,039 English lemmas (root word), which didn't include proper names or inflected forms. They used a 5-point rating scale (1 being abstract, 5 being concrete) in order to make the distinction between experience-based meaning acquisition and language-based meaning acquisition. Of Brysbaert et al.'s (2014) list, 657 words were on the CDI form and have concreteness values. The current study will use the concreteness scores for 308 nouns form the CDI.

Iconicity ratings were provided by Perry et al. (2015) on a scale of 0 to 100 (0 = the meaning of a word would likely be guessed wrong based only on how the word sounded, 100 =

the meaning of a word would be easily guessed based only on how the word sounded). Participants from Experiment 3 viewed 592 words from the CDI in their written form, and then said the word aloud before rating the iconicity of each word. Iconicity scores are available for 264 nouns that will be used in the current study.

Imageability scores were obtained for 74 nouns from Masterson and Druks (1998). Ratings for the printed labels of nouns were collected from 36 participants ranging in age from 23-40 years old. Participants were instructed to rate the word on a scale of 1-7 (1 = words arousing images with the greatest difficulty, 7 = words arousing images most readily) based on how much the noun evoked a sensory experience in the form of pictures or sounds; tactile and olfactory images were not mentioned in the instructions.

Analysis Plan

In a recent study conducted for a research poster presentation for the International Society of Autism Research (INSAR), we gathered concreteness scores for 654 words (Brysbaert et al., 2014), iconicity scores for 589 words (Perry et al., 2015), and imageability scores for 125 words (Masterson & Druks, 1998) on the CDI. These preliminary data visualization revealed that the relationship between vocabulary size and average imageability, iconicity, and concreteness scores did not follow a strict linear pattern. Therefore, when examining the associations between word features and vocabulary size in the current study, we included linear and non-linear growth terms (i.e., quadratic growth and cubic growth). After filtering the data to only include nouns, we collected concreteness scores for 308 nouns, iconicity scores for 264 nouns, and imageability scores for 74 nouns to examine each child's total noun vocabulary size. We used separate polynomial regression analyses to examine the association between each child's total vocabulary size and average word feature score (concreteness, iconicity, and imageability) and for differences in this association by group.

The dependent variable was the average word feature score. Independent variables included linear, quadratic, and cubic growth across vocabulary size, group, and then interactions of linear growth by group, quadratic growth by group, and cubic growth by group. By including these non-linear growth terms, we will provide new information to the literature documenting the non-linear association patterns. Total vocabulary scores will be derived from the number of words produced that overlapped between the CDI and the respective word-feature databases. Additionally, to determine if each of the three word features has significant unique associations with expressive vocabulary scores, a fourth regression model was implemented. Since word input frequency is a known predictor for the acquisition of nouns in non-autistic children (Goodman et al., 2008) and in autistic children (Lin et al., 2022), we will run a combined regression analysis with noun expressive vocabulary size as the dependent variable and the independent variables will be: input frequency, imageability, iconicity, concreteness, group, and interactions between group and imageability, imageability, and concreteness. As in Lin et al. (2022), word frequency data was obtained from the Child Language Data Exchange System, which is a collection of written texts containing English-speaking caregiver input (CHILDES; Li & Shirai, 2000). The database consists of about 2.6 million-word tokens used in naturalistic contexts in which children engage with their caregivers. We used word frequency measures derived from caregiver speech because of their stronger association with early language acquisition compared to other existing frequency norms based on adult-directed speech as reported in Goodman et al. (2008).

Shape Bias

Shape Bias Participants

Participants for our second research question were chosen in a similar fashion to our first research aim. The expressive vocabularies of 272 autistic children ranged from 1 to 312 words, with an average of 129.43 words produced for the autistic children. The ages for the autistic children ranged from 11 months to 173 months (M = 48.73 months). The non-autistic participant group (n = 1,021) was obtained from Wordbank and were well-matched on their expressive vocabulary size (p = 0.418). Table 3 provides information about CDI form for all participants organized by research question. Age and vocabulary sizes for autistic children whose vocabularies were used in our second research question are summarized in Table 2.

Table 2.2. Participant Characteristics for Shape Bias

	Autistic Children (*n* = 272; 62 females)			**Expressive Vocabulary-Matched Toddlers (*n* = 1,021; 276 females)**		
	M	*SD*	Range	*M*	*SD*	Range
Chronological Age (months)	48.73	29.08	11 - 173	20.87	5.75	8 - 30
Words Produced	129.43	103.94	1 - 312	135.29	106.78	1 - 312

Table 2.3. Word Feature and Shape Bias Participants Organized by Group and CDI Form

	Word Feature Participants		**Shape Bias Participants**	
	Autistic Group	Non-Autistic Group	Autistic Group	Non-Autistic Group
Words and Gestures	89	246	95	250
Words and Sentences	157	769	177	771
Total	246	940	272	1,021

Vocabulary Categories

Noun characteristics were categorized using the noun feature database that was collected by Smith and Samuelson (1999) according to adult judgments made for each of the nouns in the CDI. As in Colunga and Sims (2017), we characterized each child's vocabulary by the proportion of nouns each child knew for the each of the following categories: (a) solid things alike in shape (e.g., spoon), (b) solid things alike in material (e.g., chalk), (c) solid things alike in both shape and material (e.g., penny), (d) nonsolid things alike in shape (e.g., bubble), (e) nonsolid things alike in material (e.g., milk), and (f) nonsolid things alike in both shape and color (e.g., jeans). Looking at the proportion of noun types used in children's vocabularies will allow us to view specific similarities and/or differences in noun vocabulary composition as opposed to only overall noun vocabulary size. Specifically, nouns that provide evidence "for the system" include nouns that are categorized as: shape+solid and nonsolid+material; nouns that contribute evidence that go "against the system" include nouns that are categorized as: solid+material, solid+shape+material, nonsolid+shape, nonsolid+shape+material (Perry & Samuleson, 2011).

Colunga and Sims (2013) reported that the average 30-month-old child has a noun vocabulary that is comprised of: 52% solid shape nouns, 10% solid material nouns, 12% solid shape and material nouns, 4% non-solid shape nouns, 16% non-solid material nouns, and 6% non-solid shape and material nouns. These percentages represent the typical structure of a child's early vocabulary. Across the range of expressive vocabulary sizes in our sample, we will compare the proportion of words across these noun categories to test for group differences in the composition of noun knowledge.

Analysis Plan

For the second research question, I used a shape calculator to calculate each child's noun vocabulary according to the categories above (Samuelson & Smith, 1999). The word categories were initially developed by Samuelson and Perry in Excel (Perry & Samuelson, 2011) and later converted into an R package by Dr. Cox (Cox, in preparation). The shape bias calculator reports the number of words that supports the shape bias system and a number of words that goes against the shape bias system for each child. Then these numbers will be standardized by the size of overall nouns known to allow for comparisons of vocabulary composition across vocabulary sizes using a regression analysis. Evidence for the system values were regressed on the total noun vocabulary size for each child and then the residuals were saved.

Preliminary data visualization revealed that there was a non-linear relationship between noun vocabulary size and evidence for the shape bias system. Therefore, when examining the associations between evidence for the system and vocabulary size, the analysis included linear and non-linear growth terms (i.e., quadratic growth and cubic growth). A polynomial regression analysis was used to test whether the different growth terms were associated with evidence for the system, whether there was an overall group difference in evidence for the shape bias system, and whether the growth patterns differed by group. The dependent variable was the revisualized evidence for the system in the child's noun vocabulary. Independent variables included linear, quadratic, and cubic growth across vocabulary size, group, and then interactions of linear growth by group, quadratic growth by group, and cubic growth by group.

CHAPTER 3. RESULTS

Imageability, Iconicity, and Concreteness

The first research question asked if there was an association between the word features of imageability, iconicity, and concreteness, and noun vocabulary size in autistic children and non-autistic children. We also asked if the association between word features and noun vocabulary size differed between the two groups. We used polynomial regression analyses to examine this question. Each analysis indicated that there are associations between each word features and vocabulary size for both groups. Although results varied slightly across the word features, the earliest words learned are highly imageable, iconic, and concrete. Furthermore, group differences were observed for concreteness and iconicity. Table 3.1 displays the number of autistic and non-autistic participants included in the present study that produced at least five nouns that also had iconicity, imageability, and concreteness scores. See Table 3.2 for specific information regarding each child's average word feature score and Table 3.3 regarding average number of nouns produced with word feature ratings for their noun vocabulary compositions in the autistic and non-autistic groups.

Table 3.1. Number of Autistic and Non-Autistic Participants that Produced at Least 5 Word-Feature Nouns in their Vocabulary

	Autistic Group	**Non-Autistic Group**
Concreteness	246	939
Iconicity	243	931
Imageability	224	879

Table 3.2. Average Word Feature Score Rating Per Child in Each Group

	Autistic Group			Non-Autistic Group		
	M	*SD*	Range	*M*	*SD*	Range
Concreteness	4.865	0.03	4.74 – 4.96	4.868	0.03	4.64 – 4.98
Iconicity	37.52	2.56	31.98 – 52.87	37.91	2.64	33.27 – 52.01
Imageability	6.16	0.09	5.83 – 6.42	6.17	0.08	6.00 – 6.47

Table 3.3. Average Number of Nouns Produced with Word Feature Scores

	Autistic Group			Non-Autistic Group		
	M	*SD*	Range	*M*	*SD*	Range
Concreteness	140.98	98.94	5 – 308	144.76	102.24	5 – 308
Iconicity	122.60	84.29	5 – 264	126.14	87.04	5 – 264
Imageability	44.91	22.68	5 – 74	44.78	23.33	5 – 74

Concreteness Results

For concreteness, both groups showed significant nonlinear change as expressive vocabulary size increases. The significant linear effect indicates that the earliest learned words are highly concrete and a significant quadratic effect indicated that the decline in average concreteness scores slows as noun vocabulary size increases. A significant effect of group (p = .006) indicated that, the non-autistic toddlers produced nouns that had slightly higher concreteness values (M = 4.868) than the autistic group (M = 4.865), Cohen's d = 0.10. This group difference was most robust at the earliest vocabulary sizes; however, as seen in Figure 3.1, at around 50-75 nouns, the autistic group's overall concreteness scores began following a nearly identical trajectory as the non-autistic group. Importantly, there were significant group by linear and group by quadratic interactions, which indicate that the non-autistic group showed a stronger linear trend ($p < .001$), and the autistic group showed a stronger quadratic trend ($p < .001$). See Table 3.4 for exact results.

Table 3.4. Concreteness Polynomial Regression Analysis

	Concreteness		
	Estimate	*t*	*p*
Linear	-0.53	-19.96	< .001
Quadratic	0.07	2.67	.008
Cubic	-0.002	-0.06	.952
Group (non-autistic vs. autistic)	0.004	2.76	.006
L x Group	-0.235	-4.40	< .001
Q x Group	.188	3.57	< .001
C x Group	-0.09	-1.78	.075

Note: This analysis includes data from 246 autistic children and 939 non-autistic children that were reported to produce at least 5 words that had a word feature score.

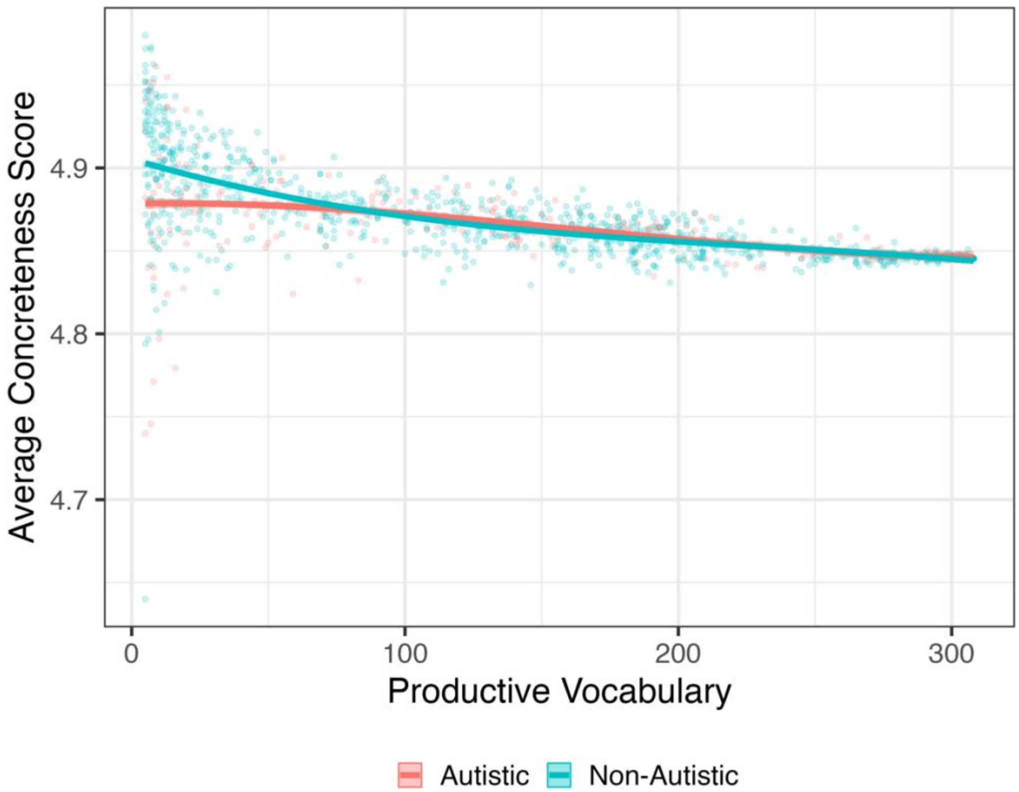

Figure 3.1. Polynomial Regression Growth Patterns Associated with Concreteness

Iconicity Results

The iconicity analysis revealed a nonlinear change across vocabulary size. The significant linear, cubic, and quadratic changes in iconicity across vocabulary size indicate that the earliest learned nouns are highly iconic, and as children learn more words, the average iconicity score decreases—but the rate of this decrease slows as noun vocabulary size increases. A significant group effect and significant group by linear and group by quadratic interactions indicates that the autistic toddlers produced nouns with lower average iconicity scores at the earliest points in their vocabulary, and the average iconicity scores had a shallower decline and plateau as noun vocabulary sizes increased. Figure 2 displays that, at around 100 total nouns, both groups began following a similar pattern of iconicity as vocabulary size continued to increase. Descriptively, the non-autistic toddlers' average iconicity score was 37.91 and the autistic toddlers' average iconicity score was 37.52, Cohen's d = 0.15. See Table 3.5 and Figure 3.2 for exact results.

Table 3.5. Iconicity Polynomial Regression Analysis

	Iconicity		
	Estimate	*t*	*p*
Linear	-63.24	-30.94	< .001
Quadratic	15.90	7.90	< .001
Cubic	-9.04	-4.49	< .001
Group (non-autistic vs. autistic)	0.425	3.63	< .001
L x Group	-13.85	-3.39	< .001
Q x Group	5.23	1.30	.194
C x Group	-1.66	-0.41	.680

Notes: This analysis includes data from 243 autistic children and 931 non-autistic children that were reported to produce at least 5 words that had a word feature score.

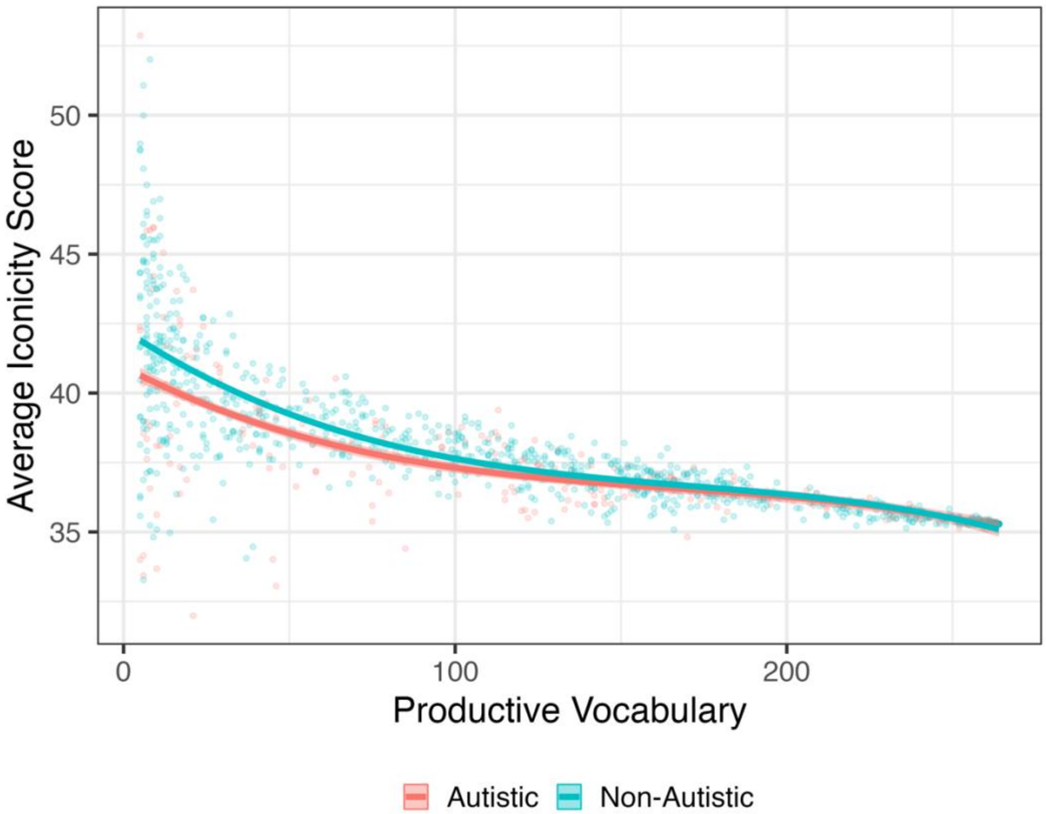

Figure 3.2. Polynomial Regression Growth Patterns Associated with Iconicity

Imageability Results

Figure 3.3 displays that the average imageability of words produced displayed an overall negative linear change ($p < .001$) and a slight quadratic change ($p = .026$) as vocabulary size increased. There were no significant group differences or significant interactions between group and the polynomial terms. See Table 3.6 and Figure 3.3.

Table 3.6. Imageability Polynomial Regression Analysis

	Imageability		
	Estimate	*t*	*p*
Linear	-2.13	-33.69	< .001
Quadratic	.139	2.23	.026
Cubic	-0.062	-1.01	.315
Group (non-autistic v autistic)	.006	1.53	.127
L x Group	-0.193	-1.53	.126
Q x Group	.092	.735	.463
C x Group	-0.136	-1.09	.275

Notes: This analysis includes data from 224 autistic children and 879 non-autistic children that were reported to produce at least 5 words that had a word feature score.

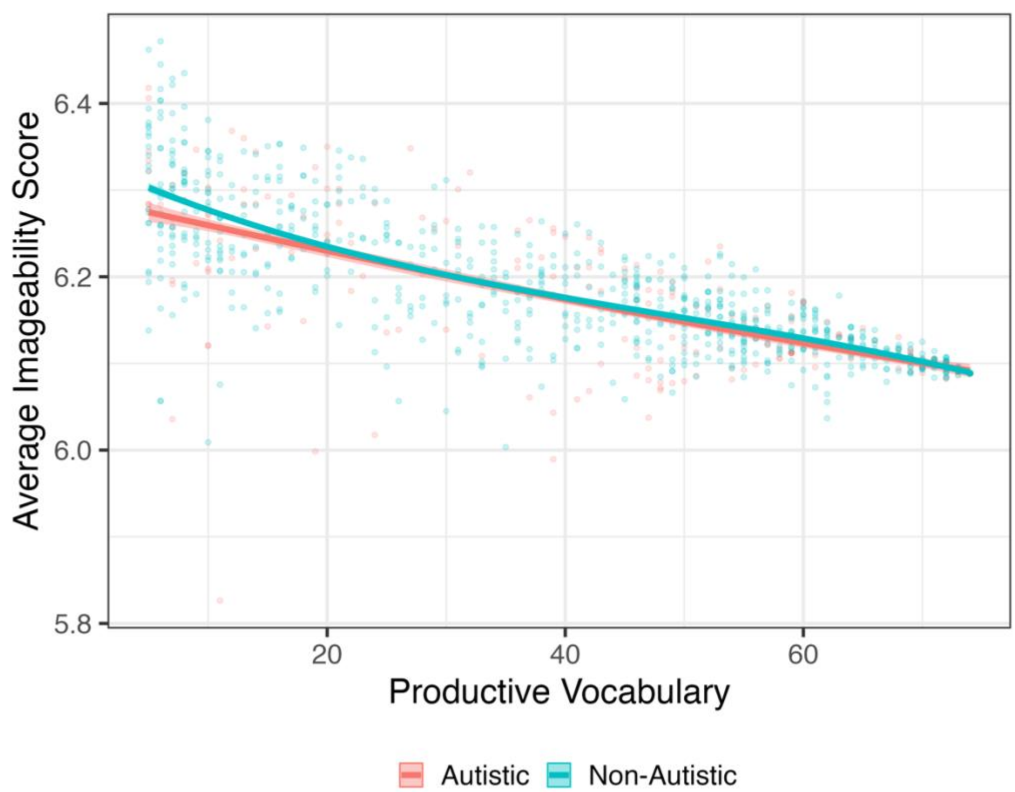

Figure 3.3. Polynomial Regression Growth Patterns Associated with Imageability

Imageability, Iconicity, and Concreteness as Predictors of Word Frequency

Lastly, I examined whether, when considered together, imageability, iconicity, and concreteness explain unique variance in language growth in the children and whether there were differences by group or interactions by group. First, bivariate correlations were examined to determine if specific word features were associated with each other. Analyses indicated that imageability is highly correlated with concreteness ($r = .844$, $p < .001$). Therefore, nouns that easily evoke a mental image tended to also be highly concrete objects or entities. Iconicity was not significantly correlated with either imageability ($r = -.054$, $p = .562$) or concreteness ($r = .038$, $p = .358$).

The combined regression model revealed that, after controlling for word frequency input, imageability, iconicity, and concreteness explain significant unique variance in expressive noun vocabulary size. There was a significant interaction between group and concreteness and interaction between group and imageability, indicating that concreteness more strongly predicted expressive noun vocabulary size in the autistic group and imageability more strongly predicted expressive noun vocabulary size in the non-autistic group. Table 3.7 provides the exact findings for the prediction model and Figure 3.4 provides a depiction of the predicted linear growth patterns for each of the word feature variables.

Table 3.7. Combined Effects of Word Input Frequency, Concreteness, Iconicity, and Imageability on Total Noun Vocabulary Size

	Predicting Vocabulary Growth		
	Estimate	*t*	*p*
Word Frequency	-0.09	-15.35	< .001
Concreteness	-0.06	-7.73	< .001
Iconicity	-5.68	-5.17	< .001
Imageability	-0.02	-9.69	< .001
Group	-0.09	-1.41	0.159
Concreteness vs. Group	0.05	3.39	0.001
Iconicity vs. Group	0.06	0.04	0.972
Imageability vs. Group	-0.02	-5.28	< .001

Figure 3.4. Model Predictions of Each Word Feature Variable Predicting Expressive Noun Vocabulary Size

Shape Bias

The second research question asked if the association between evidence for the shape bias system and vocabulary size differ between autistic children and non-autistic children. Table 3.8 provides descriptive information on the noun vocabulary structures.

Table 3.8. Noun Vocabulary Compositions for Autistic and Non-autistic Toddlers, Raw Counts and Proportions

	Evidence For the Shape Bias			**Evidence Against the Shape Bias**			**Ambiguous Nouns**		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Autistic Group	88.51	69.08	1-207	8.94	7.99	0-23	31.98	27.42	0-82
Non-Autistic Group	91.79	70.11	0-207	10.16	8.37	0-23	33.36	28.74	0-82
	M_{prop}	SD_{prop}	Range	M_{prop}	SD_{prop}	Range	M_{prop}	SD_{prop}	Range
Autistic Group	0.72	0.12	0.2 – 1	0.06	0.041	0 – 0.33	0.22	0.10	0 – 0.63
Non-Autistic Group	0.73	0.12	0 – 1	0.07	0.060	0 –1	0.20	0.10	0 – 1

Visual inspection indicated that there was a nonlinear change in evidence for the shape bias system; therefore, the analysis included the following independent variables: linear, quadratic, and cubic changes in evidence for the shape bias, group, and interactions between group and each of the polynomial terms. The dependent variable was residualized evidence for the shape bias system. The results revealed that evidence for the shape bias system is significantly associated with noun vocabulary size. Specifically, the trajectories were characterized by significant linear ($p < .001$) and quadratic ($p < .001$) change. Additionally, there was a significant group difference ($p = .031$) and there were significant interactions between group and each growth term. As depicted in Figure 3.5, the non-autistic group had a higher evidence for the system in children who had noun vocabulary sizes around 5-100 words. At a noun vocabulary size of about 50-100 words, the number of shape words for the autistic children steadily increased, even surpassing the number of shape words produced in the non-autistic group, until evidence for the system peaked at expressive vocabulary words around 150 nouns. Evidence for the system declined for both groups as noun vocabulary size reached the maximum value (312 nouns). See Table 3.9 for the specific model output values.

Table 3.9. Polynomial Regression Analysis Examining Evidence for the Shape System Across Noun Vocabulary Size

	For the Shape Bias		
	Estimate	*t*	*p*
Linear	2,527.41	332.44	< .001
Quadratic	-84.02	-11.29	< .001
Cubic	4.29	.577	.564
Group Non-Autistic v Autistic	-0.502	-2.16	.031
L x Group	-24.54	-2.89	.004
Q x Group	44.21	5.29	< .001
C x Group	27.77	3.32	< .001

Figure 3.5. Polynomial Regression Growth Patterns for Shape Bias Across Noun Vocabulary Size

Lastly, to connect the two research questions, we included an exploratory analysis to test whether shape words and non-shape words differ on average on imageability, iconicity, and concreteness scores. A logistic regression was implemented to determine whether or not each word feature is associated with whether or not a noun contributes evidence for the system. Results of the analysis revealed that, although imageability, iconicity, and concreteness are associated with noun vocabulary growth and are also perceptual features, none of these three variables are associated with whether a noun is classified as providing evidence for the shape bias system (see Table 3.10). Therefore, the lack of a shape bias throughout a child's vocabulary development cannot be directly attributed to the child producing nouns that are less imageable, iconic, or concrete; consequently, it cannot be inferred that a noun vocabulary consisting of more solid-shape and nonsolid-material words was influenced by the early acquisition of highly imageable, iconic, or concrete nouns.

Table 3.10. The Effects of Word Features on Evidence for the System

	Evidence For the Shape Bias		
	Estimate	*z*	*p*
Concreteness	2.27	0.810	0.418
Imageability	1.22	1.17	0.243
Iconicity	-0.02	-0.480	0.631

CHAPTER 4. DISCUSSION

The current study compared the noun vocabulary compositions of autistic children to non-autistic children across vocabulary size by examining several noun features. I specifically looked for associations between children's expressive noun vocabulary size and imageability, iconicity, concreteness, and evidence for and against the shape bias system. In addition, I asked if these associations differed between the autistic and non-autistic comparison groups. The analyses revealed several associations between perceptual word features and vocabulary size in both groups, and there were differences in lexical growth patterns between the groups. In the text that follows, I will discuss the results relative to the existing literature.

Word Features of Imageability, Iconicity, and Concreteness

The first research question asked if there were associations between the word features of imageability, iconicity, and concreteness and noun vocabulary size in autistic and non-autistic children, and if these associations differ between the two groups. My initial predictions were that, because autistic children have been suggested to have a processing style that demonstrates an attentional bias for low-level perceptual features, then imageability, iconicity, and concreteness could be more strongly associated with early vocabulary acquisition in autistic children (Carter & Hartley, 2020; Hartley & Allen, 2014, 2015; Lin et al, 2022; McGregor et al., 2012). I also predicted that children with small noun vocabulary sizes would have high average imageability, iconicity, and concreteness scores, and that these scores would decrease as vocabulary size continues to grow larger.

Using parent-reported measures of children's expressive vocabularies, I found that the relationship between noun vocabulary size and imageability, iconicity, and concreteness observed in the autistic children's data broadly align with the pattern observed in younger non-autistic toddlers (Hartley and Allen 2014; Lin et al., 2022; Perry et al., 2015). Each analysis indicated that word features are associated with vocabulary size for both groups, and—although results varied slightly across the word features—the earliest words learned are highly imageable, iconic, and concrete.

Furthermore, smaller vocabulary sizes were found to be associated with higher word feature scores and as total vocabulary size increases, the average word feature scores decrease in both non-autistic children and autistic children. Our results indicate that autistic children are generally attending to the same word features as their expressive vocabulary-matched non-autistic peers to acquire nouns in their lexicons. In fact, our data support the recent findings in Lin et al. (2022) that non-autistic toddlers and autistic children acquired similar quantities of imageable nouns.

However, upon extending the analysis to other word features, the autistic toddlers were found to produce nouns that had slightly lower concreteness and iconicity values for their earliest words acquired. Interestingly, as both groups acquired more nouns in their expressive vocabularies, the autistic children began to follow a near identical trajectory of decline in average concreteness and iconicity as the non-autistic children. Furthermore, the significant group effects and significant group by linear and group by quadratic interactions for both concreteness and iconicity indicate small differences between the groups that mainly occur because of variations in early noun vocabulary sizes.

Current literature proposes several theories as to why there would be more variability in the autistic group's early noun vocabulary. According to the Auditory-Visual Misalignment theory proposed by Venker, Kover, and Bean (2018), young autistic children have challenges in combining auditory and visual information as a result of differences in both social and non-social visual attention, which is thought to negatively impact lexical development. Additionally, external factors such as the quality of caregiver input are known sources of variable language outcomes. Some parents talk more and use richer, child-directed vocabulary in interactions with infants than others do, which partly contributes to later disparities among children in lexical development (Hart & Risley, 1995). Similarly, studies have shown that the quantity of caregiver input also accounts for some of the variance in early language abilities (Goodman et al., 2008).

Lin et al. (2022) found that, when controlling for word input frequency, imageability still predicted expressive vocabulary size in both autistic and non-autistic children. When conducting a similar analysis, our results supported this finding in Lin et al. (2022) and provided an extension to the word features of iconicity and concreteness. In other words, when controlling for word input frequency, all of the word features explained significant unique variance in expressive noun vocabulary size in our combined regression model. While Lin et al. (2022) found no significant group differences in their study, we did find significant interactions between group and concreteness and group and imageability. Importantly, these interactions indicated that concreteness had a stronger effect on predicting the autistic group's noun vocabulary size and imageability had a stronger effect on predicting the non-autistic group's noun vocabulary size. This finding is interesting considering our bivariate correlations found that concreteness and imageability are significantly associated. Although these word features are correlated, they do not appear to measure the same construct and it seems that autistic and non-autistic children may be attending to these features differently. Perhaps when learning new nouns, autistic children find it easier to associate form and meaning when the novel word is something they have directly experienced through their senses or actions. For example, the word "banana" is rated as both highly imageable (6.64) and concrete (5). According to our model, the non-autistic children would more likely learn this novel noun by an easily evoked mental image, whereas the autistic children would be more likely to learn the novel word if they have eaten a banana in the past or if they only looked at a banana in a book or at home.

Our results found that iconicity also explained unique variance in expressive noun vocabulary size, but there wasn't an iconicity by group interaction; therefore, iconicity predicted a similar effect on noun vocabulary size between the autistic and non-autistic children. Bivariate correlations revealed that iconicity was not significantly associated with either imageability or concreteness. Therefore, iconicity appears to capture a very different feature of the word relative to imageability and concreteness. Nevertheless, each analysis indicated that each word feature was negatively associated with expressive vocabulary size. This also may be why iconicity demonstrated different interaction by group results than the other word features in the combined regression analysis. Notably while nouns have been rated as more imageable and concrete than other word classes, and although early-learned nouns are highly iconic, existing studies report that other word classes such as verbs and onomatopoeia are even more iconic than nouns (Perry et al., 2015). Additionally, research has shown that non-autistic children and autistic children with higher receptive language skills identify the referents to iconic words more accurately than their peers with low receptive language do (Hartley & Allen, 2015b; Perry et al., 2021). Our study focused on expressive noun vocabulary size, and therefore could not evaluate the extent to which receptive language and other word classes affect children's abilities to learn other types of words based on iconicity.

This work replicates recent findings about word imageability and early lexical development in young autistic children (Lin et al., 2022) and provides an extension to other word features. Furthermore, we report unique information about the nonlinear growth patterns associated with each word feature.

Shape Bias

The second research question asked if noun vocabulary composition is associated with shape and material features differ between autistic and non-autistic children. I initially predicted that, as a group, autistic children may know more words that go against the shape bias system relative to their vocabulary-matched non-autistic peers. We also suggested that individual differences may show that autistic children with larger expressive vocabularies may yield more evidence for the shape bias system versus evidence against the shape bias system (Perry & Samuelson, 2011; Potrzeba et al., 2015).

Interestingly, although we found significant differences in the trajectories of evidence for the shape bias between autistic and non-autistic children, both groups' overall evidence for the system did not statistically differ. Additionally, autistic and non-autistic toddlers generally produced more evidence for the system than they did against the system, indicating autistic children generally use the same bias to attend to shape and material nouns ("for the system" nouns) as non-autistic children. This pattern persists even after controlling for the fact that the CDI is composed of more nouns that contribute to evidence for the shape bias system than ambiguous nouns and nouns that contribute evidence against the system. Importantly, this study was able to examine the individual growth patterns of evidence for the shape bias across vocabulary size, which, to my knowledge, has not yet been studied. Our results provide a possible answer to the existing shape bias debate in recent literature—children, whether autistic or non-autistic, generally utilize the shape bias as a helpful word-learning mechanism to grow their noun vocabulary.

To elaborate further, the crucial addition of individual growth patterns in this study may explain why several differing theories about the shape bias in autistic children seem plausible. For example, the autistic participants in Tek et al.'s (2008) experimental task did not demonstrate a shape bias as a group with an average expressive vocabulary size of 19.21 words. However, the autistic children in the study conducted by Potrzeba et al. (2015) did demonstrate a slightly stronger shape bias in an experimental shape bias task when they had a larger vocabulary size ($M = 84.78$). The finding that the prevalence of a stronger shape bias in autistic children with larger vocabularies is supported in the current study. As expressive vocabulary size grew, so did the amount of evidence for the system in both groups. Our results also support the opposing findings in Jones (2003), who found that LT children did not demonstrate a shape bias as a group, and Colunga and Sims (2017), who found that as a group, LT children did. The children in the study by Jones (2003) were nearly a year older than the children in the study by Colunga & Sims (2017), which supports our finding that the use of the shape bias may change throughout the stages of language development. It's possible that if Colunga and Sims (2017) had conducted another study a year later with the same participants, they might then have found that the structure of the LT's noun vocabularies consisted of more shape words. By taking this into account, researchers can gain a more accurate description of children's individual language abilities at different points in their development and therefore make more informed conclusions about intervention strategies.

It is important to note that the current study's findings are only descriptive of the composition of children's noun vocabulary sizes; the current study did not include an experimental task to test whether non-autistic toddlers and autistic children generalize labels according to shape (thereby demonstrating a shape bias). The results do not provide evidence on how autistic children are using the structure of their vocabulary knowledge, which favors shape-dominant words, to learn new words; the current study only documents that the nouns they produce are typically categorized as evidence for the system. However, existing literature suggests this type of noun structure may influence the development of the shape bias (Colunga and Sims, 2017).

Our findings also demonstrate that ASD does not impair fundamental mechanisms like biases to shape, which have been proposed to underpin word learning. In fact, some autistic children in our study demonstrated more evidence for the shape bias system than the non-autistic children at different points in vocabulary growth. Future work should further explore the shape bias using experimental tasks like the novel noun generalization task for autistic children with noun vocabulary sizes between 100 and 200 nouns to examine whether they are more likely to generalize labels to new objects based on shape at a higher degree relative to non-autistic children. This vocabulary range is particularly of interest because the current study identified that the autistic children had different (and higher) evidence for the shape bias within their noun vocabulary structure relative to the noun vocabulary matched non-autistic toddlers. Therefore, the data seem to indicate that the noun vocabulary structure found in autistic children, while similar in quantity, may be qualitatively different—based on shape-features—at different points in vocabulary development (i.e., during sizes of 100 to 200 nouns). Additionally, previous studies have suggested that a child must have around 50-150 count nouns in their expressive vocabulary to demonstrate use of the shape bias. The individual trajectories for autistic and non-autistic children shown in our study generally support this claim, as our figures demonstrate highly varied evidence for the shape bias until around 100 count nouns.

Given the large differences in chronological age in the two groups, it is likely that, instead of affecting the processes that support word learning, autism may affect language acquisition by disrupting children's intake of information (Arunachalam & Luyster, 2016). Impairments in social-cognition and communication may reduce the abilities of some autistic children to accurately categorize novel words by slowing and reducing the accuracy of mapping new word-referent relationships. Such impairments may include increased reliance on other categories of object features like function (Diesendruck et al., 2003; Field et al., 2016), enhanced visual processing abilities that make it harder for them to filter out irrelevant visual information (Tek & Naigles, 2017), hypersensitivity and restricted interests that limit what they are willing to add into a new category (Gilston, 2014; Tek & Naigles, 2017), or even the Weak Central Coherence theory (see Happé & Frith, 2006 for more details on this theory). Finally, the shape bias is not the only word-learning mechanism that has been found to be helpful in expanding vocabulary. It has been reported that non-autistic children extend object labels based on function and speaker's intent (Diesendruck et al., 2003). Future studies should compare different word-learning mechanisms in different word classes.

Clinical Implications

The current study provides valuable information on how to guide clinical practice of professionals working with early language acquisition in autistic children. Few studies have focused on the underlying processes of early noun learning such as attending to the perceptual features of imageability, iconicity, concreteness, and shape, especially within the autistic population. One implication from the current study is that, when selecting vocabulary targets for teaching new words to young autistic children who have a very small vocabulary size, clinicians may wish to prioritize words that are highly concrete. High iconicity and imageability is also generally associated with the earliest learned words in the autistic group, but concreteness has an even stronger relationship, as we identified in our combined model from research question 1. Future work using the current study's trajectories approach may aid in predicting and characterizing typical and atypical vocabulary acquisition in young children, which could allow for more accurate diagnoses and individualized intervention plans. Additionally, examining growth patterns of other word classes and perceptual features can further aid in understanding the underlying mechanisms utilized to facilitate word-learning in autistic children.

Limitations

This study helps to describe the relationship between word features and lexical growth patterns on early expressive language in autistic and non-autistic children; however, some limitations are noted. The current study was limited to children's expressive vocabularies, specifically object nouns from the CDI that overlapped with a set of words from multiple previous databases with existing word-feature ratings. Although parent-reported questionnaires provide considerably beneficial information for several purposes, there is always a possibility of inaccurate parental report of the words that children produce—especially when recalling specific age of acquisition information for words produced. Additionally, although there was a great deal of coverage of the CDI words for concreteness scores and iconicity scores, each database had word features scores for a different number of nouns that were included on the CDI. Imageability scores for nouns on the CDI were much lower than the other two features (i.e., imageability values for approximately 25% of the nouns on the CDI). It would have been ideal to have equal coverage on the CDI nouns for each of the word feature scores. Additionally, although autistic and non-autistic children demonstrate noun biases (Jimenez et al., 2021) our specific focus on noun production may also underrepresent our participants' early expressive vocabulary composition. Additional analyses on a larger set of words and including a greater variety of word classes (i.e., verbs) may increase the accuracy of our findings. Furthermore, Lin et al. (2022) found that imageability scores had different predictive relationships with expressive vocabulary size when verbs were examined compared to nouns; therefore, future work should also examine verbs to develop a more comprehensive understanding of how word features are associated with vocabulary knowledge in young autistic and non-autistic children.

As previously discussed, the noun classifications that were used in the current study were collected by Samuelson and Smith (1999) to obtain categories of noun characteristics. Conversely, the Colunga and Sims publications used the noun classifications collected by Colunga and Smith (2005) and only examined 222 nouns – which were not specified. Therefore, we could not directly compare the structure of the shape bias to the structure reported in Colunga and Sims (2017) and Sims et al. (2013) because they used word categories that differed from ours, with an unspecified set of words from the 312 nouns in the current study.

Conclusion

Noun vocabulary growth is associated with word features for autistic and non-autistic toddlers. Although the different word feature growth patterns broadly overlapped between the groups, divergences were observed. Surprisingly, non-autistic toddlers' vocabularies were characterized by higher concreteness, iconicity, and imageability scores relative to the autistic group, with the most pronounced group differences observed for early vocabulary sizes. While both autistic and non-autistic children produced a similar amount of overall evidence for the shape bias system, greater variance in patterns of evidence across vocabulary growth was seen in the autistic group. The most pronounced group differences in evidence for the system were also observed for the earliest learned nouns.

This work contributes novel insights into early word learning patterns in autistic children and non-autistic toddlers. Furthermore, we report unique information about the nonlinear growth patterns associated with each word feature, with evidence for the shape system, and distinctions in these growth patterns between the groups. Due to the limitations of this study and limited findings in the current literature, further research on word processing is needed to better explain lexical growth patterns in young autistic children. Future work should additionally explore word-learning and lexical growth patterns involving early verb acquisition in autistic children.

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