

Two's Company: Examining Children's Early Meanings
of the Word "Two"

by

Dominic Gibson
Class of 2010

A thesis submitted to the
faculty of Wesleyan University
in partial fulfillment of the requirements for the
Degree of Bachelor of Arts
with Departmental Honors in Psychology

Acknowledgements

I would like to thank Anna Shusterman who challenged and guided me, and without whom this project would not have been possible. Thanks to my family: Brendan Gibson, Bill Gibson, and Julia Gibson for their love, support, and constant reminders to save my work to multiple hard drives. Thanks to Kyle MacDonald, Gwynne Hunter, and Barry Finder for taking time away from their own theses to provide insight into mine. I would also like to thank my roommates, Diego Bleifuss Prados, Elise Kaye, and Jordan Brown for the friendship and balance they brought to my life during this experience. Also, thank you to the professors and students that take part in the Cognitive Science Capstone Seminar and continue to enrich my experience at Wesleyan. Finally, thanks to Lauren Feld for constant intellectual, emotional, and nutritional support.

Abstract

When do children first learn that the word “two” refers to a pair? Traditional number language research suggests that children begin with the belief that “two” means a set greater than one (Wynn, 1990, 1992b). In contrast, conceptual research has revealed an early-developing, exact concept of two (Feigenson & Carey, 2005; Feigenson & Halberda, 2008), and diary studies suggest that children are using “two” correctly, earlier than previously thought (Benson & Baroody, 2002; Mix, 2002). The present study measures comprehension of the word “two” in 12-to-30 month olds using the Preferential Looking Paradigm. Presented with a set of two objects and a set of three objects, on average, children did not look longer at the set of two after hearing the set of two labeled (label-two condition) than they did after hearing the set of three labeled (label-three condition). In contrast, participants’ ages significantly predicted whether they would look longer at the set of two in the label-two condition than they did in the label-three condition. Specifically, younger participants were more likely than older participants to look at the set of two longer in the label-two condition than in the label-three condition. Additional measures included an explicit number comprehension task and a language measure. The results of the preferential looking task are discussed with respect to age and with respect to these measures, and future directions are considered in order to more conclusively explain these effects.

Table of Contents

Acknowledgments	2
Abstract	3
Introduction	5
Conceptual Systems of Number Representation	9
Symbolic Number Language	20
Quantifiers	25
Present Study	38
Methods	44
Participants	44
Preferential Looking Assessment	44
Pointing Assessment	48
Language Assessment	50
Results	52
Discussion	56
References	68
Figure Captions	74
Figures	75

Introduction

In popular culture, the simplicity of the word “two” is taken for granted. In fact, the phrase “two plus two” is meant to convey the epitome of ease, the most basic of human knowledge. Yet the word “two” has a number of properties that seem to prevent children from easily developing the ability to use it correctly. For example, in the phrase “two elephants,” the word “two,” unlike other descriptors, such as “big” or “grey,” does not refer to any observable quality of an elephant. Instead it refers abstractly to a property of the *set* of elephants (Papafragou & Musolino, 2002). To make matters worse, “two” can have multiple, even conflicting meanings. For example, when counting two blocks, a child must reconcile the fact that in the phrase, “one, two,” the word “two” represents both a tag for the second object and the total number of objects in that set.

So why should one be interested in how children come to comprehend the word “two”? First, the very properties that make numerals, like two, difficult to learn also make them valuable tools for mentally organizing and interpreting the world. Number words help us reason about sets; even better, they allow us to reason about *exact* sets, with which we can perform any number of precise mathematical operations. They provide us with a system of symbolic number – a series of symbols (numerals) that we can use to represent exact countable quantities. A closer look at those beings who possess symbolic number language and those who do not confirms the importance of knowing a count list when performing a variety of quantity-based tasks. While preverbal infants and animals are able to form nonsymbolic number representations and perform a few basic computations with these representations, they

are clearly unable to do the type of symbolic arithmetic that most adults can accomplish with relative ease. For instance, animals and preverbal infants can form representations such as ‘16ish’ and can distinguish between 8 items and 16 items, but cannot represent ‘exactly sixteen’ or distinguish between 16 and 17. Likewise, linguistic groups, such as the Piraha and Mundurucu, whose languages lack a formal count list, are unable to succeed on similar tasks that require an understanding of large, exact numbers (Gordon, 2004; Pica, Lemer, & Izard, 2004). English-speaking adults show deficits in exact number reasoning when simultaneously performing verbal interference tasks that prevent counting (Whalen, Gallistel, & Gelman, 1999). These last two findings strongly suggest that the failure of infants to form exact numerical representations is not merely a function of their lack of experience in the world, but also a function of their lack of experience with number language.

Apart from being a single member of this important but infinite list of numerals, “two” is the first numeral in the count list that corresponds with a plural set. Prior, to reaching their second birthday, most children have already received a great deal of number language input from their parents and have begun using number words, themselves (Fuson, 1988). Specifically, the word “two” is one of the first numerals encountered by children who are just beginning to speak and dominates early infant-directed and infant-produced number language. Therefore, “two” is, quite possibly, children’s first entry into symbolic number language and a foundation on which to learn the meanings of other numerals. Accordingly, the principal concern of the current study is to take a closer look at children’s initial steps into the symbolic number system.

Many researchers have posited that children do not learn the correct meaning of the word “two” until around the age of three. Evidence for this account of number word learning comes from Give-a-Number (Give-N) studies (Wynn, 1990, 1992b). In such studies, children are required to give an experimenter a certain number of objects, a task that more accurately captures children’s comprehension of number words than counting. These studies have been replicated countless times (e.g., Condry & Spelke, 2008; Le Corre, Van de Walle, Brannon & Carey, 2006; Le Corre & Carey, 2007; Sarnecka & Gelman, 2004; Sarnecka, Kamenskaya, Ogura, Yamana & Yudovina, 2007) and suggest that children progress through a series of slow and sequential stages when learning the number words in tandem with the count list. These stages begin around the age of two, when children first start to comprehend “one,” and end around the age of four, at which point children understand all of the numbers in their count list. While these studies have contributed a wealth of knowledge to the field of number development, many unanswered questions remain.

One criticism of the Give-N task is that, due to excessive demands on memory and other cognitive processes, it may underestimate children’s knowledge of the number words (e.g., Leslie, Gelman & Gallistel, 2008). Another concern is that Give-N studies do not typically look at children under the age of two. This means that there is about a year during which children have begun to comprehend and produce words but during which we know little concerning their understanding of number words.

Studies with younger children focus on the early-developing nonsymbolic number representations that are formed by preverbal infants. These studies suggest

that prior to learning to speak, children have two conceptual systems for representing numerosities. One core system has the capacity to represent small, exact sets and the other, large approximate sets. These systems have been observed in humans and animals, infants and adults; thus, they seem to have been hardwired into our brain by millions of years of evolution (Carey, 2009). They allow children to succeed on a variety of nonverbal number tasks; however, they are also characterized by signature limitations. Importantly, neither system provides children with a concept of large, exact numbers such as “87” or even “7.” Therefore, in order to grasp large, exact numbers, children need to use both their early-developing conceptual representations and late-developing number language.

Much is known about these seemingly innate number concepts; likewise, the pattern through which children ultimately master the counting principles has been confirmed and reconfirmed through a long line of research. However, questions remain concerning the first interactions between children’s innate conceptual number systems and their earliest linguistic representations. Researchers have only recently begun studying these types of questions in an effort to fill the gap between number concepts and number language.

One hypothesis is that children initially believe that small number words, such as “one” or “two,” are comparable to other linguistic quantifiers, such as “few,” “some,” or “many”(Carey, 2004; Sarnecka et al., 2007). Research in support of and opposition to this hypothesis has the potential to shed light on how children begin to understand number words, and will, thus, be a main topic of this paper. Still, the majority of this research has continued traditional conventions of focusing on

children who have already passed their second birthday. This problem is further complicated by the fact that children's conceptual systems continue to change and evolve throughout infancy and childhood, often independently of language. Therefore, children at different stages of development have at their disposal different conceptual systems onto which they can potentially map a variety of different word-meanings. Researchers have only recently started to parse apart the complicated processes of conceptual and linguistic number development.

This study is primarily concerned with what happens in the months and years between the observed functioning of core number concepts in infancy and the development of knowledge of the counting system in late toddlerhood. The fact that "two" is so dominant in the number language of very young children and their parents means it provides an excellent window into how children first begin to think about number words. The developmental trajectory of how children think about "two" as they age and develop will be the main focus of this study. Ultimately, I will attempt to shed light on the hypothesis that children may be able to understand the word "two" at a younger age than previously thought.

Conceptual Systems of Number Representation

Approximate Number System

The approximate number system (ANS) is marked by two important characteristics: 1.) Its ability to represent number differences in groups of stimuli spanning visual, auditory, and temporal domains; 2.) Its inability to support a concept of exact number (such as 19, 20, 21, etc.). Both its power and its limitations come

from the fact that the ANS adheres to the Weber Principle, which states that the ability to distinguish between any two numbers, or magnitudes, is a function of their ratio (Carey, 2009). In other words, with the ANS, it is easier to distinguish 4 objects from 8 objects than it is to distinguish 104 from 108, despite the fact that these pairs both differ by 4 objects. Likewise, it is as easy to distinguish between 4 and 8 objects as it is to distinguish between 40 and 80 objects.

Visually, this can be represented as follows: imagine that sets of individuals are represented as lines that are roughly proportionate to the number of individuals in a given set. Thus a set of one is represented as “_”, a set of two as “__”, a set of three as “___”, a set of four as “____”, etc. (Carey, 2009). This continues through representations of larger numbers such as those of twelve (_____) and fourteen (_____), which are more difficult to distinguish than the representations of two and four.

Animals, human adults, and even preverbal infants have all demonstrated that they possess an approximate system for representing number. Studies in animals, such as rats, generally involve training the animal to press a lever a certain number of times in order to receive a reward (usually a food pellet; Platt & Johnson, 1971). As the number of presses required to receive a reward increases, so does the number of times the animals press the lever, demonstrating that they are sensitive to the increase in number. However, the variance in responses also increases as the target number increases; while the mean number of presses more or less accurately reflects the target number, the standard deviation around those means increases with the target number. This property, known as “scalar variability,” is another way of

demonstrating the Weber Function. Church & Meck (1984) extended these results to show that even when potentially confounding variables are controlled (temporal duration of lever presses, energy exerted through increased lever pressing), rats are able to discriminate between numerical sets. They achieved this by training rats to distinguish between sequences of tones. Across several conditions, they either held the number of tones constant across the two sequences while manipulating the duration of the two sequences, or held the duration constant while manipulating the number of tones. The rats were sensitive to both manipulations, demonstrating that their ability to distinguish between the sequences did not rely solely on numerical or temporal differences or on a combination of the two.

Human adults and infants also display the hallmarks of the ANS. A typical experiment with adults requires subjects to press a lever a given number of times as fast as possible without counting. Just as with animals, the mean number of presses reflects the target number, while the standard deviation increases as the target number increases (Whalen et al., 1999). Most important for our purposes, there is extensive research exhibiting this ability in infants who have not yet begun to speak. Xu & Spelke (2000) demonstrated through a habituation study that 6 month olds are able to distinguish between sets of dots even when continuous variables such as surface area, density, and dot size are controlled. At this age, infants are able to distinguish between sets of dots that are related by a 1:2 ratio, such as 8 vs. 16 and 16 vs. 32. As infants grow older, the minimum ratio at which they are able to distinguish between sets decreases. For instance, at 9 months, infants can distinguish sets that are related by a 2:3 ratio. Additionally, these results have been extended to show that infants can

distinguish between sets of tones along the same ratio limits (Lipton & Spelke, 2003, 2004). Young children can even compare sets across modalities such as arrays of dots and auditory tones (Barth, La Mont, Lipton, & Spelke, 2005). The prevalence of this pattern of results across domains provides strong evidence that there is a generalized conceptual number system that drives performance on these tasks.

The approximate number system seems to have the capacity to perform basic operations that are more complex than simple comparisons. Barth et al. (2006) found that preschool children can perform simple addition over arrays of dots even when continuous properties such as surface area and total circumference are controlled. Barth, Beckmann, and Spelke (2008) also found that young children are able to add and subtract sets across sensory modalities and compare the sum or difference to a third set. Children's performance on the addition-and-comparison task did not differ from either their performance on comparison-only tasks or their performance on addition or comparison tasks involving only one sensory modality. However, success on the subtraction task, while above chance, was inferior to the addition task and comparison-only task. Analyses designed to test whether or not children were truly performing abstract computations and comparisons were less conclusive for the subtraction condition than for the addition condition. Recent research has also suggested that kindergarten children can perform division (halving) and possibly multiplication (doubling) over nonsymbolic continuous and discrete sets (Barth, Baron, Spelke & Carey, 2009). Together, these studies demonstrate the depth and complexity of the nonsymbolic number representations that children possess before they formally learn symbolic addition, subtraction, multiplication or division.

In sum, the approximate number system has many properties that suggest it is an early developing abstract system for representing number. Most convincingly, the ANS spans sensory domains, ages, and species, allowing even preverbal infants to make basic comparisons and allowing preschoolers and kindergarteners to perform simple nonsymbolic arithmetic in the absence of formal instruction. These findings provide convincing evidence that even preverbal infants have rich innate concepts of arithmetic and quantity. However, they provide no evidence that preverbal infants are endowed with a conceptual system for representing exact small numbers, like two. The next section will outline a second number system, one that allows infants to form exact interpretations of small sets.

Parallel Individuation

While the approximate number system allows humans and animals to distinguish between large sets, it seems to break down when trying to differentiate between small sets. For sets of one, two, or three, it appears that we are endowed with another core system that is commonly referred to as our system of Parallel Individuation (Carey, 2009).

Unlike the ANS, which translates sets into magnitude representations that correspond roughly to the number of members of the given set, Parallel Individuation, represents up to three individuals in parallel files. (The term “individuals,” which gives Parallel Individuation its name and will be used throughout this paper, refers generically to countable entities such as objects, sounds, or events) For instance, a representation of one individual might be [o], a representation of two individuals,

[o o], and three, [o o o]. Similar to ANS, a number of operations can be performed over these file representations and evidence for this system can be found across species (Hauser, Carey, & Hauser, 2000). However, Parallel Individuation differs from ANS in two important ways: 1.) Individual files often incorporate continuous spatio-temporal properties rather than representing numerical information independently, and 2.) Operations over individual files are not limited by the Weber function, but by the set-size limit of three individuals.

The first evidence of a separate conceptual system for representing small numbers came from looking time studies such as Starkey & Cooper (1980) and Antell & Keating (1983). Results from these studies showed, for example, that infants were able to distinguish between object arrays of two and three but not between arrays of four and six despite the fact that both of these pairs have 2:3 ratios. Such findings suggested that infants have a separate system for small numbers that is not limited by the Weber Principle. Furthermore, Wynn (1992a) demonstrated that children formed correct expectations after seeing one object added to another object behind a screen. All of these studies, however, failed to properly control for the continuous properties of the object arrays, such as total surface area, perimeter, density, etc.

Whereas controlling for continuous properties of stimuli had no effect on the ability of infants to distinguish between large sets of numbers, several studies suggest that the same is not true for small sets. In studies that properly controlled for continuous variables, infants failed to dishabituate to novel numbers of objects when sets were small enough to activate children's parallel individuation systems (Clearfield & Mix, 1999, 2001). This finding casts doubt on the hypothesis that

children have a more acute system for representing small numbers; however, if children only have a single conceptual number system (ANS) for representing all numbers, then they should be able to distinguish between small number arrays along the same ratio as large number arrays. Feigenson, Carey, & Spelke (2002) demonstrated that this is not the case; in their study, infants failed to distinguish between arrays of one and two dots when continuous properties were controlled. These results contrast with infants' ability to distinguish large dot-arrays along a 1:2 ratio and thus motivate an important question: When faced with small sets, do children merely represent the overall quantity as characterized by continuous properties such as surface area and volume, or do children's representations of small sets include numerical content?

Several studies suggest that children are indeed paying attention to more than merely the continuous properties of small sets. This is most notably demonstrated through the signature size limit of sets that can be represented through parallel individuation. For example, when required to crawl to one of two boxes containing different numbers of graham crackers, 10-12 month old infants succeed (pick the box with more crackers) when comparing 1 vs. 2, 2 vs. 3, and 1 vs. 3, but fail when comparing 3 vs. 4, 2 vs. 4, and 1 vs. 4 (Feigenson & Carey, 2005; Feigenson, Carey, & Hauser, 2002). Like the habituation studies, when total volume of crackers is controlled, children perform at chance. However, if children were merely summing the total volume of the crackers, 1 vs. 4 trials should not be difficult. On the contrary, it seems that children are able to represent up to three objects in parallel files and that these files incorporate the continuous spatiotemporal properties of each item.

It seems that children are able to succeed on this task, by forming one-to-one correspondences between mental representations or “files” and external stimuli. In other words, children have three mental files, each of which can be filled by a representation of an individual stimulus, such as an object, tone, or event. This has been demonstrated using the Manual Search Paradigm. In this task, an infant first watches as the experimenter hides objects in an opaque box. Next, the infant is prompted to find the objects, some of which are often held surreptitiously by the experimenter in the back of the box so that the infant is unable to reach them. If the infant has seen, for example, two objects hidden but is only allowed to find one, the infant’s continued search can be seen as indicative of an understanding that one object is different than two objects. Using searching time as a measure, this method has shown that 12-14 month old infants can distinguish between one, two, and three objects, but fail to distinguish between one and four (Feigenson & Carey, 2003, 2005). Feigenson and Carey (2003) also demonstrated that even when children retrieve an object that is four times the size of the two objects they had initially seen hidden, they act as if that object only satisfies a single object-file and continue looking for the second object. This suggests that in some situations, children are able to form number representations and make one-to-one correspondences independent of continuous properties.

The studies discussed above lead to two strong conclusions: 1.) children represent small sets by employing up to three mental ‘files,’ and 2.) these files incorporate spatiotemporal information (such as volume, surface area, or the duration of tones or events). Therefore, Carey (2009) proposed a model of parallel

individuation that represents individual files in tandem with spatiotemporal properties. Rather than representing {object, object, object}, the Parallel Individuation system allows children to form representations such as {big object, small object, medium object}.

Finally, like the ANS, parallel individuation can be seen across ages and sensory domains. A number of researchers have demonstrated that children can apply the Parallel Individuation System to events and tones in addition to objects (Bijeljac-Babic, Bertoni, & Mehler, 1991; Wynn, 1996; Wood & Spelke, 2005). Adults show similar set size limits when tracking individual objects on a screen (Trick & Pylyshyn, 1994). The ubiquity of the Parallel Individuation System across ages, sensory domains, and species strongly suggests it is a very early developing core number system.

Key Extensions of Research on Parallel Individuation

The research discussed in the previous section suggests that children distinguish sets of two from sets of one or three by forming one-to-one correspondences between mental file representations and real world stimuli. This system is fundamentally distinct from the ANS, which relies on ratio-based discriminations, and thus supports less exact number representations. The fact that children are better able to distinguish two from three than two from four is testament to their predisposition to represent these small sets as precise collections of individuals rather than rough quantities. This advantage in *exactness* makes Parallel

Individuation a likely candidate for supporting children's first number word learning. However, several questions remain.

First, the majority of research that demonstrates children's failure to represent the difference between two and four focuses on infants between the age of 10 and 14 months, a relatively narrow age range. Therefore, it is not clear whether this pattern of results holds over a longer course of development especially since it is claimed that children do not understand "two" until after around 30 months. We can more readily assume that this conceptual system influences early language learning if it is steady over time and present when children are progressing through vocabulary spurts. In fact, Barner, Thalwitz, Wood and Carey (2007) demonstrated that children continue to focus on the difference between one, two, and three and fail to distinguish between two and four or even one and four until the age of about 22 months. Note that children could distinguish between one and four by merely grouping numbers like two and four into a single category, *more than one*. Instead, it seems that children have no concept of 'one vs. more than one' or 'plurality' until they are almost two years old. This is in stark contrast to their ability to mentally represent exactly two individuals by the time they are one year old.

Recall that children often begin using "two" months before reaching 22 months and hear their parents using it even earlier (Fuson, 1988). Therefore, children's earliest conceptions of "two" are likely to be influenced by a conceptual number system that provides a rich exact representation of two individuals and a weak or nonexistent representation of plurality. However, before concluding that children have the entire conceptual framework for forming an exact, correct

interpretation of “two,” we must continue to question the depth of children’s conceptual representations of two individuals.

Are children’s first conceptual number systems capable of representing ‘*a set of two individuals*’ or do they merely represent a set of two as ‘one individual and another individual?’ The majority of research on Parallel individuation seems to suggest that children focus on individuals and not sets. Understanding the concept of a *set* of two objects requires that children bind their representation of one individual and their representation of another individual into a single representation of two individuals. Feigenson & Halberda (2004, 2008) demonstrated that children do, in fact, have the ability to bind their representations of individuals. Using the Manual Search Paradigm, they presented 14 month old infants with four objects that were separated into two pairs. By visually grouping the objects in this way, the infants were able to mentally chunk them into two sets of two and successfully distinguish between three and four. This provides convincing evidence that children, as young as 14 months, can represent a *set* of two, not just [individual, individual].

Therefore, not only are infants capable of forming complex representations of sets of two, this can be contrasted to their lack of conceptual understanding of plurality until around 22 months. These contrasting abilities and inabilities are present during children’s first few months of experience with the word “two”. It is very reasonable, then, to hypothesize that children are more likely to initially believe that the word “two” refers to exactly two individuals than to a general plural set greater than one. However, as touched upon earlier and as will be discussed in the

following sections, research on the development of number language paints an entirely different picture.

Symbolic Number Language

Stages of Number Development

The Knower-Levels Theory is one of the most prevalent explanations of children's initial foray into symbolic number language. Some researchers disagree with the various implications and extrapolations of the theory, but the main developmental pattern that it seeks to explain has been robustly affirmed and reaffirmed by an abundance of research on young children's number language (i.e. Carey, 2004, 2009; Sarnecka & Carey, 2006; Sarnecka & Lee, 2009; Lee & Sarnecka, 2009). Before turning to potential shortcomings of the knower-levels theory, this section will give a brief overview of the theory's key components and highlight some of the strongest findings.

Karen Wynn (1990, 1992b) developed the knower-level theory based on the results of her Give-a-Number task. Paired with other simple tasks, such as basic counting and picture-number matching, this study revealed a fascinating pattern of number development. According to this theory, children first begin counting around their second birthday. However, the count list is first learned as a meaningless series akin to the common childhood sequence, "Eenie, Meenie, Minie, Moe..." Behaviorally, this is reflected by young children's ability to count to relatively high numbers, while lacking the ability to give the correct corresponding number of objects on the Give-N task. Children then start learning the meaning of the numbers

in their count list, slowly and sequentially. They begin by learning that the word “one” refers to a single object, thus becoming “one-knowers”. Again, they can count much higher, but on the Give-N task, they only consistently succeed when asked for one object. For all other numbers, they perform by giving the experimenter a random set of objects greater than one. After quite some time, children become two-knowers, shown by their ability to correctly hand an experimenter a set of one or two objects but always handing the experimenter a random set, greater than two, when asked for three or more objects. Children in these beginning stages of number development are referred to as subset knowers because they understand the correct meanings of a subset of the numbers in their count list. Eventually, after becoming three-knowers and often, four-knowers, children extract the pattern and are able to correctly give any number of objects within their count list; thus, they become cardinal principle knowers (CP knowers) around the age of four or later. This means that they understand the cardinal principle: when counting a set, the last number in the count list refers to the number of objects in that set.

Questions that Remain

While this general pattern is largely agreed upon, there is far less consensus on exactly *how* children comprehend number words before, during, and after going through these stages. Pre-counters, as well as one-, two-, and three- knowers are clearly thinking about number words differently than cardinal principle knowers, but while the Give-N task speaks to the existence of these stages, it says little about the conceptual representations that underlie them. Therefore, the Give-N tasks fails to

conclusively answer two questions: 1.) What knowledge *do* children have about numbers that fall outside of their knower level? and, 2.) What do children understand about number words prior to entering the knower level stages or reaching the ages that are typically studied using the Give-N task? Only through a deeper investigation into children's supposed limitations will we gain a more complete understanding of the barriers children must overcome and the tools they employ on the path to symbolic number development.

The striking pattern that results from children's success and failure on the Give-N task as they progress through the knower levels has led to a relatively conservative understanding of children's early number knowledge. Since N-knowers respond with a random number of objects (greater than N) when asked for N+1 objects, many researchers have hypothesized that N-knowers know very little about numbers greater than N. One dominant hypothesis is that N-knowers use N+1 to refer to general plural sets of objects greater than N. In contrast, children's performance on several tasks other than the Give-N task suggests that they may have a slightly deeper understanding of these "unknown" numbers. There are, in fact, several potential representations of the 'unknown' number words that are supported by this research. For instance, based on the results of the Give-N task, it is equally likely that children understand that large number words refer to specific numerosities but that they do not know which number words refer to which numerosities. Condry and Spelke (2008) along with Sarnecka and Gelman (2004) have demonstrated that children do have some comprehension of the numbers at which they fail on the Give-N task.

Evidence for an Early, Correct Understanding of “Two”

Intrigued by children’s early developing conceptual numerical representations, several researchers have begun to turn their attention to children prior to the ages when they typically enter the knower-levels. The first such studies have been diary studies that demonstrate a strikingly different pattern of number development than is usually presented by the knower-level theory. While these studies are limited by their small sample size, they are able to provide a wealth of detailed longitudinal data describing the developmental trajectory of individual children’s earliest number language. For instance, Benson & Baroody (2002) found that one child, Blake, began spontaneously labeling many pairs of objects with the word ‘two’ shortly after his second birthday, long before children typically enter the two-knower stage. Blake did not label a set of one object until after he had been labeling sets of two for some time. This provides fairly solid evidence that Blake was not a traditional two-knower when he began using ‘two’ to correctly label pairs of objects.

Kelly Mix (2002) provided an additional diary study documenting the first number words used by another child, Spencer. Again, right around his second birthday Spencer began labeling sets of two. Rather than only referring to common sets of two such as eyes or shoes, Spencer’s labeling quickly became extremely generative; he not only labeled pairs of everyday objects but also entities that are not generally labeled in such a manner. For example, after falling down twice in a row Spencer said “Ow. Ow. Two Ows.” Importantly, Mix reports that after going through this early period of correct ‘two’ use, he began to over-generalize the word ‘two’ to

refer to general plural sets of objects, consistent with descriptions of the one-knower stage.

In an attempt to take a more quantitative approach to answering these questions, Shusterman, Gibson and Finder (forthcoming) analyzed a list of child utterances found on the CHILDES database containing the word “two.” They limited their analyses to cardinal utterances (utterances referring to sets of individuals as opposed to counting or ages) made by children between the ages of 18 and 40 months that had sufficient contextual evidence to determine the number of objects to which the child was referring. This yielded six codable, cardinal utterances in the youngest age range, 18-24 months. Of the six, five referred exactly to sets of two objects and it could not be confirmed if the sixth referred to two or more objects. These data, while limited as with the diary studies, continue to favor an account of children using two early and correctly.

While these results may be surprising, they appear to be supported by children’s earliest conceptual development of number. As the research reviewed in the previous sections suggests, prior to reaching their second birthday children have a rich concept of exactly two individuals and a comparatively weak or nonexistent concept of the singular-plural distinction.

For a more subtle understanding of how children first begin to use number words, many researchers have turned to the study of quantifiers – general language markers with numerical content such as *all*, *some*, *few*, *a*, *several*, and the plural ‘s’¹. The study of how children develop and use quantifiers in relation to number words is

¹ While not technically quantifiers, plural morphology such as “-s” and determiners such as “a” are often grouped together with quantifiers in this research.

one avenue that researchers have explored in order to link the early developing core conceptual number systems and the late developing number language indicated by the knower levels. The following section will discuss the developmental trajectory of commonly studied quantifiers along with several theories concerning the relationship (or lack thereof) between quantifiers and numbers.

Quantifiers

Number words and quantifiers are similar in many key ways. First, they are used in similar contexts: both are used to describe the size of sets. Second, they have comparable syntactic properties (in English): both appear in similar sections of sentences relative to other words. These contextual and syntactic similarities can alert children to similarities in meaning.

While quantifiers and number words have a great deal in common, quantifiers may be more easily acquired than number words. For example, children tend to acquire the correct meanings of quantifiers earlier than they acquire the correct meanings of number words (Barner et al., 2009a). Also, while all known languages make use of quantifiers, some languages, such as the Mundurucu and Piraha, do not employ a count list (Gordon, 2004; Pica et al., 2004). The greater ubiquity of quantifiers in the world's many natural languages is another reason to believe that the acquisition of quantifiers poses a less serious challenge than the acquisition of exact number words.

Because quantifiers have a great deal in common with number words but emerge earlier in development, they could be ideal stepping stones on the path to

symbolic number development. For instance, some research suggests that an accurate understanding of quantifiers helps children to arrive at the realization that number words describe sets (Barner, Libenson, Cheung, & Takasaki, 2009b). In fact, other researchers have suggested that subset knowers learn the first few number words as if they were quantifiers (Carey, 2004; Sarnecka et al., 2007). According to these researchers, part of the conceptual leap that causes children to become CP knowers is realizing that number words are distinct from other quantifiers. Research in support of and in opposition to this hypothesis yields insight into children's earliest comprehension of number words. Furthermore, this area of research draws from both linguistic and developmental research to detect subtle similarities and differences in the early quantifier and number word comprehension of very young children.

Therefore, one motivation behind studying quantifiers is to better understand how children first use number words. As discussed in previous sections, some researchers believe that children first use small number words, specifically "two," to refer to general plural quantities, much like the quantifier "some." Reviewing the similarities and differences between number words and quantifiers, as well as the manners in which children use them, has the potential to shed light on whether or not children initially use "two" as a vague quantifier, such as "some," or if children have an earlier understanding that "two" refers to a precise quantity. In order to address this question, the following sections will 1.) Take a linguistic approach to analyzing the similarities and differences between number words and quantifiers in an effort to determine the likelihood that children interpret these words as the same or similar, 2.) Provide an overview of the linguistic and conceptual development of quantifiers,

specifically those associated with the singular/plural distinction in an effort to better understand how this process may affect children's understanding of the word "two," and 3.) Look critically at theories that address the role that quantifiers play in children's early number development in an effort to better understand how children first interpret number words like "two."

Linguistic Similarities and Differences between Numbers and Quantifiers

There are many reasons to believe that children who are just beginning to speak would interpret numbers and quantifiers as belonging to the same class of words, at least in the English language. First, they share many of the same syntactic properties. For example, numbers and quantifiers occupy similar positions in sentences relative to other types of words such as adjectives (One would say "four/some big birds" as opposed to "big some/four birds") (Hurewitz, Papafragou, Gleitman & Gelman, 2006). Furthermore, both numbers and quantifiers can be paired with partitives (I saw some/four *of* the birds) and singular/plural morphology (I saw one/a bird, I saw four/some birds). These syntactic similarities can alert children to potential similarities in meaning between quantifiers and numbers, thus facilitating the process through which children might bootstrap their way from one to the other.

In addition to syntactic similarities, numbers and quantifiers share several semantic characteristics. First and foremost, they refer to the same properties of the things they describe; that is to say, they both describe the number (rough or exact) of individuals in a set. Both also form naturally ordered scales such as *1, 2, 3, 4* or *few, some, many, all* (Hurewitz et al., 2006). Thus, when a certain number or quantifier is

used, it denotes particular comparisons to the other members of this scale. For example, labeling a set with the word “two” or “some” means that there are at least “two” or “some” individuals in that set.

However, behind these surface similarities lie many differences between numbers and quantifiers. Most glaringly, while numbers refer to exact sets, quantifiers are inherently indistinct. Given the relative nature of quantifiers, the same word can refer to drastically different sets. Therefore, the precise meaning of quantifiers often depends on the context in which they are used. Depending on the size of the complete set being discussed, quantifiers, such as “most,” have very different numerical meanings. For instance, “most” can refer to three in the phrase “most of the members of the Beatles,” or it can refer to millions in the phrase “most of the people in the United States.” This is a far more drastic discrepancy than the occasional ambiguity that comes with the context dependent meanings of number words, such as in the phrase, “You must have read *three* books to enter the class,” in which three means “at least three.” Therefore, if children are to bootstrap the meaning of numbers from quantifiers they must first understand that unlike quantifiers, numbers, which can take on ‘at most’ or ‘at least’ meanings, are nevertheless tied to specific numerosities (Hurewitz et al., 2006).

This difference in precision translates into important pragmatic differences between numbers and quantifiers. Above, it was noted that quantifiers and numbers both tend to have “at least” meanings. So if there were no fish present, the phrase “there are two/some fish” would clearly be incorrect. However, if there were three fish present, the phrase “there are two fish” would still be semantically correct but

would be pragmatically incorrect because it fails to be optimally relevant and informative. The pragmatic assumptions that can be drawn from phrases about quantities are known as *scalar implicatures* and they are driven by the Gricean principle that statements are maximally informative (Papafragou & Musolino, 2002). Both children and adults seem to be able to use scalar implicatures to determine the truth or falsity of a numerical statement. Conversely, research suggests that children do not compute scalar implicatures when deciding if words like “some” or “all” are more appropriate. Papafragou & Musolino (2002) demonstrated that five year olds do not object to statements using the word “some” when “all” is more appropriate, despite objecting to statements that use “two” when “three” is more appropriate. This suggests that eventually children become quite sensitive to the fact that numbers are exact and quantifiers are inexact. Nevertheless, it leaves open the question as to whether or not children go through a stage where they treat numbers and quantifiers as essentially the same before understanding their important differences (Carey, 2004). The next section will delve deeper into developmental research concerning this question as well as analyze the various resulting theories on how children use quantifiers to bootstrap representations of exact number.

Linguistic and Conceptual Acquisition of Quantifiers

Quantifiers and other forms of grammatical number marking generally do not emerge in children’s speech until the age of 24 months (Dale & Fenson, 1996; Fenson et al. 1994). Over the course of the next three years or so, children begin to develop correct and more expansive use of quantifiers. This apparent difficulty in learning

how to correctly use any linguistic form of number marking, including number words, quantifiers, determiners, or morphology, has been attributed to the abstract nature of these words (Bloom & Wynn, 1997; Papafragou & Musolino 2002). In the phrase *three little pigs*, the word three, unlike the word *little*, does not describe any observable quality of an individual pig; rather, it describes the *set* of pigs. The same can be said for quantifiers. Given preverbal infants' ability to distinguish number on simple nonverbal tasks, Bloom & Wynn (1997) concluded that learning the correct meaning of number words is primarily a linguistic mapping problem. This has led many researchers to focus on how children extract the meanings of the number words and quantifiers.

However, the difficulty of acquiring number words and quantifiers could be conceptual, rather than linguistic, in nature. Despite the presence of very early developing core number systems, children's conceptual understanding of quantification does not appear to be static. As discussed above, infants do not develop the conceptual framework necessary to successfully distinguish between one and four objects on a Manual Search Task until they are around 22 months old (Feigenson & Carey, 2003, 2005; Barner et al., 2007). These results indicate that up until this age, children do not have a generalized concept of plurality that can be used to resolve simple comparisons like one vs. more than one. Another interesting observation found in these studies is that successfully distinguishing between one and four objects on the Manual Search Task was correlated with parental reports concerning the presence of plural nouns in a child's speech.

This last finding has motivated a number of studies aimed at determining whether the acquisition of singular/plural morphosyntax, such as *a dog* vs. *some dogs*, drives or at least influences the conceptual development of one vs. more than one. An alternative hypothesis is that this is largely a process of conceptual maturation and that the difficulty in learning these words and concepts is not a matter of extracting them from abstract language but gaining the underlying concepts onto which such language can be mapped. By answering this question we can gain a better understanding of the challenges that face children in acquiring words that describe sets, allowing us to form better hypotheses concerning what children may know at different stages of conceptual and linguistic development.

Several studies have documented the co-occurrence of the development of linguistic plurality and the development of the conceptual understanding of one vs. more-than-one. For instance, through a preferential looking paradigm, Kouider, Halbeda, Wood, and Carey (2006) showed that 24 month olds but not 20 month olds were able to use verb morphology, noun morphology, and lexical quantifiers together to match a verbal cue to one of two screens displaying either a singular or plural set of novel objects. While this confirms the co-emergence of conceptual singular-plural distinctions and the production and comprehension of linguistic singular plural cues, it does not speak to the causal direction of this correlation.

This concurrent timing has naturally motivated efforts to answer the question of whether or not there is a causal relationship between conceptual and linguistic plurality. In one study, Li, Ogura, Barner, Yang and Carey (2009) demonstrated that while Japanese and Mandarin do not mark the singular-plural distinction to the same

extent as English, Japanese- and Mandarin-speaking children develop the conceptual singular-plural distinction around the same age as English-speaking children (22 months). In another study, Barner, Wood, Hauser and Carey (2008) showed that rhesus monkeys are able to spontaneously make the distinction between one and more-than-one, furthering the evidence that this concept arrives independent of language.

Taken together, this research tells us that there is an important conceptual change that occurs as children near their second birthdays and that this change does not appear to be language driven. Furthermore, it appears that children who speak languages with singular/plural marking are able to acquire singular plural morphosyntax immediately after having developed a conceptual understanding of one vs. more-than-one. Therefore, contrasting to the majority of the literature which speaks to the difficulty of learning words that describe sets, it seems that children are able to map correct singular/plural morphology onto their newly formed concepts relatively quickly. Perhaps, then, the barriers that prevent children from acquiring quantifiers before the age of two are not linguistic, but conceptual. If this is the case, we would expect to see children first acquire number words and quantifiers that are consistent with their underlying conceptual representations before moving onto less conceptually supported words. Given the rich ‘two’ concept and weak plural concept of preverbal infants, we would expect to see children acquire the correct meaning of the word “two” before they learn singular/plural determiners and morphology.

Theories on the Developmental Relationship between Numbers and Quantifiers

One line of research has suggested that acquisition of singular/plural morphosyntax along with other linguistic quantifiers facilitates children's acquisition of number words and their correct meanings. Sarnecka et al. (2007) demonstrated that children who speak languages that mark the singular-plural distinction, such as English or Russian, are quicker to develop an understanding of the words, 'one,' 'two,' and 'three' than children whose languages do not grammatically mark this distinction, such as Japanese. The authors interpreted these results to indicate that children build their initial understanding of these small number words from the conceptual framework underlying quantifiers.

Carey (2004) supports the same conclusion by pointing to the pattern with which subset knowers respond to the Give- N task. For instance, one-knowers understand that one refers to exactly one while all the other numbers in their count list refer to 'more-than-one.' She notes that this is strikingly parallel to the singular-plural distinction in English. Two-knowers, similarly, understand one to mean exactly one, two to mean exactly two, and all other numbers to mean 'more-than-two.' Again this bears a striking resemblance to languages, such as Hebrew, that employ dual markers – grammatical quantifiers that are used to refer to sets of two. One way in which children could form their earliest understandings of number words is through what Bloom & Wynn (1997) call semantic and syntactic bootstrapping. In other words, children use the unique semantics and syntax of quantifiers and number words to differentiate them from other predicates such as adjectives. Eventually children

extract an understanding of exact integers from their understanding of numerical quantifiers in combination with the verbal count list.

More evidence that children initially understand small number words such as “two” as quantifiers comes from a recent study by Clark & Nikitina (2009). Clark & Nikitina analyzed transcripts of child speech found on the CHILDES database and concluded that before children understand “two” to mean a pair, they use “two” as a general marker of plurality. According to this account, children initially use *two* to mark plural sets prior to learning alternate, correct methods of plural marking. For instance, they argued that children often use “two” with bare nouns such as “two duck.” Eventually, as children learn other plural markers such as the suffix ‘-s,’ the word “two” begins to disappear from their plural marking. Sarnecka et al. (2007), Carey (2004), and Clark & Nikitina (2009) all argue that children initially go through a period during which they view number words as belonging to essentially the same linguistic class as quantifiers. These researchers have posited that children do not learn to distinguish quantifiers from number words until relatively late.

In contrast, a recent flurry of studies from Dave Barner and colleagues suggest that children have a much earlier understanding of the differences between numbers and other quantifiers. As a result, he has put forth a theory of early number development in which quantifiers play a much more general role. In one study, Barner, Chow and Yang (2009a) found a significant age-independent correlation between children’s comprehension of linguistic quantifiers and of exact numbers, which taken by itself supports Carey (2004) and Sarnecka et al.’s (2007) claim. However, they also tested children to see if they used quantifiers and number words

in a similar manner. They found that this correlation was not driven by corresponding numbers and quantifiers such as “one” and “a” but by more general quantifiers such as “all,” “some,” and “none”. Furthermore, they demonstrated that two-year-old children use the word “a” in a general, inexact manner, often giving more than one object when asked for “a” object. This was not the case for the word “one,” which children used precisely. The authors interpreted these results as indicating that children use the similarities between number words and quantifiers to gain a firmer understanding of the properties they have in common; namely, that they both describe sets of individuals. However, from a very young age children also seem to be sensitive to the differences between quantifiers and numbers and assign exact interpretations only to number words.

They tested these conclusions in a second study involving Japanese- and English-speaking children. Barner, Libenson, Cheung, & Takasaki (2009b) found that Japanese-speaking 2-year-olds displayed a greater understanding of quantifiers than English-speaking 2-year-olds despite a relative delay in number word understanding at this age. Through a series of experiments, Barner et al. (2009b) concluded that the specific delay in number comprehension was due to the fact that numbers and quantifiers overlap syntactically to a much lesser extent in Japanese than in English. Therefore, while Japanese children displayed no relative difficulty in acquiring words that describe sets, they were less able to take advantage of the similarities between numbers and quantifiers in order to arrive at the understanding that like quantifiers, numbers describe sets. Again, this suggests that by highlighting

the fact that numbers describe sets (in English), quantifiers play a very general role in the development of number language.

In another study, Barner, Lui, & Zapf (in press) set out to directly test Clark & Nikitina's (2009) hypothesis that children initially use the word "two" as a general plural marker. Clark & Nikitina (2009) posited that if children use "two" as a marker for plurality and a stepping stone to correct usage of plural markers, then children's use of "two" to mark plural sets greater than two should decrease as their use of correct plural markers increases. However, Barner et al. (under review) found that 2-year-old children often used number words in tandem with other plural markers. In fact, those who did use number words were more likely than those who didn't to use plural markers when describing sets (e.g. "two bananas").

These studies led Barner along with his colleagues to conclude that young children use the syntactic, as opposed to semantic, similarities between quantifiers and number words to reach the conclusion that number words, like quantifiers, describe sets. However, children also understand from a young age that numbers differ from quantifiers in that only numbers are exact. This naturally leads one to ask how children come to arrive at the knowledge that numbers are exact. Barner and Bachrach (2010) suggest that children begin with weak interpretations of number, which they strengthen through scalar inferences in relation to the count list even before truly understanding how the count list works. In other words, acquisition of the count list along with the basic knowledge that number words refer to numerosities and the assumption that different words refer to different numerosities provides sufficient input to cause children to make exact interpretations of number words.

Barner and his colleagues have gone a long way towards demonstrating that very young children are able to pick up on the differences between number words and quantifiers and attribute exact interpretations only to number words. For a long time, researchers have believed that children first use number words, like “two,” to describe inexact, plural sets, and that children must overcome this initial representation to discover the exact meanings of number words. In contrast, Barner’s research indicates that children are more receptive to the exactness of number words at an earlier age than previously thought. Barner and his colleagues put forth their own theories on the barriers that children must overcome to learn number words, namely that number words describe properties of sets. Barner suggests that English-speaking children use syntactic bootstrapping to reach the understanding that number words, like quantifiers, describe sets.

More research is necessary before it can be definitely decided what prevents very young children from comprehending small number words: whether it is a lack of understanding that number words refer to sets or that numbers are exact. Current research on number language focuses largely on children who are over two years old. It is right around the age of two that children learn the count list, which children seem to first learn as a meaningless series. Acquisition of the count list could therefore disrupt any initial cardinal understanding of the word “two.” The possibility of an early cardinal understanding of “two” is supported by the observations that a.) “two” is the most common number word in infant directed speech, and b.) it is very often used in cardinal as opposed to counting contexts (Fuson, 1988). Likewise, well

before their second birthday, children begin using number words. Again, the word “two” dominates children’s early number word use (Fuson, 1988).

Despite this documented use of the word “two” by both very young children and parents speaking to children, there exists little or no experimental research on whether or not children are actually comprehending the word “two.” The present study, which will be further discussed below, aims to take a step towards addressing this gap in the number language literature.

The Present Study

To summarize the findings discussed above, research on infants’ conceptual number knowledge seems to support an exact interpretation of small numbers, such as sets of two. Prior to reaching 22 months, children are unable to resolve simple 1 vs. 4 comparisons, indicating that they lack the conceptual foundation for understanding plurality. This suggests that it is unlikely that children initially believe that “two” marks plurality as some researchers have suggested, especially since children often start using the word “two” very soon after they begin speaking. For numbers less than three, children rely on their system of Parallel Individuation which allows them to precisely conceive of up to three individuals. Furthermore, infants are able to chunk these exact representations into sets of two. Note that children at this age may not have a general concept of “set” which they can apply to other quantities. However, while infants appear to be unable to represent sets of large numbers, they seem to be fully capable of forming representations of two objects. Together, these

studies suggest that children as young as 14 months have sufficiently complex and exact mental representations to support an exact understanding of the word “two.”

From a linguistic standpoint, research has increasingly indicated that very young children understand important qualities of number words. Many of the studies reviewed above report that children as young as two years old (the youngest age included in these experiments) demonstrate an understanding that number words refer to exact quantities. Additionally, while the acquisition of number words and quantifiers is often thought to be marked by a series of difficulties and delays, research on the singular/plural distinction suggests that in some cases, children are able to immediately map new words and grammar onto newly formed set-based concepts. Nevertheless, even those researchers who believe that children understand that numbers refer to exact quantities contend that infants are unable to correctly match number words to these quantities.

Why do researchers continue to favor a developmental story that begins with children using the word “two” to mean not just “two” but any quantity greater than one? Certainly, a contributing factor is that for years, researchers have operated under the assumption that learning the linguistic distinction between one vs. many is easier than learning the exact meaning of “two.” The above research suggests that this intuition may not be supported by a thorough analysis of infants’ first conceptual representations. The reason that such conceptual research is not reflected in research on number language development could be that research in this second area does not focus on young enough children. The vast majority of research on the acquisition of number language focuses on children who have already passed their second birthday.

This means that the majority of children in these studies have already acquired the conceptual singular-plural distinction and began using singular plural morphology in their every day speech. It could be the case that these conceptual and linguistic developments disrupt an early understanding of the word “two.” In other words, children go through a period during which they successfully map the word “two” onto conceptual representations of *exactly two* before turning their attention to the singular/plural distinction.

While the conceptual and linguistic singular-plural distinction is an obvious suspect for the disruption of an early understanding of “two,” children at this age are also presented with other confusing uses of number words. For instance, as children near their second birthday, they begin to learn the count list. If Carey is correct that children go through a stage in which they believe two is a quantifier, comparable to a dual marker, perhaps this happens before children discover that quantifiers and number words belong to different classes of words through a partial understanding of the count list (as suggested by Barner and Bachrach, 2010). In this case, acquisition of the count list may disrupt an early, cardinal understanding of “two.”

Given the coincidental timing of when children learn the count list and when they acquire the conceptual and linguistic singular-plural distinction, I propose the following developmental trajectory of the word “two” as a reasonable alternative to the story provided by the majority of literature on children’s earliest number language: Perhaps a strong concept of ‘exactly two’ and language input from parents that is largely composed of cardinal uses of “two” allow children to initially comprehend the word “two.” Children likely initially comprehend “two” in a way that

is very similar to a quantifier, such as a dual marker. This is supported by the fact that children seem ready to grasp the singular-plural distinction as soon as they have the necessary conceptual underpinnings, at which point they already have a rich concept of ‘exactly two.’ Furthermore, Barner has demonstrated that while children at this age understand that quantifiers refer to sets, it takes them quite a while to realize that numbers in the count list also refer to sets. Therefore, upon developing the conceptual distinction between one and more-than-one, realizing that English does not employ dual markers, and learning that “two” belongs in the count list (of which they have little real knowledge), children lose their understanding of “two.” Children only reacquire an understanding of the word “two” during the two knower stage.

Diary studies and preliminary CHILDES (MacWhinney, 2000) analyses seem to support this developmental trajectory (Benson & Baroody, 2002; Mix, 2002; Shusterman et al., forthcoming). Furthermore, this is consistent with the large body of research that suggest that children do go through a relatively long one-knower stage in which they understand the meaning of “one” but not “two.” While a U-shaped developmental pattern may seem strange, it is not unprecedented; children develop in a similar fashion while learning verb morphology. Children begin by learning correct irregulars (“I went”) then over generalize a rule (“I goed”) before ultimately reacquiring the exceptions to this rule (“I went”).

Using the Preferential Looking Paradigm developed by Golinkoff, Hirsh-Pasek, Cauley, and Gordon (1987), the present study tested the hypothesis that children go through a period during which they understand that “two” refers exactly to a pair of objects. In a standard preferential looking study, children are seated in

front of two screens each displaying a different stimulus, children then hear an auditory stimulus that corresponds to one of the two visual displays. If children spend more time looking at the display that corresponds to the auditory stimulus, it is reasonable to assume that children understand that the auditory stimulus corresponds to labels that display. The Preferential Looking Paradigm is predominantly used in word learning and comprehension studies. Kouider et al. (2006) used it to shed light on children's acquisition of the singular plural distinction. However, the present study is the first to use this paradigm to measure children's understanding of number words.

Specifically, the current experiment presents children with two different sets of familiar objects that differ in terms of the number of objects in the set and the color of the objects. Then, children are presented with an auditory stimulus that corresponds to one of the two sets. For example, during one trial, children are simultaneously shown a set of two blue birds on one display and a set of three red birds on another display, and are then told to look at the set with the two birds.

One of the main advantages of this design is that it does not require children to make any explicit indications of their knowledge. This allows us to study children who may be too young to perform more complex tasks, like the Give-N task, in a laboratory setting, but may nevertheless have interesting knowledge of the number words. Accordingly, the present study focuses on children between the ages of one year and two and a half years, a relatively wide age range. Therefore, any number of interesting patterns of development could potentially be discovered. For example, children may succeed at a young age and fail at the older ages, suggesting that children do have an initial understanding of the word two followed by a temporary

loss of this knowledge (i.e. U-shaped developmental pattern). Another possibility is that children at the upper end in the age range do succeed, suggesting that children at ages that have previously been studied are more knowledgeable of number words than indicated by difficult tasks such as Give-N and related tasks. A third possibility is that due to the variability in the rates that children develop, there may be no observable effect of age on the comprehension of the word two. To mediate this, I asked parents to fill out the MacArthur-Bates Communicative Development Inventory in order to get a measure of participant's relative language abilities, which may be more related to number word knowledge than age.

The present study hopes to detect any interesting number knowledge that has previously been missed by a.) focusing solely on children older than two years or b.) using tasks that put excessive cognitive demands on young children and thus potentially underestimate their abilities. In total, three different procedures were used to shed light on the developmental trajectory of the ability to comprehend small number words, specifically the word two. The primary focus of this study was the preferential looking task which evaluated children's comprehension of the word "two" by measuring their ability to associate visual stimuli, sets of objects ranging from one to three, with an auditory cue, a voice that labeled one of the sets for each trial. In addition to looking for an effect of age on children's comprehension of "two", this study used a parental report measuring language development in order to explore the relationship between general language acquisition and acquisition of the number words. Finally, an explicit measure of number word comprehension was

used in order to rule out the possibility that children within this age range were extremely early two-knowers.

Methods

Participants

Participants were 18 infants between 13 and 29 months of age (mean age = 21.3 months; 8 female and 10 male). Four additional infants were tested but not included in the final analyses due to fussiness or experiment errors. All participants were recruited from Middletown, Connecticut, and the surrounding area.

Preferential Looking Assessment

Stimuli

The visual stimuli comprised six pairs of pictures created in Adobe Flash. The pictures within each pair were identical except for the number and color of the objects displayed. For instance, during one trial, three red birds were displayed on one monitor and two blue birds were displayed on the other monitor. The objects depicted were designed to be familiar to young children. Objects for which infants typically know the name were chosen using tables provided by Fenson et al. (1994). The auditory stimuli consisted of three parts: 1.) a call for the child's attention ("Look baby! Look!") 2.) Labeling number and type of objects ("Two Birds!") 3.) Repetition of the number ("Two")!

INSERT FIGURE 1 HERE

Procedure

Infants were seated on their parent's lap 24 inches away from and directly in between two identical, 17 inch, monitors encased in a black box. The monitors were spaced 11 inches apart and there was a camera in between them for recording looking time and direction. Also in between the monitors were hidden speakers for presenting auditory stimuli. Curtains enclosed the area, covering everything but the two screens and thus blocking outside visual stimuli. Parents were instructed to look down and close their eyes to avoid influencing the direction of the child's gaze. Infants watched a series of six trials, which were comprised of four different trial types. The first two trials were 2 vs. 3 comparisons during which participants were prompted to look at the set of "two" objects; the fourth and fifth trials were 2 vs. 3 comparisons during which participants were prompted to look at the set of "three" objects; the third and sixth trials were control trials in which participants saw a 2 vs. 1 comparison and a 3 vs. 1 comparison, respectively, and were prompted to look at the set of "two" objects or the set of "three" objects, respectively.

Trials began when the visual stimuli were simultaneously presented on each screen. Again, these stimuli differed in the color and number of the objects. The visual stimuli remained on the screen in silence for three seconds so that the child had the opportunity to become accustomed to both displays. After three seconds, the participants were presented with the auditory stimulus that prompted them to look at one of the screens. On half of the trials, the auditory stimulus labeled the set of two objects and on the other half of the trials, the auditory stimulus labeled the set of three objects. Looking time and direction were recorded for 7 seconds following the

auditory stimulus. After 7 seconds, this set that was not labeled by the auditory stimulus (the incorrect screen) disappeared and the set that was labeled by the auditory stimulus (the correct screen) briefly danced to music.

To control for effects of color and orientation of the displayed objects, over the course of the six trials the color of the objects on the left and right screen, the color of the labeled and unlabeled displays, and the screen (left or right) that displayed the correct and incorrect sets were balanced. A separate version of the presentation was an exact mirror image of the first (e.g., stimuli that were presented on the right in version 1 were presented on the left in version 2). Half of the participants saw each version.

Experimental Design

Dependent variable. The dependent variable was the proportion of time spent looking at the screen that displayed two objects relative to the time spent looking at either screen.

Conditions. There were two within subjects conditions. In both conditions participants saw four test trials, all of which displayed two objects on one screen and three objects on the other. In the first condition, the “label-two” condition (first two trials), the auditory stimulus directed participants to look at the screen with two objects. In the second condition, the “label-three” condition (fourth and fifth trials), the auditory stimulus instructed participants’ to look at the screen with three objects.

Coding & Analysis

Coding. Looking time and direction were measured using Supercoder (Hollich, 2005) by a coder who was blind to the condition and thus unaware of which screen displayed the correct set of objects (the set labeled by the auditory stimulus). Coding was performed frame by frame at 30 frames per second. For each frame, looking could fall into one of three categories: 1.) the child was looking at the left screen 2.) the child was looking at the right screen 3.) the child was looking at neither screen. The total time spent looking at each screen was summed to give a trial-by-trial measurement of the time spent looking at the correct and incorrect screen. In addition to this raw looking time measurement, the proportion of time spent looking at each screen relative to the total amount of time looking at either screen (and not away) was calculated. This allowed for comparisons across participants who may have differed in their overall attentiveness.

Proportion of time looking at two objects. General analyses included determining whether ‘proportion of time spent looking at two’ was significantly different than chance in the label-two and label-three conditions as well as whether time spent looking at two was significantly different between the conditions.

Difference score. In order to create a single dependent measure, the ‘proportion of time spent looking at two’ during the label-three condition was subtracted from that of the label-two condition. If this difference score was positive, it indicated that participants spent a greater proportion of time looking at two objects after having heard the set of two labeled than after having heard the set of three labeled. The opposite was true if this proportion was negative. This computation

allowed for the possibility that all children would look more at three than at two objects, but that this tendency might be reduced after hearing the set of two labeled. In order to determine if such results were significant, mean difference scores were compared to a chance value of zero.

Age. Analyses were also conducted to investigate the relationship between age and participant's difference scores. A linear regression was used to explore the potential effect of age on difference scores. Furthermore, age was also separated into three categories (Category 1: 12-18 months; Category 2: 19-24 months; Category 3: 24-30 months) and the mean difference scores for each category was compared to both zero and to the other age categories.

Pointing Assessment

Stimuli

Stimuli were composed of twelve pictures presented in pairs in a three-ringed binder. Each pair of pictures was composed of the same type of objects (e.g. birds) and could be differentiated both by color and set-size. Pictures were paired into three possible comparisons: 2 vs. 3, 1 vs. 2, and 1 vs. 3.

Procedure

The participants were seated across from the experimenter in their own chair or on their parent's lap, according to their preference. The three-ringed binder was placed in front of them so that, for any given trial, the pictures were centered in relation to their body and not skewed towards one side. The first trial began when the

binder was opened to reveal the first pair of pictures. Participants were then asked to point to the picture that contained the set with the target number of objects. Several phrases were used to elicit a response, such as, “Point-to-X,” “Do you see X [objects],” “Can you show me the picture with X,” and “Where are the X [objects].” If participants still did not provide a response, they were asked to point to the card that had objects with a given color, and then asked the number questions again for the next card. Participants’ responses to color questions were not included in their final score. Trials ended after the child pointed, stopped pointing (if the child continued to point more than once), or had clearly refused to point. The experimenter then moved on to the next trial by flipping to the next pair of pictures.

Apart from the difference in measure, the types of the objects used as stimuli, and minor changes in order, trials were identical to those of the preferential looking task. Participants were presented with six pairs of pictures resulting in six trials. Half of the trials required the child to point to the card with two objects and half of the trials required the child to point to the card with three objects. Of the trials in which the participant was asked to point to two objects, two were 2 vs. 3 comparisons and one was a 1 vs. 2 comparison. Likewise, of the trials in which participants were asked to point to three objects, two were 2 vs. 3 comparisons and one was a 1 vs. 3 comparison. Since this task was being used only to give a rough indication of whether or not a participant might be a two-knower, order and relative position of the correct cards remained consistent for all participants.

Analysis

First and foremost, participants' responses were coded on whether they pointed correctly or incorrectly; however, in order to determine correctness, whether they pointed to just a single picture, both pictures, or neither of the pictures was also recorded. Whether or not participants responded correctly on any given trial was primarily determined by the direction in which they made their first point. If it was clear that a participant's second point was her final response, demonstrated by either a quick, unprompted, emphatic switch and/or verbal cues, then this point was taken to be their ultimate response. Furthermore, if children pointed randomly from one picture to the other without making a clear decision, their first point was discounted even if it was correct. Participants who refused to point were marked as incorrect.

Participants were deemed to be probable two-knowers if they were correct on at least four out of the five trials that involved a set of two objects. These results were mainly used as grounds for excluding participants from analyses and not in actual analyses themselves.

Language Assessment

MacArthur-Bates Communicative Development Inventory

The language assessment was acquired using the MacArthur-Bates Communicative Development Inventory (MCDI), a parental-report form that includes a long list of items concerning a child's language development. The MCDI is further broken down into the Words and Sentences inventory and the Words and Gestures inventory. The Words and Gestures form is for children who are younger than 16-18

months and who tend to produce fewer words. The Words and Sentences inventory is designed for children who are older than 16-18 months. This vague cutoff point is due to the variation in children's language development. If 16-month-old participants were advanced speakers, they were given the Words and Sentences Inventory; if 18-month-old participants were not speaking much, they were given the Words and Gestures Inventory.

Procedure

Parents were given either the Words and Gestures inventory or the Words and Sentences inventory based on the age of the child as well as the parent's verbal response to the experimenters inquiry into how much their children were speaking. Apart from a few instructions specific to each form, all parents were given the same basic instructions that are included in the MCDI manual. Parents who were not able to take the 20-30 minutes required to fill out the inventory while in the lab were given it in an envelope to take home, fill out, and send back. All but two inventories that were taken home were promptly sent back.

Analysis

While there are multiple sections of the MCDI, the vocabulary inventory was the main measure of interest due to its high correlation with other measures of language abilities (Fenson et al., 2007). Normally, raw scores taken from the vocabulary measure can be compared to a series of norms provided in the MCDI manual to find the percentile that corresponds with that age and gender. However,

raw scores could not be used to compare across the Words and Gestures and the Words and Sentences inventories due to differences in the vocabulary scales.

Therefore, raw scores were used to find each child's language age, an approximate indicator of the age of the child in terms of their stage of language development and not their chronological age. This was calculated by matching the raw vocabulary score of each child to the age at which that score corresponds to the 50th percentile.

Regressions were used to determine if language age scores were predictive of participants' comprehension of the word two as demonstrated by their difference scores in the preferential looking measure. Additionally, through a stepwise regression, I investigated interactions between chronological age and language age in terms of their capacity to explain the variance of the difference scores on the looking time measure.

Results

The independent variables of interest were *Age* and *Language Age*.

Participant's ages ranged from 13 to 29 months with a mean age of 21.28 months (N=18, SD = 5.03). Similarly, language age ranged from 10 to 30 months and with a mean age score of 20.68 months (N=16, SD = 6.88). Two parents did not fill out and return the MCDI so two participants were dropped from analyses that used language age as a variable. The vast majority of the participants did not succeed on the "Point-to-X" task. Only one participant (Age: 29 months) seemed to succeed on this task. If I had only counted first points, this child would have failed; however, on two trials he seemed to definitively switch his answer, so to be safe, he was labeled a potential

two-knower. Nevertheless, given that this participant did not have an inflated difference score, and that the overall group was clearly not abounding with two-knowers, I decided to include all participants in the analyses.

The dependent measure, proportion of time spent looking at two, was determined by dividing the number of frames spent looking at the screen with two objects by the number of frames spent looking at either screen. Overall, participants were very attentive and spent an average of 83% (SD = 15%) of the period during which looking was recorded, looking at one of the two screens and not away. Furthermore, the average percentage of time spent looking at either screen did not differ significantly between the first (M = 83%, SD = 19%) and last (M = 81%, SD = 25%) trial, suggesting that participants maintained their interest throughout the course of the experiment ($t(17) = .53, p = .60$).

We were specifically interested in how the proportion of time spent looking at two was affected by condition. On average, across all ages and both conditions participants spent 47% (SD = 9%) of the time that they were attentive to either screen, looking at the set of two objects, during trials in which one screen displayed two objects and one screen displayed three objects. This did not significantly differ from chance ($t(17) = -1.12, p = .28$). In the label-two condition, across all ages, when participants heard the set of two objects labeled, they spent on average 48% (SD = 13%) of the total time spent looking at either screen, looking at the set of two objects. Again, this did not differ significantly from chance ($t(17) = -.42, p = .68$). In label-three condition, across all ages, when participants heard the set of three objects labeled, they spent on average 45% (SD = 12%) of their total looking at either screen, looking

at the set of two objects. Again, this did not differ significantly from chance ($t(17) = -1.38, p = .19$) nor did it differ from the average proportion of time spent looking at two objects after hearing “two” labeled ($t(17) = -.70, p = .49$).

INSERT FIGURE 2 HERE

Difference scores, determined by the difference between looking time (at two objects) during the two conditions, ranged from .25 to .27 with a mean of .3 (SD = .16). A linear regression revealed that age significantly predicted difference scores, $b = -.02, t(17) = -2.12, p = .05$. Age explained about 22% of the variance in difference scores, $R^2 = .22, F(1, 17) = 4.50, p = .05$. All eighteen participants were included in this analysis. A scatter plot (Fig. 3) with age on the x-axis and difference score on the y-axis illustrated a general downward trend of difference scores as age increases, indicating that as participants got older they tended to look less reliably at “two” when they heard two objects labeled.

INSERT FIGURE 3 HERE

A second linear regression revealed that language age did not significantly predict difference scores, $b = -.004, t(15) = -.60, p = .56$. Accordingly, it failed to explain a significant portion of the variance in difference scores, $R^2 = .03, F(1, 14) = .35, p = .561$. This analysis excluded participants for whom there were no language age scores ($N = 2$). When age and language age were both included as independent variables in a single model, both significantly predicted the difference scores, $b = -.05, t(15) = -4.61, p < .001$ (age); $b = .03, t(15) = 3.35, p = .005$ (language age). The resulting model explained a significant portion of the variance, $R^2 = .630, F(2, 15) = 11.06, p = .002$. However, these interaction effects were discounted due to the high

collinearity of the independent variables. This was indicated by the relatively low tolerance of the model, .30, and high correlation between age and language age, $r(14) = .84, p < .001$. However, this high correlation between age and language age makes it somewhat puzzling that language age does not also significantly predict difference score independent of age.

Nevertheless, these results left age as the only significant predictor of difference score. In order to further test the effects of age on difference score, the data were split into three age categories. The first age category ranged from 13 months to 18 months ($M = 15.67, SD = 1.75, N=6$), the second age category ranged from 20 to 23 months ($M=21.57, SD = 1.27, N = 7$), and the third age category ranged from 25 to 29 months ($M = 27.60, SD = 1.95, N = 5$). A one sample t-test was used to determine if mean difference scores at each age category differed significantly from zero (chance). For the middle or oldest categories, difference scores were not significantly above chance, $t(6) = .45, p = .67$, and $t(4) = -.71, p = .52$, respectively. For the first age category, difference scores approached but did not reach significance above chance, $t(5) = 2.20, p = .08$. Similarly, the difference between the mean difference scores of the youngest and oldest age groups did not reach significance, $t(9) = .17, p = .12$. The relative lack of significance of these statistics in comparison the linear regression is due, at least in part, to the loss of power associated with grouping data into categories.

Still, such comparisons across age categories were helpful in revealing the overall patterns present in the data. We also analyzed the mean proportion of time spent looking at two, for each of the four test trials, at each of the three age

categories. Proportion looking at two was not significantly higher than chance on any given trial for any age category. However, the differences in means for each age, and each trial (Fig. 4), while not significant, did provide insight into possible controls and modifications that will be considered further in the discussion.

INSERT FIGURE 4 HERE

Discussion

The aim of the three measures conducted in the present study was to explore the extent to which children, prior to becoming two-knowers, comprehend the word “two.” I was interested to see if age or relative language development had any interesting relationships to children’s comprehension of “two.” Children were given both an implicit and explicit number comprehension task to test their relative performance on each. The explicit task, the ‘Point-to-X’ task, has been used in other research as an alternative number comprehension measure that is correlated with the Give-N Task (Wynn, 1990; 1992b). The implicit task, which uses a preferential looking paradigm, applied a frequently used method in language acquisition to the context of number language. It marks the first time that this paradigm has been adapted to test children’s comprehension of small number words like “two.” Furthermore, I used this task to study an age range that is not typically explored in research on number language. Given the lack of existing experimental data on the number language of children who are younger than two years old, I selected a relatively wide age range, from 12 to 30 months.

The decision to employ a novel method to investigate the number word comprehension of a wide, rarely-studied age range inherently limited my ability to answer my questions conclusively. However, the increased sensitivity of this method, which only requires that children look freely at two screens, combined with a broad scope of ages, increased the chances of detecting any interesting preliminary patterns. Accordingly, the combination of three measures yielded several interesting findings as well as the motivation for a number of follow-up studies and controls.

As expected, the 'Point-to-X' task proved to be too difficult for nearly all the children in this sample, ruling out the possibility that children who succeeded on the looking task were actually just precocious two-knowers. Thus, I was confident that any results found with the preferential looking task could not be attributed to an extremely developmentally advanced sample. The results of the MCDI, specifically the high correlation between chronological age and language age, also confirmed that this sample was not developmentally advanced. Concerning the preferential looking task, I first looked for a main effect of condition on the length of time that participants spent looking at two objects as opposed to three. The motivation behind this initial analysis was to investigate the hypothesis that children comprehend "two" long before they are able to succeed on more demanding, explicit tasks, and thus be labeled two-knowers. I found no such main effect of condition. In other words, overall, participants spent an equal proportion of time looking at two objects after hearing the set of two labeled by the auditory stimulus as they did after hearing the set of three labeled by the auditory stimulus.

In contrast, age significantly predicted participants' performance, as measured by the difference between the proportions of time spent looking at two objects in the label-two condition and the label-three condition. A linear regression revealed a downward trend, suggesting that as children age, their performance decreases. This means that the older participants were less likely to look longer at the screen with two objects after having heard the set of two labeled than after having heard the set of three labeled. I further tested these results by splitting children into three age categories (12-18 months; 19-24 months; 25-30 months) and comparing the mean difference scores of each age category to zero and to each other. The mean difference score of the youngest age group was the only mean difference score that differed from chance with a level of significance that approached .05 in a stringent two-tailed analysis ($p=.08$).

Indeed, I expected to see children in a younger age range succeed in comprehending the word "two" while older children failed. These predictions were based on research that indicates that during the beginning portion of children's lives, prior to around two years, children seem predisposed to conceptualize two objects exactly and, according to some data, produce the word "two" primarily in the context of pairs of objects. This has been demonstrated through a number of tasks that provide evidence for a system of Parallel Individuation, which seems to allow children to represent exactly two individuals as well as chunk those individuals into sets, but not form a basic rule of one vs. more-than-one. Despite this apparent consistency between my predictions and results, the children driving this pattern were

younger than expected. For this reason, I searched for alternative explanations of these results.

It could be that children are able to comprehend two at an even younger age than I predicted; children in the youngest age category seemed to do best while based on Benson and Baroody's (2002) study and Mix's (2002) study, I predicted that the middle category would excel. Nevertheless, the research reviewed in the introduction suggests that children have a rich conceptual understanding of 'a set of exactly two individuals' by fourteen months of age. If this 'two concept' is sufficiently rich, the main problem facing the infant in learning the word "two" is mapping the word to their preexisting concept. Perhaps children are able to do this earlier than expected. In fact, language comprehension often comes before production, a point which was clearly demonstrated in a recent study by Bergelson and Swingley (2010). Their findings suggest that children's language comprehension is more robust earlier in infancy than has previously been suspected. Using a method similar to the preferential looking method used in this study, they found that both previous research and current parental reports underestimated 6-9 month-old infants' abilities to use verbal labels to direct their attention towards corresponding visual stimuli. This suggests that children are extracting the semantic content of words at a much earlier age and for a larger range of words than previously suspected. Perhaps then, even very young children are able to extract the meaning of the word "two" and match it to their conceptual representations.

However, a serious factor complicating our ability to make a clear interpretation of the data is that even in this youngest age group, children did not

demonstrate clear preferences. As seen in Figure 4, graphs of the trial-by-trial proportion of time spent looking at two objects (by category), children's success at matching the auditory stimulus to the correct visual stimulus varied across trials. Importantly, it even varied across the same types of trials. For instance, in both trial one and trial two, children saw three objects on one screen and two objects on another screen, and were directed by the auditory stimulus to look at the screen with two objects. However, children in all categories, but especially those in youngest age category, looked at the set of two objects less during the first trial than during the second trial.

Many possible explanations can be provided to account for these data. In all scenarios, participants may begin by spending more time looking at the set of three objects, simply because children tend to prefer to look at more objects or more 'stuff'. After noticing that looking at the set of two objects was rewarded with the opportunity to see the two objects dance at the end of the trial, participants could form various rules concerning the relationship between the visual stimuli, the auditory stimulus, and the reward. At this point, all possible explanations of the data more or less break down into categories: 1.) participants' behavior was based on the auditory stimulus, and 2.) children largely ignored the auditory stimulus and based their behavior on other perceptual cues between the displays.

Participants could potentially be using the auditory stimulus in two ways. First, participants could realize that the semantic content of the auditory stimulus, namely, the word "two" or "three", can be used to predict which set will ultimately provide the reward. In this ideal case, the rewards acts as motivation for the

participants to match the auditory stimulus to the correct visual stimulus and overcome their bias to look at ‘more.’ Participants could also be using the auditory stimulus in a more general way; for instance, merely the labeling of the sets in both of the first two trials could generally alert participants to the possibility that similarities might exist between the screens that are rewarded. Children might then be better able to pick on subtle perceptual differences.

Children could also potentially be ignoring the auditory stimulus and using other perceptual cues to guide their looking behavior. For instance, one possibility is that children come away from the first trial thinking that looking at the screen with ‘less stuff’ is rewarded. Another possibility is that children come away from the first trial thinking that looking at the screen with ‘two objects’ is rewarded. While this last rule may be closer to what I hoped to see, neither requires the auditory stimulus to guide looking time and direction.

Whether or not the youngest children are using the auditory label has implications concerning why they are outperforming the older children. Perhaps, children in the youngest age group, who have less experience with language, are better able to ignore the auditory stimulus and pay attention solely to the other perceptual cues that can also be used to predict the reward. However, it could also be that children in the youngest age group have formed an early hypothesis that “two” refers to exact pairs while the older children have already over-generalized the word “two” to refer to an indistinct plural set, as seen during the one-knower stage. In this case, the youngest children may have merely been ignoring the auditory stimulus in the first trial but are able to use it successfully when more motivated to do so.

In order to distinguish between these possibilities, additional analyses, controls, and new studies are needed. First, incorporating more controls will help determine which of the explanations mentioned above accurately describes the behavior of the children in this sample. One useful step would be to code and analyze children's looking time and direction at a baseline level. Baseline would be measured using children's looks during the 3-second period after the visual stimuli have been presented but before the auditory stimulus has been presented. By measuring and comparing children's looking time and direction before and after the presentation of the auditory stimulus, I can determine the unique effect of the auditory stimulus. If children are not paying attention to the auditory stimulus and merely using other cues, then there should be no difference between their looking time and direction before and after hearing the auditory stimulus. If there is a significant difference, then we can be more comfortable in assuming that children are using the auditory stimulus to guide their looking.

An additional control that could be added into the next experiment is a brief block of familiarization trials in the beginning of each session. During these trials, a single familiar object would be displayed on one screen and a second familiar, but different, object would be displayed on the other screen. The child would then hear an auditory stimulus labeling one of the objects with a noun, but no number (e.g., "Look at the dog!"). Again, at the end of the trial this object would dance. These trials would serve several functions. First, they would allow us to determine if children within this sample are capable of using the auditory stimulus to direct their looking to the correct screen. If participants are unable to succeed on these trials that

merely involve comparing a single object on one screen and a single, different object on another screen, it would suggest that something else is wrong with the task's design. Second, it would allow the participants to get accustomed to the paradigm and learn to associate the auditory stimulus and the reward prior to beginning the test trials, in order to encourage anticipatory looking. Finally, it would reduce the novelty of the situation and help address the possibility that the younger children could be overwhelmed by the amount of 'stuff' and thus look at the screen with fewer pictures.

A third approach to prevent children from succeeding by using cues other than the auditory stimulus would be to eliminate the reward aspect of each trial. This would obviously prevent children from forming an association between unwanted variables, such as relative amount of 'stuff,' and a reward. However, it would also prevent children from forming an association between the auditory stimulus and a reward, which is the reason I initially included the reward. The fact that children in the youngest age group did not succeed on the first trial, but did succeed on the second trial, suggests that this reward was integral for motivating that effect. A similar modification that I considered when first designing the experiment (but ultimately rejected) was controlling the two screens for continuous variables such as surface area. On one hand, this would provide participants with fewer perceptual cues on which to base the orientation of their gaze. On the other hand, it could cause infants to have more difficulty distinguishing between the two sets and prevent them from correctly matching the auditory stimulus to one of the screens. Support for this concern comes from studies on infants' system of Parallel Individuation, which report

that children fail to dishabituate between sets of two and three when overall surface area is controlled (Clearfield & Mix, 1999, 2001).

The future directions discussed above are all in an effort to properly control for potentially confounding variables and establish whether children at the youngest age do in fact know something about the meaning of “two.” In addition to this, I plan to test more children from targeted age ranges in order to better reveal the effects found in this study. While I found a significant effect of age on difference score, there are number of reasons to believe that this effect could be even larger than revealed by the first experiment. For instance, the fact that the relationship between age and difference score did not hold up when children were grouped and mean scores were analyzed using t-tests is to be expected considering the low sample size and wide age range used in this study. By grouping children into age categories the analyses lost a good deal of statistical power due to the high amount of variance across a wide age range. The wide sample of ages used in the initial experiment was crucial to the endeavor to not miss any important stages of number language development. However, now that I have preliminary results, I can use more targeted age ranges to pinpoint the effect.

Furthermore, an effect that I expected to see but was ultimately found not to be significant was the effect of language age on difference score. Not only did I form this expectation in the predictions prior to conducting the experiment, the high correlation between the two variables is another reason to expect to see an effect of language age that is similar to that of age. One possible difficulty was that accuracy was lost when attempting to compare across the two MCDI forms. In future studies, I

could address this by giving parents a single productive vocabulary measure in order to more accurately compare language skills between children.

Another future direction is to make modifications to the actual preferential looking task in an effort to make it easier for the children in this age range. Initially, I opted to use the simplest possible sentence as the auditory stimulus. However, there is growing consensus that even young children can benefit from more natural sentence structures (Fernald, 2006). Therefore, I am now running a study in which the auditory stimulus is phrased as a question (i.e. Where are the *two* birds? Two!). By phrasing the auditory stimulus as a question, I hope to encourage children to actively seek the correct visual stimulus.

In addition to this change in auditory stimuli, I have opted to use novel objects and names for the visual stimuli in this experiment. Initially, I avoided doing so, thinking that using novel stimuli might prove overwhelming for the children in this age range. Also, if children's comprehension of the word "two" in this age range is limited in its generativity, they may be more likely to understand it within the context of familiar objects. However, there are a number of advantages to using novel objects and novel names. For instance, one drawback of using familiar objects is that both the set of two and the set of three must to be comprised of the same objects. This leads to a significant problem; if, for example, one screen displays two birds and the other displays three birds, a set of two birds can be found on both screens. In other words, a set of two birds is contained within the set of three. This makes the referent of the auditory stimulus somewhat ambiguous when it is labeling a set of "two." Such ambiguity may have dampened out initial effect. Using novel objects and

names allows us to display one type of object on one screen and another type on the other screen. Since children know through mutual exclusivity that different objects tend to have different names, they should know that a phrase like “two blaps” can only refer to the objects on one of the screens (Clark, 1987). Furthermore, this study should motivate children to find the referent of the novel word, which they can only do by using the numerical information, thereby increasing the possibility that they will seek the stimulus that matches the number word.

Nevertheless, the current study has revealed that the independent variable, age, significantly predicts participants’ difference scores, suggesting that important developmental changes may affect participants’ ability to look at two objects for a longer proportion of the time after having heard the set of two labeled by the auditory stimulus than after having heard the set of three labeled by the auditory stimulus. This is in contrast to the absence of a main effect of condition on children’s difference scores, averaged across all ages, which means I did not find evidence for a broad understanding of “two” prior to reaching the two-knower stage (regardless of age). Furthermore, a linear regression revealed that older participants were *less* likely look at two objects for a longer proportion of the time after having heard the set of two labeled than after having heard the set of three labeled. Unfortunately, in the absence of a clear preference across and within conditions, it is unclear exactly what is driving this effect of age. It is possible that participants formed associations between perceptual cues, such as surface area, and the reward shown at the end of each trial, and that this was a larger determiner in participants’ gaze duration and direction than the auditory stimulus. Further analyses of the data obtained from the

current experiment, such as comparing looking direction and duration to a baseline score, will seek to resolve this uncertainty.

Future studies should seek to mediate this potential confound, focus on targeted age ranges, and take steps towards making the task more straightforward for the young children in this age range. This last piece can be achieved through new, more natural auditory stimuli and the use of novel objects to remove ambiguity. In conclusion, the present study was designed to provide a preliminary indication concerning whether or not children between the ages of twelve and thirty months may comprehend of the word “two.” In this effort, the present study succeeded; this study highlights age as a significant predictor of the degree to which children in this sample were able to better focus their attention on two objects after having heard the set of two labeled, than after having heard the set of three labeled. This effect motivates future studies in order to better understanding the forces that cause these interesting results.

References

- Antell, S. E., & Keating, L. E. (1983). Perception of numerical invariance by neonates. *Child Development, 54*, 695–701.
- Barner, D., & Bachrach, A. (2010). Inference and exact numerical representation in early language development. *Cognitive Psychology, 60*, 40-62
- Barner, D., Chow, K., & Yang, S. (2009a). Finding one's meaning: A test of the relation between quantifiers and integers in language development. *Cognitive Psychology, 58*, 195-219.
- Barner, D., Libenson, A., Cheung, P., & Takasaki, M. (2009b). Cross-linguistic relations between quantifiers and numerals in language acquisition: Evidence from Japanese. *Journal of Experimental Child Psychology, 103*, 421-440.
- Barner, D., Lui, T., & Zapf, J. (under review). Is *two* a plural marker in early child language?
- Barner, D., Thalwitz, D., Wood, J., Yang, S., & Carey, S. (2007). On the relation between the acquisition of singular-plural morpho-syntax and the conceptual distinction between one and more than one. *Developmental Science, 10*(3), 365-373
- Barner, D., Wood, J., Hauser, M., & Carey, S. (2008). Evidence for a non-linguistic distinction between singular and plural sets in rhesus monkeys. *Cognition, 107*, 603-622.
- Barth, H., Baron, A., Spelke, E., & Carey, S. (2009). Children's multiplicative transformations of discrete and continuous quantities. *Journal of Experimental Child Psychology 103*, 441-454.
- Barth, H., Beckmann, L., & Spelke, E. (2008). Nonsymbolic, approximate arithmetic in children: Evidence for abstract addition prior to instruction. *Developmental Psychology 44*, 1466-1477.
- Barth, H., La Mont, K., Lipton, J., Dehaene, S., Kanwisher, N., & Spelke, E. (2006). Nonsymbolic arithmetic in adults and young children. *Cognition, 98*, 199-222.
- Barth, H., La Mont, K., Lipton, J., & Spelke, E. (2005). Abstract number and arithmetic in preschool children. *Proceedings of the National Academy of Sciences, 102*, 14116-14121.
- Benson, A.P. & Baroody, A.J (2002, April). The case of Blake: Number-word and number development. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

- Bergelson, E. & Swingley, D. (2010, March) *6-9-Month-Olds Match Spoken Words to Visual Referents*. Poster session presented at the 2010 International Conference on Infant Studies, Baltimore, MD.
- Bijeljic-Babic, R., Bertoni, J., & Mehler, J. (1991). How do four-day-old infants categorize multisyllabic utterances? *Developmental Psychology*, 29, 711-721.
- Bloom, P., & Wynn, K. (1997). Linguistic cues in the acquisition of number words. *Journal of Child Language*, 24(3), 511-533.
- Carey, S. (2004). Bootstrapping and the origins of concepts. *Daedalus*, 59-68.
- Carey, S. (2001). Evolutionary and Ontogenetic Foundations of Arithmetic. *Mind and Language*, 16(1), 37-55.
- Carey, S. (2009). *The Origin of Concepts*. New York, NY: Oxford University Press
- Carlson-Luden, V. (1979). *Causal understanding in the 10-month-old*. Unpublished doctoral dissertation. University of Colorado at Boulder.
- Church, R. M., & Meck, W. H. (1984). The numerical attribute of stimuli. In H. L. Roitblatt, T. G. Bever, & H. S. Terrace (Eds.), *Animal cognition* (445-464). Hillsdale, NJ: Erlbaum.
- Clark, E. V. (1987). The principle of contrast: A constraint on language acquisition. In B. MacWhinney (Ed.), *Mechanisms of language acquisition* (pp. 1-34). Hillsdale, NJ: Erlbaum.
- Clark, E. V., & Nikitina, T. V. (2009). One vs. more than one: Antecedents to plural marking in early language acquisition. *Linguistics*, 47(1), 103-139.
- Clearfield, M. W., & Mix, K. S. (2001). Amount versus number: Infants' use of area and contour length to discriminate small sets. *Journal of Cognition and Development*, 2, 243-260.
- Clearfield, M. W., & Mix, K. S. (1999). Number versus contour length in infants' discrimination of small visual sets. *Psychological Science*, 10, 408-411.
- Condry, K., & Spelke, E. S. (2008). The development of language and abstract concepts: The case of natural number. *Journal of Experimental Psychology: General*, 137, 22-38.
- Dale, P.S. & Fenson, L. (1996). Lexical development norms for young children. *Behavior Research Methods, Instruments, & Computers*, 28, 125-127.

- Feigenson, L. & Carey, S. (2005). On the limits of infants' quantification of small object arrays. *Cognition*, 97(3), 295-313.
- Feigenson, L. & Carey, S. (2003). Tracking individuals via object files: Evidence from infants' manual search. *Developmental Science*, 6(5), 568-584.
- Feigenson, L., Carey, S., & Hauser, M. (2002). The representations underlying infants' choice of more: Object files vs. analog magnitudes. *Psychological Science*, 13, 150-156.
- Feigenson, L., Carey, S., & Spelke, E. (2002). Infants' discrimination of number vs. continuous extent. *Cognitive Psychology*, 44, 33-66.
- Feigenson, L., Dehaene, S., Spelke, E. (2004) Core Systems of Number. *Trends in Cognitive Sciences*, 8(7), 307-314.
- Feigenson, L., & Halberda, J. (2004). Infants chunk object arrays into sets of individuals. *Cognition*, 91, 173-190.
- Feigenson, L. & Halberda, J. (2008). *Conceptual knowledge increases infants' memory*. Proceedings of the National Academy of Sciences, 105(29), 9926-9930.
- Fenson, L., Dale, P.S., Reznick, J.S., Bates, E., Thal., D.J., Pethick, S. J., Tomasello, M., Mervis, C.B., & Stiles, J. (1994) Variability in Early Communicative Development. *Monographs of the Society for Research in Child Development*, 59, i-185.
- Fenson, L., Dale, P.S., Reznick, J.S., Thal, D., Bates, E., Hartung, J.P., Pethick, S., & Reilly, J.S. *MacArthur-Bates Communicative Development Inventories, Second Edition*. Baltimore: Paul H. Brookes Publishing Co., 2007.
- Fernald, A. (2006). When infants hear two languages: Interpreting research on early speech perception by bilingual children. In P. McCardle & E. Hoff (Eds.) *Childhood Bilingualism: Research on Infancy through School-Age*.
- Frye, D., Braisby, N., Lowe, J., Maroudas, C., & Nicholls, J. (1989). Young Children's Understanding of Counting and Cardinality. *Child Development*, 60(5), 1158-1171.
- Fuson, K.C. (1988) *Children's Counting and Concepts of Number*, Springer-Verlag, New York.

- Golinkoff, R.M., Hirsh-Pasek, K., Cauley, K.M., Gordon, L. (1987). The eyes have it: Lexical and syntactic comprehension in a new paradigm. *Journal of Child Language*, 14(1), 23-45.
- Gordon, P. (2004). Numerical cognition without words: Evidence from Amazonia. *Science*, 306, 496-499.
- Hauser, M., Carey, S., & Hauser, L. (2000). Spontaneous number representation in semi-free-ranging rhesus monkeys. *Proceedings of the Royal Society: Biological Sciences*.
- Hollich, G. (2005). Supercoder: A program for coding preferential looking (Version 1.5). [Computer Software]. West Lafayette: Purdue University.
- Hurewitz, F., Papafragou, A., Gleitman, L., & Gelman, R. (2006). Asymmetries in the acquisition of numbers and quantifiers. *Language Learning and Development* 2, 77-96.
- Kouider, S., Halberda, J., Wood, J.N. & Carey, S. (2006). The acquisition of English number marking: the singular-Plural distinction. *Language Learning and Development*, 2(1), pp. 1-25.
- Le Corre, M. & Carey, S. (2007). One, two, three, four, nothing more: An investigation of the conceptual sources of the verbal counting principles. *Cognition*, 105, 395-438
- Le Corre, M., Van de Walle, G., Brannon, E. M., & Carey, S. (2006). Re-visiting the competence/performance debate in the acquisition of the counting principles. *Cognitive Psychology*, 52(2), 130-169.
- Lee, M. D. & Sarnecka, B.W. (under review). A model of knower-level behavior in number-concept development.
- Li, P., Ogura, T., Barner, D., Yang, S., & Carey, S. (2009). Does the conceptual distinction between singular and plural sets depend on language? *Developmental Psychology*, 45, 1644-1653.
- Lipton, J. S., & Spelke, E. (2004). Discrimination of large and small numerosities by human infants. *Infancy*, 5, 271-290.
- Lipton, J. S., & Spelke, E. S. (2003). Origins of number sense: Large number discrimination in human infants. *Psychological Science*, 15(5), 396-401.
- MacWhinney, B. (2000). *The CHILDES project: Tools for analyzing talk. Third Edition*. Mahwah, NJ: Lawrence Erlbaum Associates.

- Mix, K. (2002). The construction of number concepts. *Cognitive Development, 17*, 1345-1363.
- Papafragou, A., & Musolino, J. (2002). The pragmatics of number. *Proceedings from the 24th Annual Conference of the Cognitive Science Society*. Hillsdale, NJ: Erlbaum, 2002.
- Pica, P., Lemer, C., & Izard, V. (2004). Exact and approximate arithmetic in an Amazonian indigene group. *Science, 306*, 499-503.
- Platt, J. R., & Johnson, D. M. (1971). Localization of position within a homogeneous behavior chain: Effects of error contingencies. *Learning and Motivation, 2*, 386-414.
- Sarnecka, B. W. & Carey, S. (2008) How counting represents number: What children must learn and when they learn it. *Cognition, 108*, 662-674.
- Sarnecka, B.W. & Gelman, S.A. (2004). Six does not just mean a lot: Preschoolers see number words as specific. *Cognition, 92*, 329-352.
- Sarnecka, B.W., Kamenskaya, V.G., Yamana, Y., Ogura, T., & Yudovina, J.B. (2007). From grammatical number to exact numbers: Early meanings of "one," "two," and "three" in English, Russian, and Japanese. *Cognitive Psychology, 55*, 136-168.
- Sarnecka, B. W. & Lee, M. D. (in press). Levels of number knowledge in early childhood. *Journal of Experimental Child Psychology*
- Schaeffer, B., Eggleston, V. H., & Scott, J. L. (1974). Number development in young children. *Cognitive Psychology, 6*, 357-379.
- Starkey, P., & Cooper, R. (1980). Perception of numbers by human infants. *Science, 210*, 1033-1035.
- Trick, L., & Pylyshyn, Z. (1994). Why are small and large numbers enumerated differently? A limited-capacity preattentive stage in vision. *Psychological Review, 101*, 80-102.
- Whalen, J., Gallistel, C.R. & Gelman, R., 1999. Nonverbal counting in humans: the psychophysics of number representation. *Psychological Science, 10*(2), 130-137.
- Wood, J. N., & Spelke, E. S. (2005). Infants' enumeration of actions: Numerical discrimination and its signature limits. *Developmental Science, 8*(2), 173-181.
- Wynn, K. (1992a). Addition and subtraction by human infants. *Nature, 358*, 749-750.

- Wynn, K. (1992b). Children's acquisition of the number words and the counting system. *Cognitive Psychology*, 24, 220-251.
- Wynn, K. (1990) Children's understanding of counting. *Cognition*, 36, 155-93.
- Wynn, K. (1996). Infants' individuation and enumeration of actions. *Psychological Science*, 7, 164-169.
- Xu, F. (2003) Numerosity discrimination in infants: evidence for two systems of representations. *Cognition*, 89, B15-B25
- Xu, F., & Spelke, E.S. (2000) Large number discrimination in 6-month old infants. *Cognition*, 74, B1-B11

Figure Captions

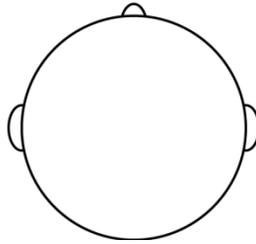
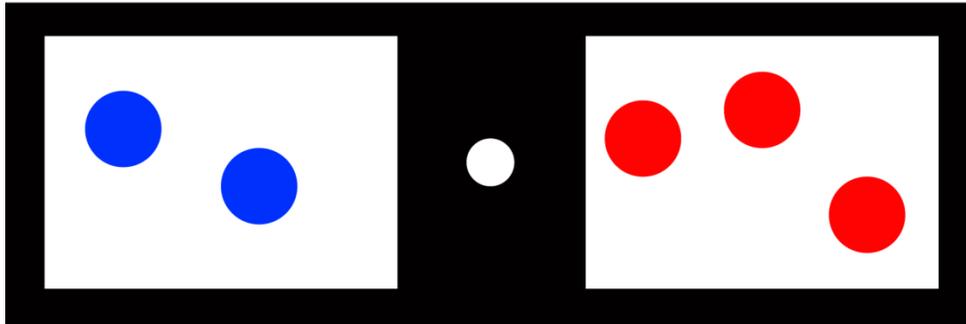
Figure 1. Schematic illustration of visual and auditory stimuli for the preferential looking task; label-two condition and label-three condition.

Figure 2. Mean proportion of time spent looking at objects in the label-two condition and in the label-three condition.

Figure 3. Scatter plot of difference scores by age.

Figure 4. Mean proportion of time spent looking at two objects, per trial (first five trials) for age category one, 12-18 months (A); age category two, 19 – 25 months (B); and age category three, 25-30 months (C).

Figure 1



“Look, baby! Look! Two Balls! Two!”

Label-Two Condition



“Look, baby! Look! Three Balls! Three!”

Label-Three Condition

Figure 2

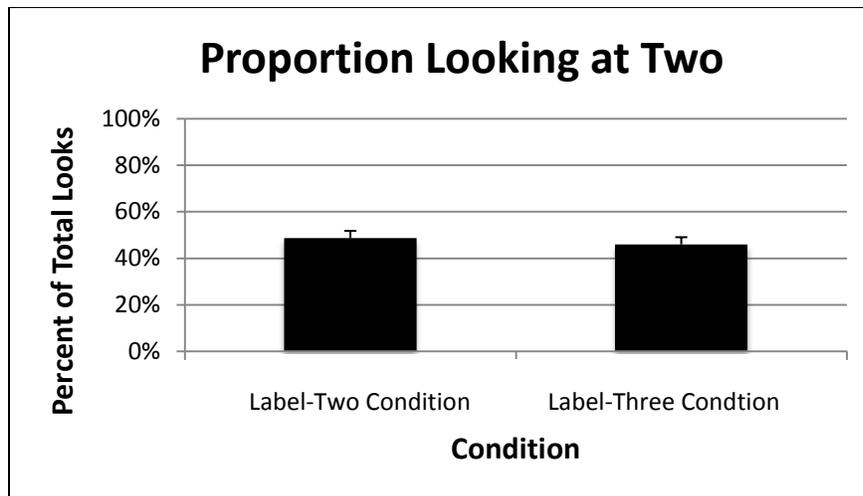


Figure 3

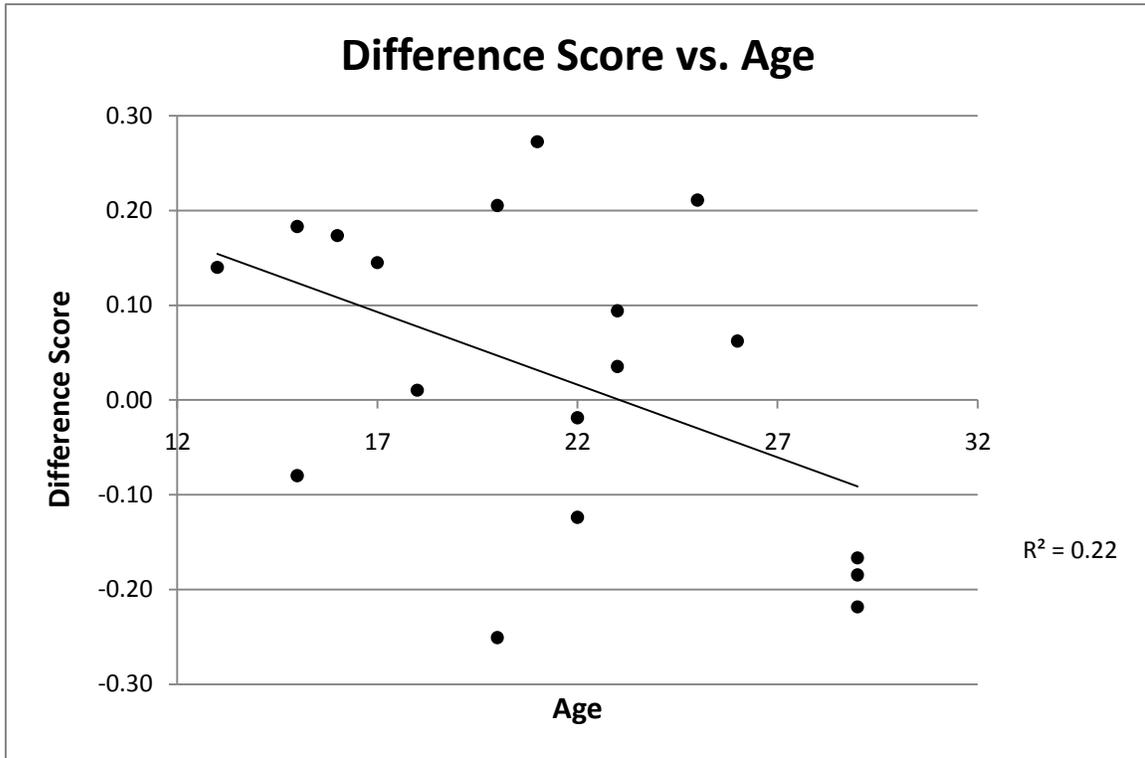
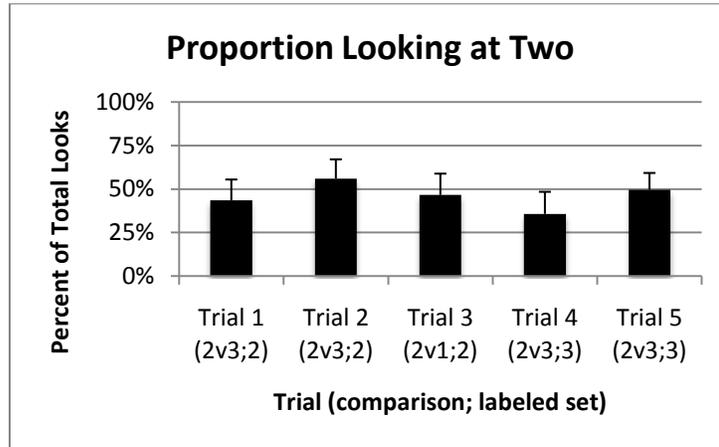
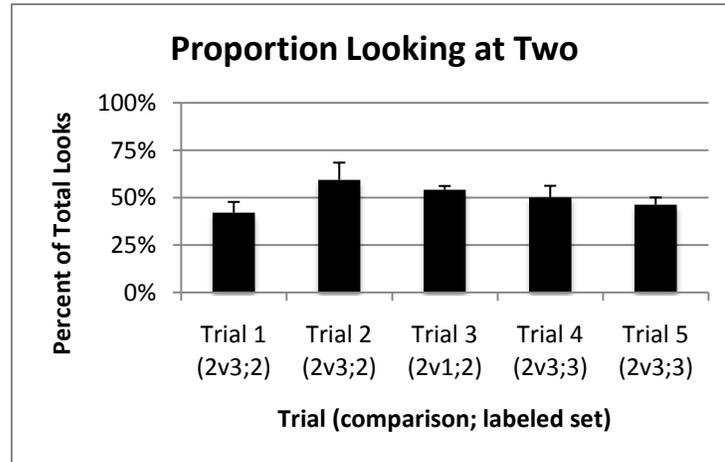


Figure 4

A.



B.



C.

